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Does macropru leak? Evidence from a UK policy experiment

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Shekhar Aiyar,[1] Charles W Calomiris[2] and Tomasz Wieladek[3]

Abstract

The regulation of bank capital to improve the resilience of the financial system and, related to this aim, as a means of smoothing the credit cycle are central elements of forthcoming macroprudential regimes internationally. For such regulation to be effective in controlling the aggregate supply of credit: (i) changes in capital requirements need to affect loan supply by regulated banks, and (ii) substitute sources of credit should not fully offset changes in credit supply by affected banks. This paper examines micro evidence — lacking to date — on both questions, using a unique data set. In the United Kingdom, regulators have imposed time-varying, bank-specific minimum capital requirements since Basel I. Over the 1998–2007 period, UK-regulated banks reduced lending in response to tighter capital requirements. But non UK-regulated banks (resident foreign branches) increased lending in response to tighter capital requirements on a relevant reference group of regulated banks. This 'leakage' was material although only partial: it offset — by about one third — the initial impulse from the regulatory change. These results suggest that, on balance, changes in capital requirements can have a substantial impact on aggregate credit supply by UK-resident banks. But they also affirm the importance of cross-country co-operation on macroprudential policies.

Key words: Macroprudential regulation, credit cycles, regulatory arbitrage, transmission mechanism, bank lending, instrumental variables.

JEL classification: G21, G28, E32, E51, F30.

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Summary

The regulation of bank capital to improve the resilience of the financial system and, related to this aim, as a means of smoothing the credit cycle are important elements of forthcoming macroprudential regimes internationally. For such regulation to be effective in controlling the aggregate supply of credit it must be the case that: (i) changes in capital requirements affect loan supply by regulated banks, and (ii) substitute sources of credit—or ‘leakages’—are unable to offset fully changes in credit supply by affected banks. Despite the centrality of both these propositions to the macroprudential enterprise, empirical evidence on either proposition is scant.

The United Kingdom provides an ideal testing ground for these questions because of the country’s policy regime in the 1990s and early 2000s, when the Financial Services Authority (FSA) set time-varying minimum capital requirements—so-called ‘trigger ratios’—at the level of individual banks. These trigger ratios were set for all banks under the FSA’s jurisdiction, ie, for all UK-owned banks and all subsidiaries of foreign banks operating in the United Kingdom. The discretionary regime was intended to fill gaps in the early Basel I regime, which simply imposed a uniform minimum capital requirement of 8% of risk-weighted assets.

This study collects quarterly data on minimum capital requirements for all FSA-regulated banks between 1998 and 2007. Over the period the variation in minimum capital requirements as a percentage of risk-weighted assets was large, ranging from a minimum of 8% to a maximum of 23%. Moreover, although the FSA’s mandate over the period was explicitly *micro*prudential, the aggregate outcome of its bank-by-bank decisions was in fact countercyclical, just as one might expect in a future macroprudential regime.

Changes in bank lending to the real economy are regressed on several lags of changes in the trigger ratio. Control variables include GDP growth and a number of bank-specific balance sheet characteristics. Several different strategies are employed to control for demand shocks. A large and significant impact of changes in minimum capital requirements on bank lending is found across all specifications. A rise in the

trigger ratio of 100 basis points is estimated to induce a cumulative reduction in the growth rate of bank lending of between 6% and 9%.

Next, the study investigates leakages. The United Kingdom is host to a large number of branches of foreign-owned banks, which are not subject to FSA regulation, but are regulated by the country authorities of the parent bank. When capital requirements are tightened on FSA-regulated banks, this confers a relative cost advantage on the foreign branches operating in the United Kingdom, which might raise lending in response. Of course, this is only one potential source of leakage (others include capital markets and cross-border lending), but it is likely to be the most important one.

The change in lending by foreign branches is regressed on several lags of the change in lending by a reference group of regulated banks. For each foreign branch, the reference group of regulated banks comprises banks that specialise in lending to the same sectors of the economy as the branch; thus the reference group captures the relevant set of competitor banks. A technique called instrumental variables is used to ensure that the changes in lending examined are restricted to those caused by changes in regulatory capital requirements.

It is found that foreign branches increase lending in response to a regulation-induced decline in lending by competing regulated banks. The average branch increases lending by about 3% in response to a decline in lending by its reference group of 1%.

An economy-wide aggregate assessment of leakages needs to further take into account that (i) foreign branches outnumber UK-regulated banks; and (ii) the average foreign branch is much smaller than the average UK-regulated bank. Accounting for these factors yields an estimate of aggregate leakages of about 32%. That is, for any given change in minimum capital requirements across the regulated banking system, leakages through foreign branches reduce the credit supply response by a third. The fact that the offset is only partial implies that, on balance, changes in capital requirements can induce a substantial impact on aggregate credit supply by UK-resident banks.

1 Introduction

Capital requirements have been a central tool of the prudential regulation of banks in most countries for the past three decades. Recently, under Basel III, regulators have agreed to vary minimum capital requirements somewhat over time, as part of the cyclical mandate of macroprudential policies.[1] During boom times, capital requirements would increase, and during recessions they would decline. That variation is intended to achieve three macroprudential goals: (1) cooling off credit-fed booms with higher capital requirements, (2) mitigating credit crunches during recessions with commensurate reductions in capital requirements, and (3) boosting capital and provisioning requirements during booms to provide an additional cushion to absorb losses during downturns.[2]

This paper analyses the extent to which this sort of variation in capital requirements is effective in regulating the supply of bank lending over the cycle. Our analysis is made possible by an apparently unique policy experiment performed in the United Kingdom during the 1990s and 2000s. As we explain more fully in Section 2, the Financial Services Authority (FSA) varied individual banks' minimum risk-based capital requirements substantially. The extent of this variation across banks in the minimum required risk-based capital ratio was large (its minimum was 8%, its standard deviation was 2.2%, and its maximum was 23%). The variation in the average capital requirement over the business cycle was also large, and tended to be countercyclical, as envisaged under Basel III.

Before undertaking our empirical analysis in Sections 2 through 5, we begin by reviewing the theoretical foundations of macroprudential capital regulation and the empirical literature relating to those foundations. Three necessary conditions need to hold the if time-varying, macroprudential capital requirements envisioned under

[1] In addition to cyclical variation of capital ratios, macroprudential policy could entail other cyclical variation in policy instruments (eg, liquidity and provisioning requirements) as well as 'structural' interventions to promote financial stability. For more details, see Tucker (2009, 2011), Galati and Moessner (2011), Bank of England (2009), and Aikman, Haldane and Nelson (2011).

[2] As regulations have evolved over time, the complexity of capital regulation has also increased. Under the Basel I system, capital requirements consisted of three ingredients: definitions of capital that distinguished between Tier 1 and Tier 2 capital, a formula for measuring risk-weighted assets, and setting constant minimum ratios of 8% for the total risk-based capital (defined as the sum of Tier 1 and Tier 2 capital, divided by risk-weighted assets), and 4% for the Tier 1 risk-based capital. Under Basel II, the calculation of risk-weighted assets was modified to permit, under some circumstances, the use of internal models and rating agency opinions. Under Basel III, the Basel I minimum ratio is being raised, with a greater focus on the common equity component of capital, and the so-called 'countercyclical capital buffer' implies that minimum risk-based capital ratios will now vary over the economic cycle.

Basel III are to be effective in controlling system-wide credit growth: (1) equity (the key variable of interest in bank capital regulation) should be a relatively costly source of bank finance, (2) capital requirement ratios should have binding effects on banks' choice of capital ratios, and (3) when macroprudential regulation changes the supply of credit by banks subject to macroprudential policy, other sources of credit should not fully offset such changes.

Necessary condition 1: equity must be a relatively costly source of finance

The supply of loans from regulated banks will not respond to changes in capital requirements unless bank capital is a relatively costly means of financing bank activities. If bank leverage were irrelevant to the cost of bank finance – as implied by the Miller-Modigliani Theorem – then changes in minimum capital requirements would not be useful in reducing credit growth during booms or in mitigating credit crunches; banks would costlessly adjust their capital ratios without any effect on their lending activities.

Theoretical models that incorporate tax benefits of debt finance and asymmetric information about banks' conditions and prospects imply that, in general, raising funds from external equity finance is more costly for banks than from debt finance, which implies that a rise in capital requirements will raise the cost of bank finance, and thus lower the supply of lending.[3] The favourable tax treatment of debt results from the deductibility of interest payments, but not dividend payments.

With respect to asymmetric information costs of equity, Myers and Majluf (1984) show that adverse-selection costs of raising external equity (which take the form of under-pricing of the equity offerings of unobservably healthy banks in their model) apply more to junior securities (like equity) than to relatively senior debt instruments. The Myers and Majluf (1984) model envisions adverse-selection costs as entirely reflected in the pricing of an equity offering, since in their model, there is no technology available to firms to invest in overcoming problems of asymmetric

[3] There is also a theoretical literature in banking that discusses how agency problems arising from greater capital or capital requirements can give rise to social costs in addition to credit contraction – for example, changes in managerial effort or risk preferences. We do not describe this literature, since it is not directly related to the amount of lending, which is our focus. For a review of that literature, see VanHoose (2008) and Kashyap, Rajan and Stein (2008). Admati *et al* (2011) express scepticism about the magnitude of equity capital costs for banks.

information. More realistically, part of the cost of asymmetric information takes the form of paying high underwriting costs to investment bankers who market equity offerings. Firms pay those costs to mitigate the more severe adverse pricing effects on equity offerings that otherwise would result from asymmetric information (Calomiris and Tsoutsoura (2011)).

Equity may also be relatively costly as a source of finance because of *ex-post* verification costs, another form of asymmetric information. For example, Diamond (1984) and Gale and Hellwig (1985) show that banks that offer debt contracts can economise on those costs. Additionally, Calomiris and Kahn (1991) show that agency problems associated with asymmetric information about portfolio realisations will tend to encourage demandable debt contracting rather than long-term debt issuances (in their model, equity is supplied entirely by insiders). In that model, requiring bankers to raise the ratio of equity to risky assets would result in less lending by banks (since outside equity finance is prohibitively expensive. That model is extended by Diamond and Rajan (2000, 2001).

The negative signalling effects of equity offerings modelled by Myers and Majluf (1984) will be mitigated if equity offerings respond to an observable regulatory change, and so, the raising of equity capital to respond to observable changes in macroprudential regulation will have a lower cost than the raising of equity in response to unobservable changes in requirements or other unobservable motivations for raising new equity. That does not imply, however, that the imposition of observably higher regulatory capital requirements would eliminate the negative signalling effects of choosing to issue equity to meet higher regulatory requirements.

First, even if all banks went to the equity market at the same time to raise equity, banks would differ according to their investment banking choices; banks whose managers knew that they were in better condition would have an incentive to expend more on underwriting to ensure that investors receive more information about their superior condition. Those expenditures contribute to the costs of equity capital requirements, and would also have signalling effects on the pricing of both high underwriting cost and low underwriting cost banks.

Second, in equilibrium, bank heterogeneity would also result in differences among banks in the extent to which they would choose to raise equity as opposed to shrinking their risk-weighted assets in response to higher capital requirements. Banks in relatively good condition would eschew equity offerings more, *ceteris paribus*, to avoid long-term dilution of incumbent stockholders. For these reasons, higher equity capital requirements do not eliminate the information costs, and attendant adverse selection risks, that make equity offerings relatively costly.

There is a substantial empirical literature in support of the general proposition that equity capital is relatively costly to raise, and that financing costs of debt sources of funding increase in the extent to which the debt claim is more equity-like – that is, costs are lowest for deposits, higher for contractual debt and preferred stock (which are *de jure* junior to deposits in many countries and also *de facto* junior because of their longer maturity), higher still for mezzanine instruments (eg, debt that is convertible into equity), and highest for equity.[4] Equity prices tend to decline in reaction to an announcement of an equity offering, especially when issuers are informationally opaque, and that announcement effect is lower for convertible debt, and zero for straight debt (James (1987), James and Wier (1990)). Underwriting costs for equity are also much higher than for debt (Calomiris (2002)). Ediz *et al* (1998) and Francis and Osborne (2009) also find that, consistent with Myers and Majluf (1984), UK banks behave as if Tier 2 capital is less costly to raise than equity, and that banks that have relatively low costs of raising equity raise equity capital more (as opposed to contracting risky assets) in response to increases in capital requirements.

Because the high cost of equity capital is a necessary condition for credit supply to respond to either a loss of equity capital or an increase in capital requirements, evidence that contractions of credit result from these phenomena is powerful evidence that equity finance is costly. The literature on bank 'capital crunches' documents that shocks to bank equity capital have large contractionary effects on the supply of

[4] The view that junior instruments are more costly sources of finance also explains the common regulatory reluctance to impose large increases on banks' minimum capital ratios. The initial Basel minimum capital requirements were set at ratios that were quite close to those prevailing at the time. Indeed, the distinctions between Tier 1 and Tier 2 capital, and the 4% and 8% minimum risk-based capital ratios, were devised in 1988 to allow banks that were subject to the Basel guidelines to comply with the new guidelines without raising significant new capital, and despite significant differences in the capital structures of banks across countries.

lending (Bernanke (1983), Bernanke and Lown (1991), Kashyap and Stein (1995, 2000), Houston, James and Marcus (1997), Peek and Rosengren (1997, 2000), Campello (2002), Calomiris and Mason (2003), Calomiris and Wilson (2004), Cetorelli and Goldberg (2009)).

Many studies also have suggested that increases in regulatory capital requirements can precipitate contractions in the supply of credit (see VanHoose (2008) for a review). Some of these existing studies analyse banks' lending behaviour around the time of regulatory regime changes (Chiuri *et al* (2002)), and thus do not isolate the effects of bank capital ratio changes, *per se*. Others analyse cross-sectional differences in lending by banks that differ according to their regulatory circumstances, including whether they are the subject of a regulatory action, or whether they have relatively small buffers of capital relative to the minimum requirement (eg, Peek and Rosengren (1995a,b). Experiencing a regulatory action is a special event, however, and one that is highly endogenous to a variety of circumstances that may affect bank lending. Similarly, the relative sizes of banks' capital buffers do not provide a reliable measure of the relative degree to which banks are constrained by regulation; the sizes of a banks' capital buffers are endogenous to banks' particular circumstances, which can produce substantial variation in their targeted capital buffers (more on this below). Finally, it is important to control for cross-sectional variation in loan demand when measuring the effects of capital requirements on loan supply, which only some of the pre-existing studies of lending attempt to do.

To our knowledge, our study is the first analysis of bank-specific responses to variation in regulatory capital requirements. Unlike prior studies, we are able to identify regulatory capital requirements at the level of individual banks, and we show that these requirements vary substantially cross-sectionally and over time. Furthermore, when measuring the loan-supply response of banks to capital requirements we are able to control for contemporaneous variation in loan demand because we have access to detailed information about the composition of bank loan portfolios. These features of the study make it more robust to the Lucas critique than, say, a macroeconomic time series analysis relating aggregate credit to changes in regulatory capital requirements across the banking system.[5]

Necessary condition 2: capital requirements must bind

A second necessary condition for bank capital requirements to affect the loan-supply decisions of banks is that regulatory capital requirements must continuously act as binding constraints on bank capital ratio choices. If market discipline motivates banks to maintain ratios of capital far in excess of those required by regulators, then changes in regulatory requirements might have no effect on bank capital choices, and therefore, no effect on bank loan supply. Calomiris and Mason's (2004) study of credit card banks in the 1990s shows that, under some circumstances, market discipline can motivate capital ratios substantially in excess of the regulatory minimum.

When capital requirements bind, the equilibrium amount of total bank capital will still exceed the minimum requirement by a buffer chosen to minimise the costs of complying with capital requirements. The dynamic behaviour of buffers is a matter of some theoretical controversy. Repullo and Suarez (2009) derive a dynamic model of capital buffers under the Basel II regime. They show that the determination of risk under Basel II contributes greatly to the procyclicality of capital requirements (when compared with Basel I); during recessions, capital requirements effectively rise. Thus they argue that banks will choose to hold high buffers of capital during expansions, anticipating the need for additional capital during recessions, and that this effect is so large that it is not fully mitigated by the extent of variation in macroprudential policy. Aliaga-Diaz *et al* (2011) develop a dynamic optimisation model to analyse the effectiveness of macroprudential policy, based on parameters drawn from Latin American experience. They show that variation in capital requirements may have to be large to make macroprudential policies effective. In their framework, however, anticipated reductions in capital requirements due to macroprudential policy lead banks to endogenously choose capital buffers that are *smaller* during booms than during economic declines. That means that the countercyclical effect of capital

[5] In particular, the microeconomic data here allow the analysis of regulatory arbitrage, or 'leakages'. Because we are able to derive parameter estimates of regulatory leakages, the study is much better able to relate empirical evidence from the past to a future in which the regulatory regime may be different, for example due to greater international co-operation in setting minimum capital requirements.

requirement changes can be mitigated by the endogenous offsetting decisions of banks with respect to their chosen buffers. The difference between the conclusions reached by Repullo and Suarez (2009) and Aliaga-Diaz *et al* (2011) about the cyclical properties of capital buffers reflect differences in assumptions about the size of macroprudential capital requirement variation over the cycle and the extent to which recessions are associated with substantial changes in risk weights on assets.

Empirical research has identified substantial heterogeneity with respect to bank responses to capital requirements, and particularly, the extent to which capital requirements bind on banks' choices of capital ratios. In many studies, actual capital ratios respond strongly to changes in capital requirements, but in other studies, there is little observed response, which indicates that in some circumstances market discipline may be the dominant influence on variation in capital ratios (VanHoose (2008)).

For our sample of UK banks, there have been two studies examining the extent to which changes in bank-specific capital requirements affected actual capital ratios (Alfon *et al* (2005) and Francis and Osborne (2009)). Both studies find a substantial impact, and both conclude that capital requirements were binding on capital ratio choices. In Section 2, we confirm that capital requirements appear to have been binding on bank capital decisions continuously for our sample of UK banks from 1998 to 2007. Moreover, since binding regulatory requirements are a necessary condition for capital requirement changes to affect bank credit supply, our empirical finding in Section 3 – confirming that capital requirement changes have important effects on the supply of credit – further corroborates that capital requirements were binding.

Necessary condition 3: limited substitutability of alternative funding

The effectiveness of macroprudential variation in capital ratios depends on limited substitutability between the credit supplied by banks that are subject to capital regulation, and the financing provided by other sources not subject to minimum capital requirements. To the extent that other sources can offer substitutes for the loans of regulated domestic banks, there will be offsetting 'leakages' to macroprudential policy-induced variation in the supply of loans by regulated banks.

These other sources could include lending by foreign branches operating in the United Kingdom, cross-border bank lending and securities offerings (such as commercial paper, corporate bonds or equity offerings).

The theoretical and empirical finance literature suggests that loans from intermediaries are not perfect substitutes for securities offerings. Loans involve much more detailed contracting terms than bonds – many pages that describe conditions pertaining to warranties, covenants, and collateral – which must be custom-designed for each loan contract and which require monitoring and enforcement after the loan is made.[6] Furthermore, the importance of 'soft' information for limiting the screening, monitoring and enforcement costs of bank lending imply that there are limits to the ability of offshore lending to substitute for local intermediation, except in the case of very large firms that operate internationally, for whom access to local information is less relevant.[7] Thus, although 'leakages' from all alternative sources of finance could potentially offset the variation in loan supply that results from macroprudential regulation of affected banks, the most powerful potential substitute for regulated bank lending is lending by local intermediaries that are not subject to domestic capital regulation.

The problem of 'leakages' involving local intermediaries is particularly acute for an economy like the United Kingdom, which is a global financial centre. Resident foreign branches of banks headquartered abroad are not subject to FSA prudential regulation (unlike domestically headquartered banks and resident foreign subsidiaries), but are regulated by their home country regulatory authorities. Such foreign branches account for the majority of banks resident in the United Kingdom; in our sample they comprise 173 out of 277 banks.[8] Moreover, as described in Section 4, these branches account for a non-trivial share of lending to the UK real economy, and are important in several subsectors of the real economy. That means that if the FSA decided to raise capital requirements, while other countries did not, foreign branches operating in the United Kingdom could be a significant source of leakage. Nor is the issue of leakages restricted to global financial centres, although it may be most acute

[6] There is a large empirical literature on the special characteristics of loans, beginning with James (1987).
[7] Evidence that local, 'soft' information is relevant for most bank lending is provided in various studies, including Petersen and Rajan (2002) and Agarwal and Hauswald (2010).
[8] See Aiyar (2011) for a more detailed account of the structure of the banking industry in the United Kingdom, especially relating to the difference between regulated foreign subsidiaries and unregulated foreign branches.

there: under European passport rules, for example, a bank incorporated in any EU member state can open a branch in another member state, which would be subject to regulation by the home state rather than the host state.

The possibility of regulatory leakages have understandably been a concern to policymakers engaged in the construction of macroprudential regimes. In the United Kingdom, for example, Paul Tucker, Deputy Governor of Financial Stability at the Bank of England, has frequently commented upon the potential problem of the ‘dilution’ of cyclical macroprudential policies, and how this underlines the need for international co-ordination:

> Co-operation will be especially important in the deployment of ‘cyclical’ instruments. If one country tightens capital or liquidity requirements on exposures to its domestic economy, the effect will be diluted if lenders elsewhere are completely free to step into the gap. Basel and the EU are addressing how to handle that where the instrument is the Basel 3 Countercyclical Buffer. (Tucker (2011))

In Section 4, we investigate the extent to which Deputy Governor Tucker’s concerns about dilution are warranted. Specifically, we ask whether foreign branches operating within the United Kingdom increase their lending to ‘step into the gap’ when UK-regulated banks experience increases in their capital requirements. We find that this dilution effect from leakages is material and statistically significant.

In the remainder of the paper, we proceed as follows: Section 2 describes the bank-specific UK data base that we employ to measure the relationship between changes in capital requirements and changes in lending, reviews the process that governed changes in capital requirements, reports summary statistics about changes in capital requirements, and describes the relationship between capital ratio requirements and capital ratios. We also show that, despite the absence of any explicit macroprudential mandate in FSA supervision, average capital requirements across the banking system were in fact strikingly countercyclical.

Section 3 focuses on the connection between capital requirement changes and bank lending for the UK-resident banks that were subject to FSA capital regulation. We report regression results that demonstrate a large and statistically significant relationship between bank-specific changes in capital requirements and changes in bank lending.

Section 4 estimates the loan supply response of foreign branches operating in the United Kingdom (which are not subject to FSA capital regulations) to changes in the capital requirements imposed on UK-owned banks and resident foreign subsidiaries (which are subject to FSA capital regulation). We find evidence for material leakages, which partially offset the effect of capital requirement changes on the lending of UK-regulated banks. Section 5 concludes.

2 UK capital regulation, 1998-2007

Our empirical analysis of UK banks' capital ratio and lending responses to bank capital requirement changes is made possible by a regulatory policy regime that set bank-specific, time-varying capital requirements. These mimimum capital requirement ratios were set for all banks under the jurisdiction of the FSA, ie all UK-owned banks and resident foreign subsidiaries. Bank capital requirements are not public information. We collect quarterly data on capital requirements, and other bank characteristics, from the regulatory databases of the Bank of England and FSA. Our sample comprises 104 regulated banks (48 UK-owned banks and 56 foreign subsidiaries), and 173 foreign branches operating in the United Kingdom. Bank mergers are dealt with by creating a synthetic merged data series for the entire period. The variables included in this study are listed and defined in Table 1, and Table 2 reports summary statistics.[9]

Discretionary regulatory policy played a much greater role in the United Kingdom's setting of minimum bank capital ratios than in the capital regulation of other countries. A key focus of regulation was the so-called 'trigger ratio': a minimum capital ratio set for each bank that would trigger regulatory intervention if breached.

The FSA also maintained a separate requirement for a 'target ratio' which was set above the trigger ratio and was intended to provide a capital cushion to help prevent an accidental breach of the trigger ratio. In 2001, following the Financial Services and

[9] The data used in this study exclude outliers based on the following criteria: (1) trivially small banks (with total loans less than £3,000 on average), or (2) observations for which the absolute value of the log difference of lending in one quarter exceeded one.

Market Act, the FSA stopped setting target ratios, but even before then, the trigger ratio was the primary focus of regulatory compliance. Changes in trigger ratios were communicated to the Board of Directors of the bank in a formal letter. According to Francis and Osborne (2009):

> ...the FSA inherited from the Bank of England the practice of supplementing the Basel I approach with individual capital requirements, also known as 'trigger ratios', based on analysis of firm-specific characteristics and management practices, and this practice has been retained under Pillar 2 of Basel II. These firm-specific requirements are periodically reassessed and, where necessary, revised to reflect changing bank conditions and management practices. As part of these reviews, the FSA have considered it to be good practice in the financial services industry for a UK bank to hold an appropriate capital buffer above the individual capital ratios advised by the FSA....
>
> UK supervisors set individual capital guidance, also known as 'trigger ratios', based on firm-specific reviews and judgments about, among other things, evolving market conditions as well as the quality of risk management and banks' systems and controls. These triggers are reviewed every 18-36 months, which gives rise to considerable variety in capital adequacy ratios across firms and over time.

The authors further note that the unique, bank-specific, discretionary UK capital regulation regime was intended to fill the gaps from the early Basel I system, which did not consider risks related to variation in interest rates, or legal, reputational and operational risks. An implication of that view is that discretionary variation of bank-specific capital ratios may have been viewed as less necessary after the introduction of interest rate risk measurement in 1998 and the implementation of the Basel II system in 2007. Francis and Osborne also note that the introduction of Basel II in 2007 generally resulted in substantial reduction in risk-weighted assets for a large number of UK banks.

When measuring the capital requirement (trigger ratio) for risk-based capital that is assigned to the individual bank, some complications arise with respect to the treatment of the 'banking book' and the 'trading book' of the bank. For banks that had both a banking book and a trading book (which is a characteristic of larger, more complex banks, comprising about one third of the regulated banks in our sample), the FSA often assigned different trigger ratios for the banking and trading book, and uniformly, the trading book capital requirement is less than or equal to the trigger ratio on the banking book. When we describe capital requirements in tables and graphs, we will often refer to the 'trigger ratio' and 'capital requirement ratio', but we will always be referring to the banking-book trigger ratio, which is also the measure used in our regression analysis. By focusing on the banking-book trigger ratio to measure regulatory changes, our measure captures truly exogenous change, as we avoid the distortions that result from endogenous changes in the proportion of risk-weighted assets held in the trading book. It is also comparable across banks that maintain trading books and those that do not.

As Table 2 and Figure 1 show, the variation in capital ratio requirements is large. The mean capital requirement ratio is 10.8, the standard deviation is 2.26 , the minimum value is 8%, and the maximum value is 23%. Figure 2 displays the distribution of changes in capital requirements, which are divided according to the change in the size of the capital requirements that are imposed on the banks. When defining capital requirement changes in Figure 2, and in the regression analysis below, we exclude very small changes (changes of less than 10 basis points) which result from errors in rounding, and which are reversed in subsequent quarters.[10] Not surprisingly, there are no observed changes in capital ratio requirements of between 10 and 30 basis points. The elimination of rounding errors results in 132 remaining observations of changes in banking-book capital requirements in our sample. In general, there are more small changes in capital requirements than intermediate or large changes, although that pattern is more pronounced for UK-owned banks than foreign subsidiaries. As Figure 3 shows, most banks either experienced zero or one capital requirement change during our sample period, but 35 banks experienced two or more changes.

Figures 4, 5 and 6 plot the average capital requirement ratio for the regulated banking system, with 'average' defined in three different ways, against GDP growth. Figure 4 takes a simple (non-weighted) average of the capital requirement for all regulated banks in the sample. Figure 5 weights these capital requirements by the assets of each bank. Figure 6 weights by lending to the real economy rather than by assets, and calculates the average capital requirement not directly in levels but by cumulating across *changes* in the capital requirement over successive periods; the latter is to ensure that the graph abstracts from changes in the sample of banks between time

[10] Our method of computing the trigger ratio requires that one divide required capital by risk-weighted assets, which creates very small rounding errors that give rise to small implied 'changes' in required capital ratios, which are not economically significant changes.

periods due to entry or exit, and only reflects changes in capital requirement ratios. All three measures are closely and positively associated with movements in GDP (the simple correlation co-efficient is 0.44, 0.52 and 0.64 respectively, in Figures 4, 5 and 6 respectively). The pattern of association is stronger for weighted than for non-weighted capital requirements, although the range of variation is smaller. Average non-weighted capital requirement ratios ranged from a minimum of 10.2% in 2007 to a maximum of 11.2% in 2003. This is a striking amount of countercyclical variation given that the sample period was one of varying positive growth, but no actual recessions (by way of comparison, the Basel III countercyclical buffer is to vary between 0 and 2.5% over the entire business cycle inclusive of recessions). Thus, although the FSA lacked any explicit macroprudential mandate over the period, the outcome of its decisions made on a bank-by-bank basis was in fact macroprudential in nature. This provides an ideal testing ground for the likely efficacy of future explicitly macroprudential regimes.

After 2006, around the time Basel II was introduced,[11] capital requirements declined markedly, and this happened in spite of an acceleration of growth, which was contrary to the previous pattern of countercyclical changes in requirements. That pattern differs from the rises of prior expansionary periods, although the decline is less pronounced for weighted capital requirements than for non-weighted capital requirements (which actually fell during the 2006-07 expansion). The sample period is too short to draw reliable conclusions, but it is possible that the introduction of Basel II (which was designed to provide a more comprehensive measure of bank risks than the prior system) may have led to supervisors to place less reliance on discretionary setting of bank-specific capital ratios.

To understand the FSA's approach to setting capital requirements better, it is useful to divide the sources of variation in capital ratio requirements into three sets of factors: (1) capital requirement differences that reflect long-term cross-sectional differences in bank type, operations or condition, (2) high-frequency cross-sectional changes in bank operations or condition that capture, for example, sudden changes in bank loan quality, and (3) variation over time in average minimum capital requirements for banks that reflect what could be termed macroprudential goals. Of these, the variation

[11] Basel II was formally introduced on January 2007 in the United Kingdom, but the transition period most likely started before that.

over the cycle has already been discussed above; below we document variation in the long-term cross-sectional characteristics of banks and high frequency cross-sectional changes.

In Table 3, we report summary statistics for average long-term bank characteristics and relate those to average capital ratios. The long-term bank characteristics we examine are: size, liability mix, loan write-off ratio, and concentration. Across the four quartiles of average required capital ratios, higher capital requirements are monotonically associated with smaller bank size and a smaller proportion of what could be termed core deposits (the sum of sight and time deposits, which excludes repos, certificates of deposit, and all non-depository sources of funding). Higher capital requirements are also monotonically increasing in sectoral concentration, defined as a bank's lending to the sector to which it has the greatest exposure divided by the bank's total lending.[12] With respect to loan write-offs, banks in the highest quartile of average capital requirements have substantially higher write-offs, but within the first three quartiles of average capital requirements, banks do not differ with respect to write-offs.

At high frequency – examining responses of capital requirements to quarterly changes in bank behaviour over the prior four quarters – we found almost no connection between changes in bank condition and changes in capital requirements. High-frequency changes in write-offs were negatively correlated with capital requirement changes that occurred within the same quarter, indicating that when some banks experienced large write-offs (resulting in diminished capital) regulators occasionally reduced those banks' minimum capital ratios. It is possible that high-frequency increases in write-offs are moments when supervisors believe that ongoing uncertainty about prospective bank losses has been resolved, in which case it may make sense to reduce capital requirements accordingly. This high-frequency

[12] Lending here refers to non-financial sector, non-household lending. The household sector is excluded from the measure of concentration because lending to households is not comparable in concentrating risk to lending to a particular sector. For many banks lending to households is by far the biggest individual lending category. The large size of the household sector means that a bank specialising in household lending may be well diversified *within* the sector, eg regionally or across different types of consumer loans, and thus less risky. At any rate, this appears to have been the view of the regulators: including household lending in the definition of concentration used here eliminates the monotonic relationship between sectoral concentration and capital requirements.

connection between write-offs and capital requirements explained only about 1% of the panel variation in capital requirements.[13]

Overall, therefore, we find substantial variation across banks and over time in minimum capital requirements, and we find that changes in capital requirements reflected discernible responses by the FSA to long-term bank characteristics, as well as cyclical changes in economic and market conditions, and (to a small extent) high-frequency bank changes in circumstances.

As a rough gauge of the extent to which capital requirements were binding on bank behaviour, Figure 6 plots the co-movements between weighted capital ratios and weighted capital ratio requirements over time, with banks sorted into quartiles according to the buffer over minimum capital requirements. For all four groups of banks, the variation in capital requirements was associated with substantial co-movement in capital ratios, confirming the conclusions of Alfon *et al* (2005) and Francis and Osborne (2009) that capital ratio requirements were binding on banks' choices of capital ratios for UK banks during this sample period.

3 The effect of minimum capital requirement changes on lending by affected banks

In this section, we estimate the effect of capital requirement changes on bank lending. Our measure of bank lending is loans to the non-financial sector. We construct that measure by aggregating all of the sectoral loan categories of a bank's lending except for its loans to financial institutions. As discussed in Section 1, changes in capital requirements should affect lending by a regulated bank only when bank equity is relatively expensive to raise, and when regulatory requirements are binding constraints. Bank lending may also vary due to changes in loan demand. To identify loan-supply responses to capital requirement changes, in this section, we control for loan-demand changes in several alternative ways. Following Aiyar (2011), the basic strategy is to exploit differences in the sectoral concentration of lending by different banks to identify cross-sectional differences in loan demand faced by different banks.

[13] If supervisors believe that write-offs resolve ongoing uncertainty about prospective bank losses, it may make sense to reduce capital requirements accordingly.

For *each bank*, we construct three different measures of sectoral loan demand as follows: in any quarter, each sector's total lending is measured by aggregating all lending into that sector by *other* banks in the sample. Denote that variable as Z_{iqt}, where t indexes the quarter, q indexes the sector and i indexes the bank for which it is constructed. Allowing small-case letters to denote logs, Δz_{iqt} represents percentage changes in sectoral lending thus constructed. Then we aggregate across sectors, weighting the change in lending in each sector by that sector's importance to bank i; thus $z_{it} = \sum_q s_{iqt-1} \Delta z_{iqt}$, where s_{iqt} denotes the share of sector q in bank i's lending portfolio in period t.

The variable z_{it} serves as our first measure of *bank-specific* loan demand. However, the measure is imperfect because growth in aggregate lending by all other banks may still reflect the common supply-side effect of macroprudential policy. We construct two additional measures designed to address that problem. First, for each sector we simply subtract total (non-sectorally weighted) bank lending growth for all banks from the bank-specific measure z_{it}. This subtraction should remove supply-side influences that are common to both total bank lending and sectorally weighted bank lending, leaving only the bank-specific weighted sectoral deviations of loan growth, which should reflect demand-side influences. We call this measure 'adjusted z'. Our second approach is to regress z_{it} on the time series average (asset-weighted) change in bank capital requirements. The bank-specific time series residual from that regression is a proxy for loan demand growth faced by that particular bank. We call this measure 'residual z'.

Thus the general specification is:

$$\Delta l_{it} = \alpha_i + \sum_{k=0}^{3} \beta_{t-k} \Delta KRR_{it-k} + \sum_{k=0}^{3} \gamma_{t-k} z_{it-k} + X\Pi + \varepsilon_{it}$$

where Δl_{it} denotes lending growth in period t by bank i, ΔKRR_{it} denotes the change in the capital requirement ratio, α_i is a bank-specific fixed effect, and X is a vector of controls. z_{it} is the demand proxy discussed above, in any of its three varieties.

Both the contemporaneous change in capital requirements and three lags are included in the equation. As noted by Francis and Osborne (2009), on the basis of regulatory data we only observe a change in the capital requirement when the trigger ratio in a particular report differs from the trigger ratio in the preceding report from three months earlier; we do not know when, within that three-month period, the change in capital requirements was introduced. Moreover, it is possible that FSA regulators—who maintain an ongoing dialogue with the banks they supervise—might inform a bank in advance of a forthcoming change in the capital requirement ratio. Both these considerations indicate the necessity for a contemporaneous term of the dependant variable in addition to lags.

Table 4 reports five versions of our baseline loan-supply regressions. All specifications are estimated in a panel fixed-effects framework, where the bank-specific fixed effect should capture heterogeneity in lending growth arising from relatively long-run, time-invariant bank characteristics.[14] The first column does not include any demand controls. The second column introduces the raw value of *z* as a control. The third and fourth columns include, respectively, the adjusted *z* and residual *z* demand proxies discussed above. The fifth column introduces GDP growth and other bank-specific characteristics as additional controls. Specifically, we include TIER1, RISK, SUB, and BIG. TIER1 is Francis and Obsborne's (2009) measure of a bank's low cost of equity capital relative to other banks (which is revealed by its relatively high dependence on Tier 1 capital). RISK is a measure of the riskiness of bank assets, also used in Francis and Osborne, which is the ratio of risk-weighted assets to total assets. SUB is an indicator variable that captures whether the bank is a subsidiary of a foreign bank. BIG is an indicator variable that captures whether the bank has assets in excess of £10 billion.

We find that loan supply responds negatively to increases in capital requirements. Controlling for demand tends to strengthen the magnitude of that effect. Using the 'residual of *z*' demand proxy produces the largest and most statistically significant estimates of capital requirement changes on loan supply; the cumulative response for that specification (adding the coefficients on four various lags) is roughly 0.09. That is, an increase in the capital requirement ratio of 100 basis points induces, on average,

[14] A fixed-effects specification is preferred to random effects because we have no strong prior that the bank-specific effect is not correlated with other explanatory variables—as required by random-effects. Post-estimation Hausman tests reject the null of a random-effects specification.

a cumulative fall in lending growth of 9 percentage points.[15] More generally, the cumulative impact of a 100 basis points increase in the capital requirement ratio lies between 6 and 9 percentage points, depending on which of the specifications in Table 4 is used. Other control variables (TIER1, RISK, SUB, and BIG) are not significant.

We also estimate, but do not report, the first four specifications in Table 4 with the addition of time dummies. This is intended to investigate whether the effects of changes in capital requirements depend on their timing, as well as to account for omitted variable bias stemming from any variable that affected the whole banking system over time. The specification tests whether a bank that experiences a capital requirement increase at times when many other banks are experiencing one (as part of a macroprudential policy) responds differently to that increase than a bank that is experiencing a capital requirement increase when other banks are not. The coefficient magnitudes on the capital requirement ratio variable are similar whether or not the time dummies are included in the regression, suggesting that the response of an individual bank to a microprudential capital requirement increase is similar to its response to a macroprudential capital requirement increase.

Table 5 looks more carefully at the role played by the capital buffer, and by bank size, by introducing a term interacting the change in the capital requirement with dummy variables for, respectively, banks in the lowest quartile of buffer size, banks in the lower half of buffer size, banks in the highest quartile of bank size and banks in the upper half of bank size. Column 1 suggests that the response of a bank in the first quartile of capital buffers—ie a bank which has an average (over time) capital buffer which is 'low' relative to other banks—to a change in capital requirements is *smaller* than the response of a bank which is not in this quartile. This effect is not statistically significant. But, as shown in column 2, there *is* a significant difference in the responsiveness of banks which have an average capital buffer below that of the median bank.

This finding is consistent with recognising the endogeneity of capital buffers to bank-specific characteristics. Banks with relatively easy access to capital markets choose to

[15] Strictly speaking, the cumulative impact on lending growth will differ from 9% due to compounding.

hold smaller buffers, and have a smaller loan supply response to changes to capital requirements. On the other hand banks which find it difficult to access capital markets choose to hold larger buffers and also have a larger loan supply response to changes in capital requirements. These results are analogous to a well-known phenomenon in the investment literature: firms with larger cash holdings exhibit greater cash-flow sensitivity of investment, and even greater cash-flow sensitivity of cash (Calomiris, Himmelberg and Wachtel (1995), Almeida, Campello and Weisbach (2004), Acharya, Almeida and Campello (2007)). Moreover, as illustrated by columns 3 and 4, it appears that bank size is a (noisy) indicator of capital buffers, with larger banks tending to hold smaller capital buffers and *vice versa*.[16]

4 Leakages associated with foreign branches

In Section 3, we showed that UK-regulated banks exhibit a strong loan-supply response to changes in required capital ratios. Here we explore the extent to which those loan-supply effects are mitigated by endogenous loan-supply decisions by foreign branches operating in the United Kingdom, which are not subject to domestic UK capital regulation. As noted in Section 1, such branches may 'step into the gap' created by macroprudential policy; when capital-regulated banks contract their loan supply, foreign branches operating in the United Kingdom may offer substitute sources of credit to borrowers.

As Figure 7 shows, the aggregate amount of lending by foreign branches is substantial, although smaller than the aggregate amount of lending by banks that are subject to UK capital regulation. Moreover, branch lending is not confined to one or two sectors, but is rather broad-based. In four sectors lending by branches accounts for 40% or more of total sectoral lending.

Our empirical strategy is to regress foreign branch lending growth on the instrumented lending of a 'reference group' of regulated banks. The instrument is the change in capital requirements that occurred for that reference group. We report results for reference groups defined alternatively as the entire set of regulated banks,

[16] This finding is consistent with (although not equivalent to) evidence that larger banks tend to hold less capital in a large cross-country sample of banks (Cihak and Schaeck (2007)).

or as a branch-specific reference group weighted by the sectoral exposures of the branch. As before, we use the 'residual of *z*' to proxy for loan demand.

Thus the specification is:

$$\Delta l_{jt}^{BRN} = \alpha_j + \sum_{k=0}^{3} \beta_{t-k} \Delta l_{jt-k}^{REF} + \sum_{k=0}^{3} \gamma_{t-k} z_{jt-k} + X\Pi + \varepsilon$$

where Δl_{jt}^{BRN} denotes lending growth by the foreign branch *j* and Δl_{jt}^{REF} denotes lending growth by branch *j*'s reference group of regulated banks. Note that *j* indexes branches, while *i* is reserved to index regulated banks. Δl_{jt}^{REF} is instrumented using several lags of ΔKRR_{jt}^{REF}. And both Δl_{jt}^{REF} and ΔKRR_{jt}^{REF} come in aggregate and branch-specific varieties, whose precise construction is described below.

Let $\tilde{z}_{qt}$ denote the log of aggregate lending by all regulated banks to sector *q* in period *t*. Then the *aggregate variety* of Δl_{jt}^{REF} is constructed as: $\Delta l_{jt}^{REF} = \sum_q \Delta \tilde{z}_{qt}$, and the *branch-specific variety* is constructed as: $\Delta l_{jt}^{REF} = \sum_q s_{jqt-1} \Delta \tilde{z}_{qt}$. Note that the aggregate variety of Δl_{jt}^{REF} is identical for all branches.

The *aggregate variety* of ΔKRR_{jt}^{REF} is simply defined as: $\Delta KRR_{jt}^{REF} = \sum_i \sigma_{it-1} \Delta KRR_{it}$, where σ_{it} denotes economy-wide lending by bank *i* as a share of economy-wide lending by all regulated banks in period *t*. Again, note that the aggregate variety of ΔKRR_{jt}^{REF} is identical for all branches.

Let $\Delta KRR_{qt} = \sum_i \sigma_{iqt-1} \Delta KRR_{it}$ where σ_{iqt} denotes lending by bank *i* to sector *q* as a share of lending by all regulated banks to sector *q* in period *t*. This is a measure of the sector-specific change in capital requirements in each period. Then the *branch-specific variety* of ΔKRR_{jt}^{REF} is defined as: $\Delta KRR_{jt}^{REF} = \sum_q s_{jqt-1} \Delta KRR_{qt}$.

Note that Δl_{jt}^{REF} is defined in terms of weighted *changes* in regulated bank lending, and that the weights—the sectoral exposure pattern of the branch—are taken for the *previous* period. This is to ensure that Δl_{jt}^{REF} reflects actual changes in lending by relevant regulated banks, rather than simply changes in the sample of regulated banks across time periods (because of entry or exit of some regulated banks from the sample). Identical considerations apply to the construction of ΔKRR_{jt}^{REF} .

Again, both the contemporaneous term and lags of the independent variable of interest—reference group lending—are included in the specification. If banks are made aware by the FSA of an impending increase in capital requirements, those banks are in turn likely to inform loan customers of an intent to contract lending (eg by reducing or eliminating lines of credit as they mature). Bank borrowers, therefore, may seek new lending relationships that begin simultaneous with the contraction in loan supply induced by changing capital requirements.

The instruments we use have considerable intuitive appeal in this application. We have shown in the previous section that lending by regulated banks responds strongly to changes in capital requirements. Moreover, it is hard to imagine any channel through which changes in capital requirements could affect lending by foreign branches except *via* the impact on lending by regulated banks.

Table 6 presents results from instrumental variables regressions. Columns 1 through 3 report results using the aggregate reference group of all regulated banks, while columns 4 through 6 report results from using a branch-specific reference group as described above. Columns 1 and 4 include no controls. Columns 2 and 5 include our preferred ‘residual *z*’ demand control. Columns 3 and 6 include, in addition, GDP growth and three branch-specific variables: SIZE, KAR and WHL.[17] SIZE is the log of the bank’s total assets. KAR is a measure of leverage, the capital asset ratio. WHL is a measure of reliance on wholesale funding, being the ratio of repo liabilities to total liabilities. We find that lending by foreign branches is strongly negatively related to instrumented lending by the foreign branch’s reference group. That is, a reduction in loan supply by regulated banks in response to tighter capital requirements indeed induces an increase in loan supply by foreign branches. Bank-specific controls are not found to be significant.

[17] Foreign branches do not file the BSD3 report on capital adequacy which we used to construct the bank-specific balance sheet controls in Table 4. But they are required to report (less detailed) balance sheet data using the BT form, which are used to construct the control variables here.

The result on leakages holds for both the broad and narrow reference group specifications, but the results are, unsurprisingly, stronger for the branch specific reference group. Table 6 also reports a set of post-estimation statistics. The Sargan-Hansen test of overidentifying restrictions indicates that capital requirements weighted by branch-specific sectoral exposures are much better instruments than the unweighted change in capital requirements. Conventional tests for weakness of instruments—for example comparing the Kleibergen-Paap Wald F-statistic against critical values for an 'acceptable' level of bias—are not possible, because the relevant critical values have not been tabulated.[18] However, to assuage concerns about weak instruments, we report two tests for robust inference in the presence of weak instruments.[19]

What do these numbers say about the magnitude of leakages from prudential regulation? From column 6, the cumulative impact of a *capital requirement induced* reduction of 1% in lending growth by regulated banks is an increase in lending growth of 2.9% by foreign branches. As noted earlier, regulated banks are, on average, much bigger than foreign branches and lend more into the real economy. Across the sample, quarterly lending by the average regulated bank was £9.5 million, about 15 times larger than quarterly lending by the average foreign branch, which stood at £630,000. On the other hand, there are more foreign branches (173) in our cross-section than regulated banks (104). The product of these ratios between branches and regulated banks yields a rough estimate of leakages. Thus, over our sample period, the regulatory leakage from foreign branches amounted to about one third: 32% = (2.9*(63/950)*(173/104)*100).

It appears, therefore, that over the sample period leakages from foreign branches operating in the United Kingdom were qualitatively and quantitatively material, offsetting about one third of the contractionary credit-supply impact of a tightening in capital requirements. The partial nature of the offset suggests that, on balance,

[18] See Stock and Yogo (2002). The authors tabulate critical values for various combinations of number of endogenous regressors and number of instruments.

[19] Results are given for the Anderson-Rubin Wald test and Stock-Wright S test. The null hypothesis tested in both cases is that the coefficients of the endogenous regressors in the structural equation are jointly equal to zero, and, in addition, that the overidentifying restrictions are valid. Both tests are robust to the presence of weak instruments. The tests are equivalent to estimating the reduced form of the equation (with the full set of instruments as regressors) and testing that the coefficients of the excluded instruments are jointly equal to zero (see Stock, Wright and Yogo (2002) for further discussion). Both tests indicate rejection of the null across all specifications.

changes in capital requirements can have a significant impact on aggregate lending by UK-resident banks.[20] The results also validate the focus on reciprocal arrangements between financial regulators to prevent international leakages from forthcoming macroprudential regimes, eg the reciprocity principle enshrined in the Basel III countercyclical capital buffer.[21]

5 Conclusion

We consider the consequences for bank credit supply of macroprudential capital regulation, using a unique UK 'natural experiment' (the practice of setting bank-specific, time-varying capital requirements) to gauge the potential effectiveness of macroprudential changes in bank capital requirements. We employ data on individual banks operating in the United Kingdom from 1998 to 2007.

For macroprudential policy to be effective in controlling the aggregate amount of lending in an economy, three necessary conditions need to be satisfied: (1) it should be relatively costly to raise equity capital, (2) regulatory capital requirements should bind on banks, and (3) macroprudential 'leakages'— substitutes for regulated banks' lending—should not fully offset the loan-supply effects of variation in capital requirements. The UK evidence suggests that all three conditions were satisfied in the United Kingdom.

Banks that were subject to UK capital regulation display large and statistically significant responses in their loan-supply behaviour to changes in regulatory capital requirements. The loan-supply behaviour of banks that were not subject to UK capital requirements – foreign bank branches operating in the United Kingdom – responded to increases in UK capital requirements by increasing their loan supply, even as

[20] We also estimated the model as a panel-VAR with the difference of branch-specific reference group capital requirements, branch-specific reference group regulated bank lending and unregulated bank lending. To identify a capital requirements shock, we imposed block exogeneity of the capital requirement and assumed that upon impact the change in the capital requirement reacts to regulated bank lending growth with a lag to identify a capital requirements shock. This exercise suggested that the maximum response of unregulated bank lending to a 100 basis point change in the capital requirement is roughly 21%, consistent with the estimate provided by the corresponding instrumental variables regression. These results are available upon request and are robust to estimating the panel-VAR model either via a fixed effects or the mean group estimator.

[21] The principle of reciprocity is intended to create a level playing field for all institutions providing credit in a given jurisdiction, irrespective of whether the institution is incorporated in the jurisdiction. Where a banking group operates in more than one country, it is required to calculate its own countercyclical buffer based on a weighted average of all of the countercyclical capital buffers in force in each Basel III country to which the group has any credit exposure.

regulated banks contracted lending. Although this ‘leakage’ was found to be material it only partially offset the initial impulse from the regulatory change. This suggests that, on balance, changes in capital requirements can have a significant impact on aggregate lending by UK-resident banks. The results also reinforce the need for macroprudential regulators to co-ordinate changes in capital requirements to prevent regulatory arbitrage by banks.

Appendix: Charts and tables

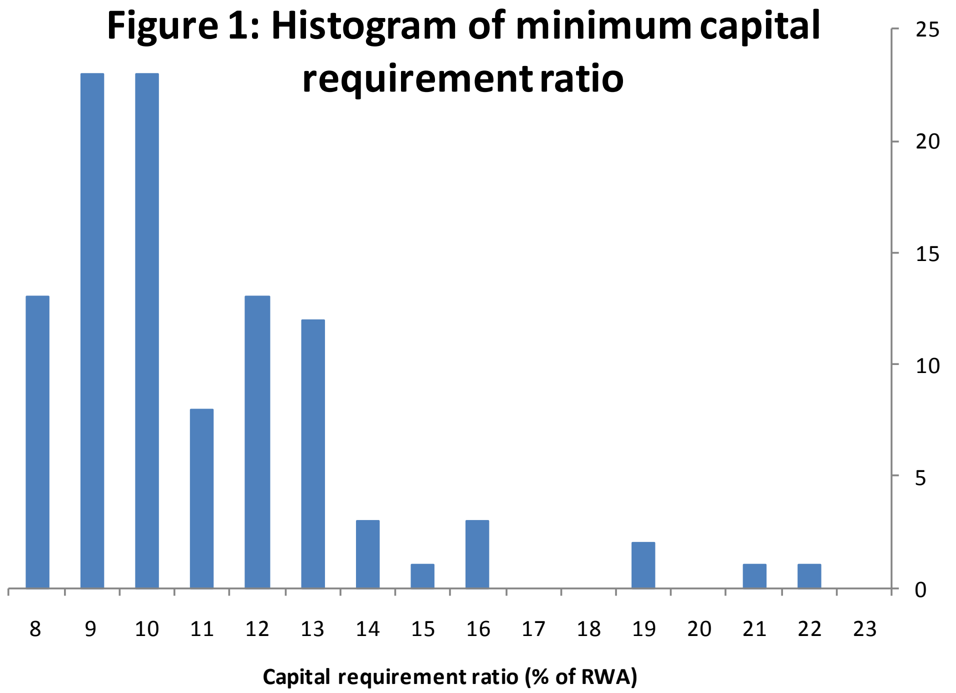
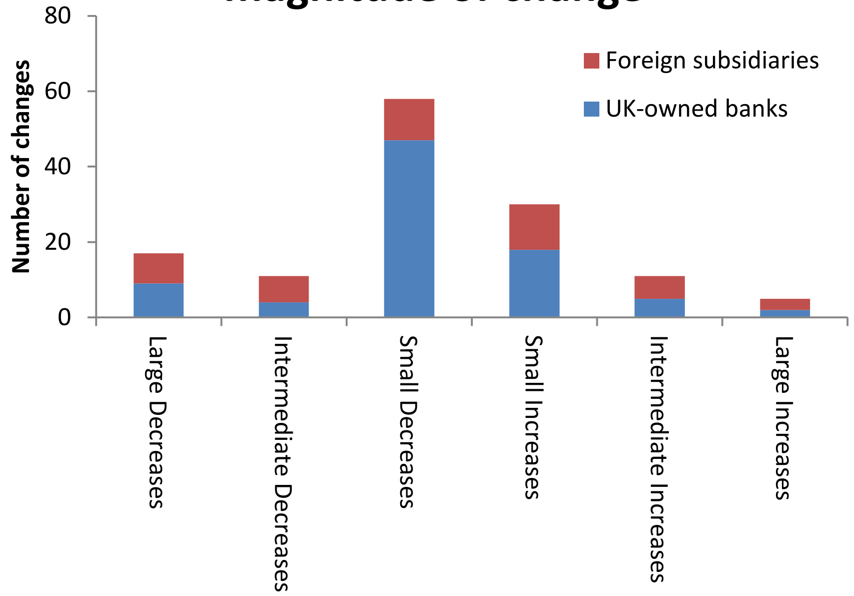


Figure 2: Distribution of changes in capital requirement ratios by magnitude of change



Large decrease = DKR<-150bp
Intermediate decrease = -150bp<DKR<-100bp
Small decrease = -100bp<DKR<-10bp
Large increase = DKR>150bp
Intermediate increase = 150bp>DKR>100bp
Small increase = 100bp>DKR>10bp

Figure 3: Distribution of banks by number of changes to capital requirement ratio

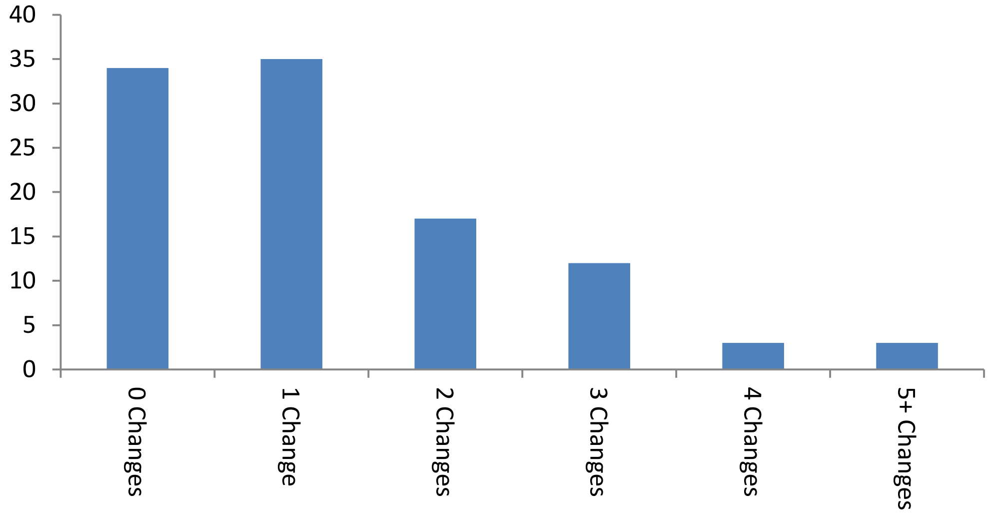


Figure 4: Time series of average capital requirement ratio

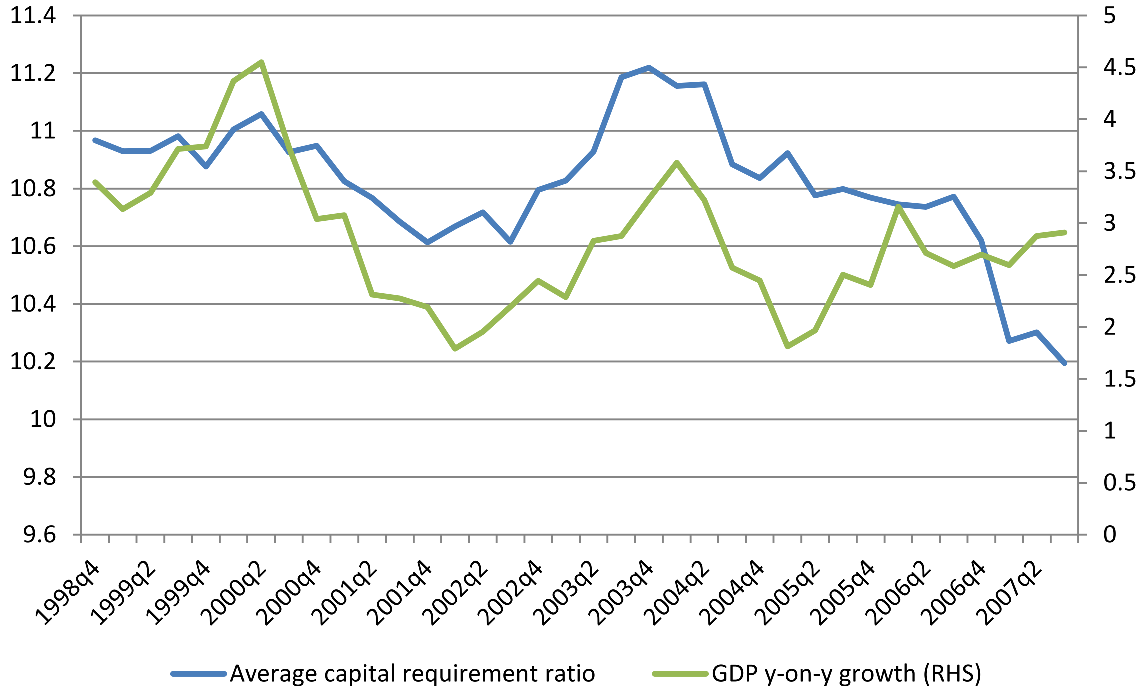


Figure 5: Time series of average weighted capital requirement ratio

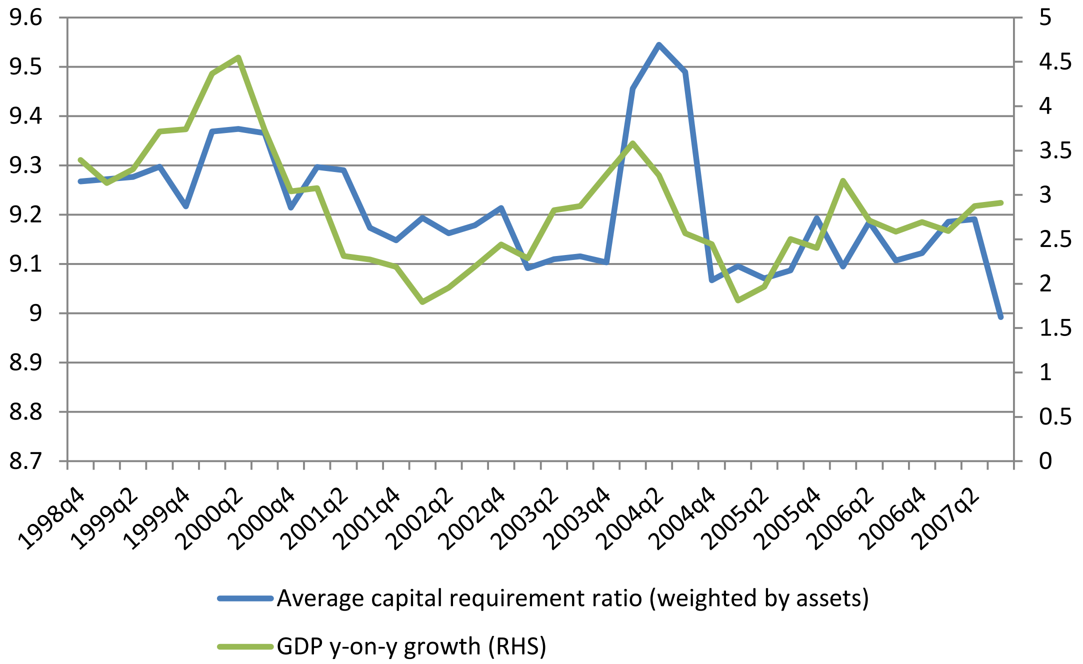


Figure 6: Time series of average weighted capital requirement ratio (cumulated changes)

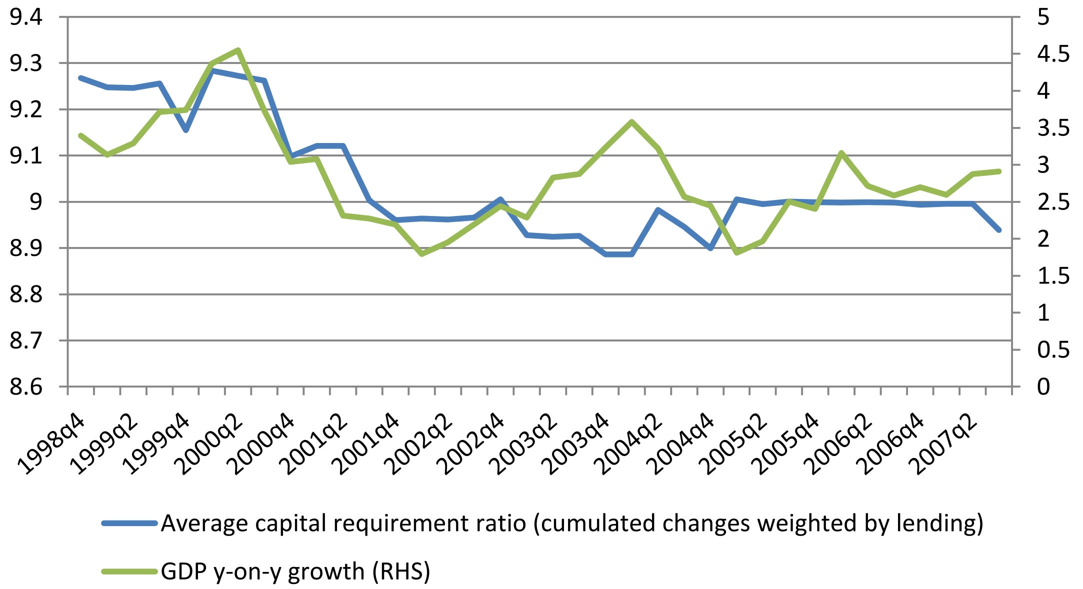


Figure 7: Covariation between average capital requirements and average capital

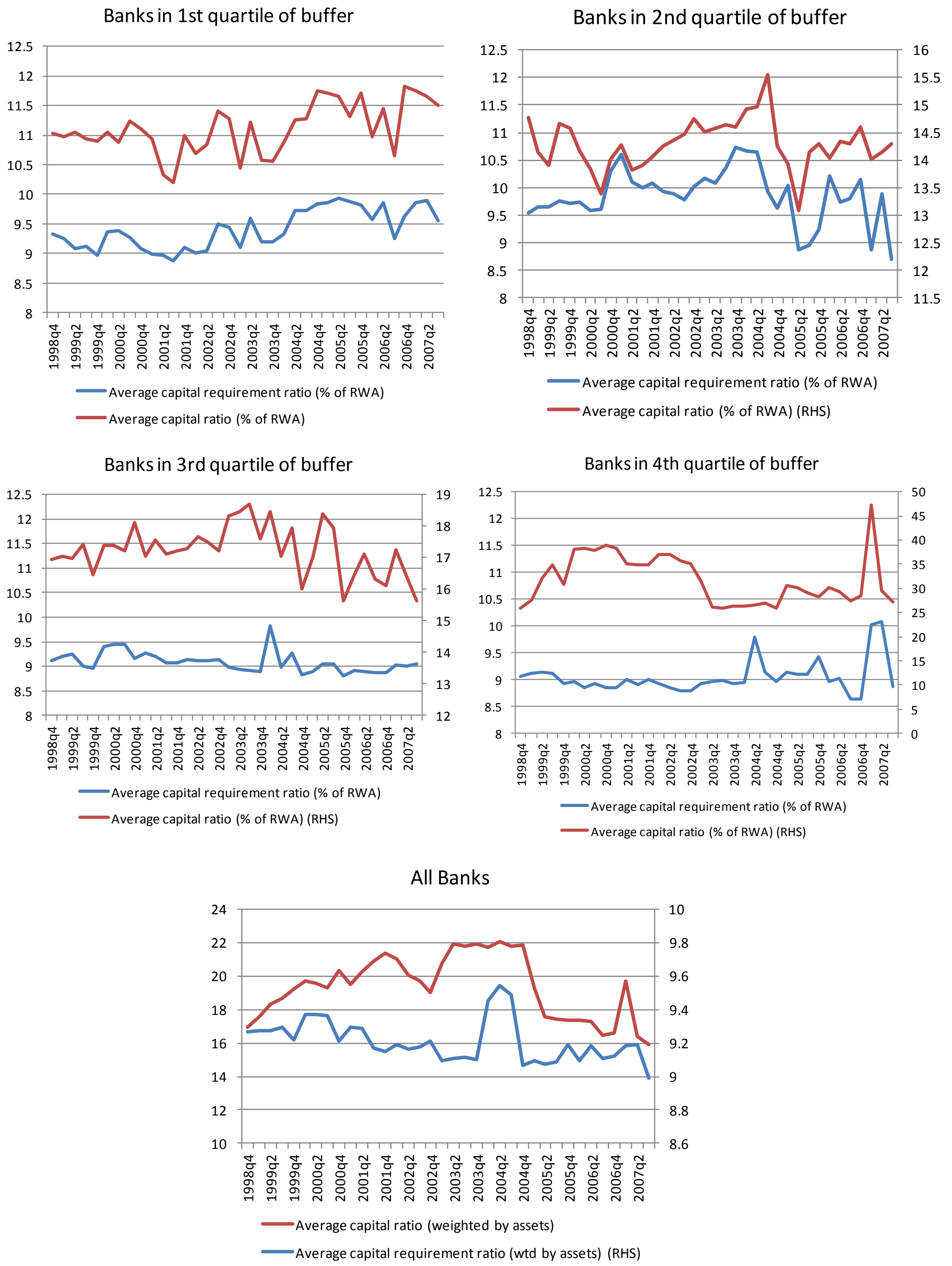


Figure 8: Sectoral pattern of lending by foreign branches

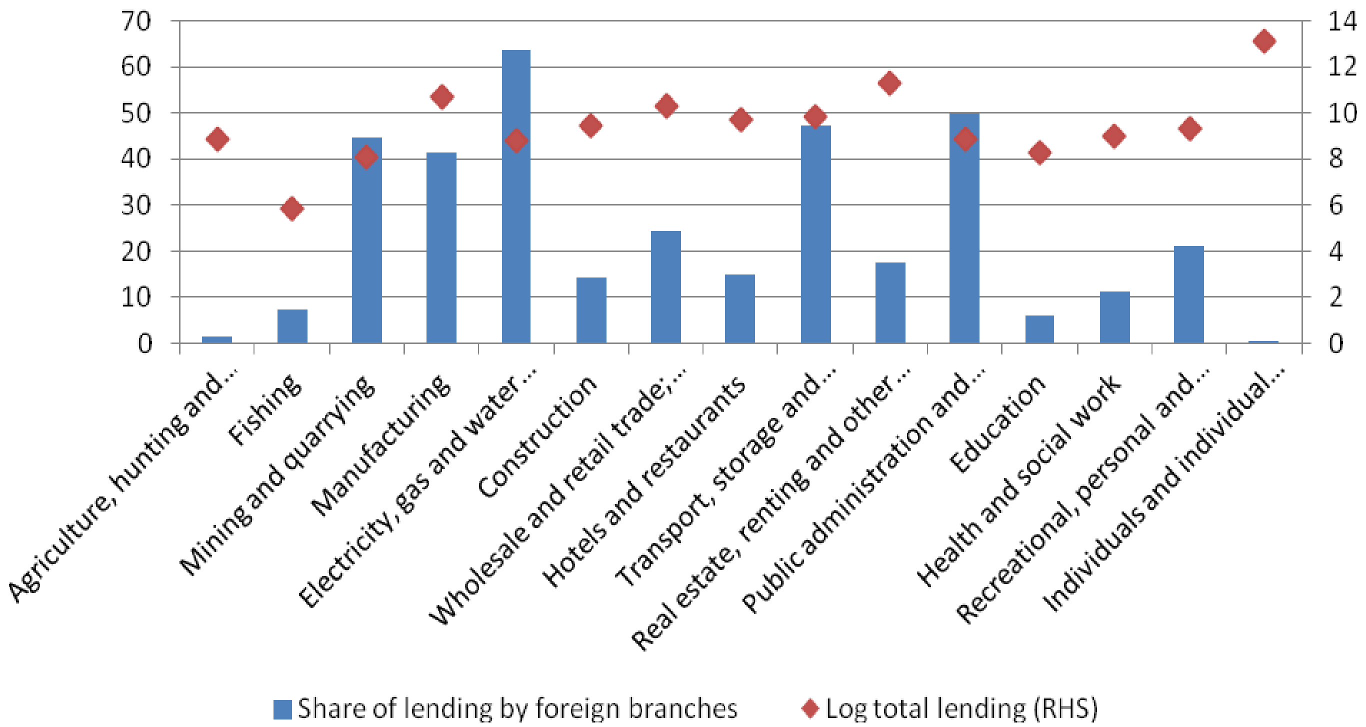


Table 1: Variables and data sources

Variable	**Definition**	**Source (Bank of England Reporting Form)**	**Notes**
Capital requirement ratio	FSA-set minimum ratio for capital-to-risk weighted assets (RWA) for the banking book. Also known as 'trigger ratio'.	BSD3	
Lending	Bank lending to non-financial sectors of the economy	AL	
TIER1	Ratio of Tier 1 capital to RWA.	BSD3	
SIZE	Total assets	BSD3 / BT	BSD3 for regulated banks; BT for foreign branches.
BIG	Dummy variable = 1 when SIZE is in highest decile.	BSD3	
RISK	Ratio of RWA to total assets.	BSD3	
SUB	Dummy variable = 1 when bank is a resident subsidiary of a foreign bank.		Information from the Bank of England's Monetary and Financial Statistics Department.
BUF	Difference between actual capital and the capital requirement ratio, divided by RWA.	BSD3	
KAR	Capital asset ratio	BT	
WHL	Ratio of repo liabilities to total liabilities	BT	

Table 2: Summary Statistics

Variable	Entity	Units	Mean	SD	Min	Max	Obs
Capital requirement ratio	Regulated banks	%	10.8	2.26	8	23	2,630
Change in capital requirement ratio	Regulated banks	Basis points	-1.4	29.7	-500	500	2,524
Lending to real economy	Regulated banks	£ 000s	9,483	28,510	0	274,140	2,630
Lending to real economy	Foreign branches	£ 000s	630	893	0	10,175	3,976
Change in lending to real economy	Regulated banks	%	0.8	16.5	-98.3	85.3	2,503
Change in lending to real economy	Foreign branches	%	0.3	20.9	-98.7	98.4	3,792

Table 3: Average capital requirement ratio by various bank attributes 1/

Variable	Percentiles 25 <	25-50	50-75	> 75
Writeoffs 2/	10.36	10.44	10.15	11.57
(Mean value within quartile)	(0.00)	(0.13)	(0.48)	(2.48)
Size 3/	12.30	11.06	10.63	9.54
(Mean value within quartile)	(0.03)	(0.10)	(0.32)	(5.16)
Retail Deposits 4/	12.45	10.79	10.08	10.21
(Mean value within quartile)	(3.0)	(15.4)	(44.3)	(73.6)
Sectoral Specialisation 5/	10.51	10.87	10.90	11.25
(Mean value within quartile)	(16.1)	(39.4)	(59.3)	(89.4)

1/ The mean values of the variables within each quartile are provided in brackets below the associated mean capital requirement.
2/ Defined as total amount written-off as a share of risk-weighted assets.
3/ Defined as asset size relative to total assets of the banking system.
4/ Defined as the sum of sight and time deposits as a fraction of total liabilities.
5/ Defined as lending to the sector to which the bank has the greatest exposure in percent of total lending by the bank to all non-financial non-household sectors.

Table 4: The impact of minimum capital requirements on bank lending 1/
Dependant variable: Rate of growth of lending

	1	2	3	4	5
Change in capital requirement ratio (summed lags)	-0.0676***	-0.0666***	-0.0684***	-0.0906***	-0.0904***
(Prob > F)	0.0021	0.0026	0.0016	0.0046	0.0049
DEMAND (summed lags)		0.374	0.27	0.272	0.201
(Prob > F)		0.315	0.653	0.46	0.596
Demand variable		z	Adjusted z	Residual z	Residual z
GDP growth (summed lags)					0.0145
(Prob > F)					0.532
TIER1					-0.0008
(p-value)					0.159
BIG					0.009
(p-value)					0.641
RISK					-0.0003
(p-value)					0.09
SUB					0.01
(p-value)					0.621
Observations	2135	2114	2114	1826	1826

1/ This table presents results from fixed effects panel regressions of regulated banks. The dependant variable is the growth rate of bank lending to the real sector. Four lags each are used of the first three variables in the table: the change in capital requirement, the demand proxy and the rate of growth of GDP. The table entries show the sum of coefficients for these lags, together with the probability that the sum of coefficients is significantly different from zero. The remaining coefficients are shown together with p-values. *, ** and *** denote significance at the 10%, 5% and 1% level respectively. The same conventions are followed in the remainder of the tables presenting regression results.

Table 5: The interaction of minimum capital requirements with capital buffers and bank size
Dependant variable: Rate of growth of lending

	1	2	3	4
Change in capital requirement ratio (summed lags)	-0.106***	-0.179***	-0.102**	-0.091***
(Prob > F)	0.008	0.006	0.012	0.008
DEMAND (summed lags)	0.272	0.240	0.278	0.271
(Prob > F)	0.46	0.54	0.46	0.47
Demand variable	Residual z	Residual z	Residual z	Residual z
BUF in 1st quartile (interaction) (summed lags)	0.07			
(Prob > F)	0.21			
BUF less than median (interaction) (summed lags)		0.135**		
(Prob > F)		0.05		
SIZE in 4th quartile (interaction) (summed lags)			0.04	
(Prob > F)			0.472	
SIZE greater than median (interaction) (summed lags)				0.014
(Prob > F)				0.954
Observations	1826	1826	1826	1826

Table 6: Leakages from regulation of bank capital (Instrumental Variables)
Dependant variable: Rate of growth of lending of resident foreign branches

	Aggregate IV			Branch-specific IV		
	1	2	3	4	5	6
Change in lending by all regulated banks (summed lags)	-2.275***	-1.602*	-2.001**	-3.12***	-2.656***	-2.916**
(Prob > F)	0.009	0.065	0.012	0.0014	0.003	0.036
DEMAND (summed lags)		0.322***	0.398***		0.291	0.225
(Prob > F)		0.0018	0.0002		0.186	0.201
Demand variable		Residual z	Residual z		Residual z	Residual z
GDP growth (summed lags)			0.076**			-0.063
(Prob > F)			0.021			0.135
SIZE			-0.017			-0.025
(p-value)			0.217			0.274
KAR			0.0001			-0.0001
(p-value)			0.86			0.887
WHL			0.0014			-0.0063
(p-value)			0.76			0.33
Hansen J statistic	38.04	31.54	6.77	2.6	4.67	2.64
(Prob > chi-squared)	0	0	0.15	0.63	0.32	0.62
Anderson-Rubin Wald test statistic	55.25	44.42	18.85	43.88	37.05	22.75
(Prob > chi-squared)	0	0	0.016	0	0	0.004
Stock-Wright S statistic	53.17	42.56	18.58	41.85	35.06	21.88
(Prob > chi-squared)	0	0	0.017	0	0	0.005
Observations	2648	2645	2645	2490	2490	2490
Instrument	Change in average capital requirement of all regulated banks			Change in capital requirement of regulated banks weighted by sectoral exposures of branch		

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