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# The international transmission of bank capital requirements: Evidence from the UK☆

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ABSTRACT

We use data on UK banks' minimum capital requirements to study the impact of changes to bank-specific capital requirements on cross-border bank loan supply from 1999Q1 to 2006Q4. By examining a sample in which each recipient country has multiple relationships with UK-resident banks, we are able to control for demand effects. We find a negative and statistically significant effect of changes to banks' capital requirements on cross-border lending: a 100 basis point increase in the requirement is associated with a reduction in the growth rate of cross-border credit of 5.5 percentage points. We also find that banks tend to favor their most important country relationships, so that the negative cross-border credit supply response in "core" countries is significantly less than in others. Banks tend to cut back cross-border credit to other banks (including foreign affiliates) more than to firms and households, consistent with shorter maturity, wholesale lending which is easier to roll off and may be associated with weaker borrowing relationships.



## 1. Introduction

It is well documented that globalized banks transmit balance sheet shocks across borders. Cetorelli and Goldberg (2011) show that during the global financial crisis, liquidity shocks to banking systems in advanced countries caused a contraction in lending to emerging markets. Aiyar (2011, 2012) and Hoggarth, Hooley, and Korniyenko (2013) document that foreign banks withdrew funding from UK-resident banks during the crisis, contributing to a contraction in domestic lending. De Haas and Van Horen (2013) show that cross-border retrenchment by banks was particularly severe in countries where the bank was less integrated in the local banking system. And ample

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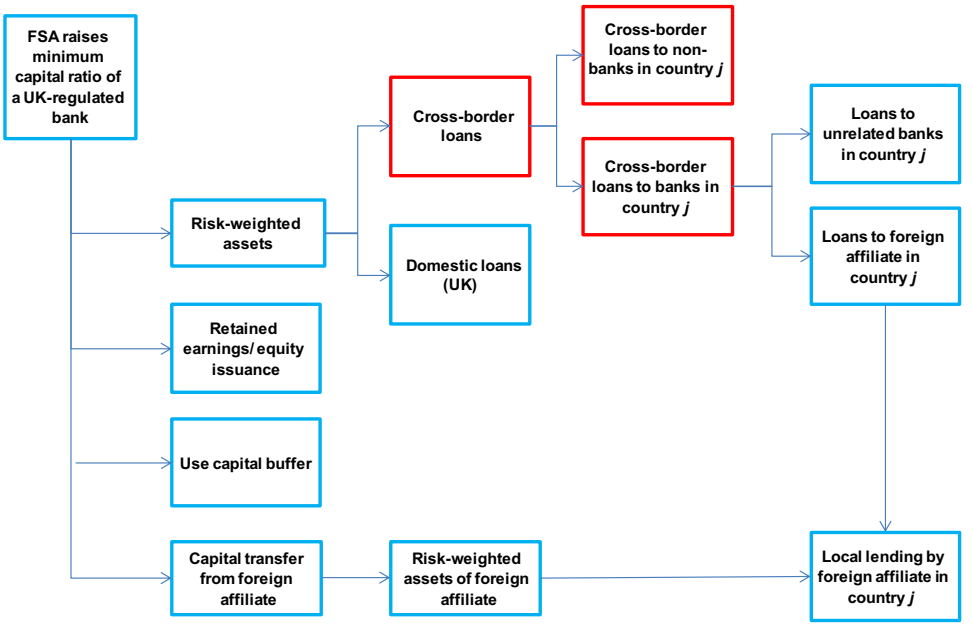


**Fig. 1.** International transmission of changes in domestic capital requirements.[a] ([a]Note this study focuses on the cross-border lending aspect of the transmission mechanism, highlighted in red.) (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

pre-crisis evidence from diverse episodes and settings is marshaled by contributions such as Peek and Rosengren (1997) and Schnabl (2012).

An important instance of an externally imposed balance sheet adjustment is a regulatory change in minimum capital requirements. A separate literature has found that changes in capital requirements can trigger shifts in domestic credit supply. Several papers use cross-sectional data for this purpose, or examine changes in aggregate bank lending around the time of a regulatory regime change (see Vanhoose (2008), for a review).[2] A more recent literature focuses on a unique data-set from the UK—where the regulator imposed time-varying, bank-specific capital requirements—to better identify the impulse from regulatory changes in minimum capital requirements to bank lending (Aiyar, Calomiris, and Wieladek, 2014a, 2014b; Francis and Osborne, 2012; Bridges, Gregory, Nielsen, Pezzini, Radia, and Spaltro, 2014; Noss and Toffano, 2014). All of these papers share the trait that the credit supply response analyzed is purely domestic.

It is important to emphasize that these effects reported in previous papers are based on observed sample averages during the 1998–2007 period. In theory, higher capital requirements could increase lending at banks with very low or negative net worth; if capital ratio requirements help to prevent or overcome a so-called "debt overhang" problem, which can occur at very low capital ratios, then in principle, higher capital could encourage lending. Furthermore, our results measure short-term loan-supply reactions. It is not surprising that a decline in the loan supply is associated with a transition to higher capital requirements, but in the longer run, improvements in the stability of the banking system that result from higher capital requirements could improve banks' ability to raise funds in the market and thereby mitigate the short-run declines in loan supply that we document here.

But even then, there is little reason to think that the response to such a balance sheet shock would be restricted to the country in which the regulatory change originates. Indeed, the literature on the international transmission of bank liquidity shocks suggests that the response is very likely to be transmitted to other countries into which the subject bank lends. The mechanism may be illustrated by considering a stylized bank balance sheet. When a bank's minimum capital requirement is raised, it can react by either raising new capital (including via retained earnings), running down any 'buffer' of capital it holds in excess of the minimum requirement, or reducing risk-weighted assets (Fig. 1). To the extent that the bank reduces assets, it could either cut back on domestic assets or cross-border assets. A reduction in cross-border assets in turn, could involve cutting back on its claims on foreign-resident banks (including affiliated foreign banks), or its claims on foreign-resident non-banks (i.e., households and firms). A reduction in lending to foreign-resident non-banks directly reduces the credit available to finance real economic activity in the foreign country. A reduction in lending to foreign banks, on the other hand, is in effect a liquidity shock to the foreign country's banking system, and likely to be transmitted to the economy via a reduction in credit supplied by the (liquidity constrained) banking system.

[2] Chiuri et al. (2002) examine changes in bank lending behaviour around the time of a regulatory regime change. Peek and Rosengren (1995a, 1995b) and Gambacorta and Mistrulli (2004) are examples of papers that analyze 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.

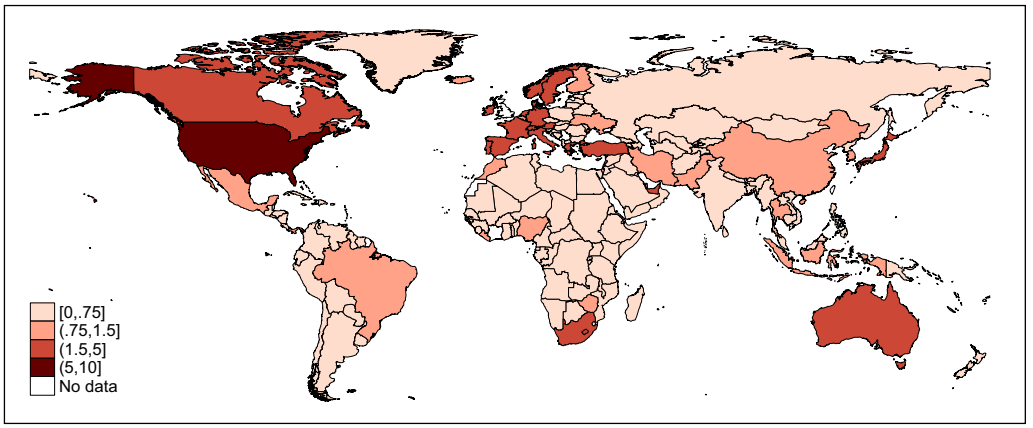


**Fig. 2.** Total country share (percent) of UK-regulated banks' total cross-border lending (2006).

These are not abstract concerns. Many regulatory authorities in advanced economies are announcing higher core tier 1 capital targets and the creation of temporary capital buffers to strengthen bank balance sheets. While important from the perspective of shoring up bank resilience, there has been much policy debate about the possible consequences of such measures on bank credit supply, not just within the advanced countries, but also in emerging markets (many of which are particularly reliant on credit from foreign banks).[3]

More generally, the recent global financial crisis has led to an increasing focus on so-called macro-prudential regulation. One element of macro-prudential regimes going forward will be time-varying minimum capital requirements on banks. These will encourage banks to build capital buffers in good times (creating greater loss absorption capacity in bad times), while also incentivizing banks to rein in excessive lending when the financial system is judged to be overheating. The idea is enshrined in Basel III, under which national regulators will impose a so-called counter-cyclical capital buffer on banks under their purview. In the UK, regulators can also vary banks' capital requirements on exposures to specific sectors. But such time-varying minimum capital requirements may affect not just domestic credit supply, but also credit supplied abroad and are likely to affect both advanced economies and EMEs. The relative importance of these effects will depend on whether banks subject to macro-prudential policy actions decide to scale back their cross-border lending uniformly across all destination countries or selectively. It will also depend on the relative importance of cross-border funding flows as a funding source for banks and non-banks in the affected countries. Such considerations will, therefore, determine whether EMEs are, for example, more impacted than advanced economies. Our results in this paper suggest that it is actually the role of a country in the affected bank's business model which determines the extent of the credit contraction associated with a capital requirement increase, rather than the pure geographical distinction between advanced and emerging economy.

In this paper we examine whether a rise in micro-prudential minimum capital requirements on UK banks is transmitted to foreign economies through a change in the supply of cross-border credit for the period 1999Q1–2006Q4. The UK provides an ideal testing ground for the analysis, for at least two reasons. First, UK-resident banks tend to be very globalized, not just through affiliated banks abroad, but also through cross-border lending and liabilities. Cross-border lending accounted for a substantial 26% of the total lending of UK-owned banks and foreign subsidiaries resident in the UK in 2006 (the end of our sample period) and the average bank had cross-border credit outstanding in 65 countries. Figs. 2–4 give some idea of the scale and geographic dispersion of cross-border lending by UK banks.

Second, during the 1990s and 2000s, the UK micro-prudential regulator, the Financial Services Authority (FSA), imposed individual bank-specific, time-varying minimum capital requirements on the banks under its purview. This apparently unique regulatory regime is elaborated in Section 2. Here, we simply note that the extent of variation across banks in the minimum required risk-based capital ratio was large (the minimum required capital ratio was 8%, its standard deviation was 3.1, and its maximum was 23%). The variation in the average capital requirement over the business cycle was also large, and tended to be counter-cyclical, as envisaged under Basel III. Merging these regulatory data with detailed data on each bank's cross-border lending creates a unique database that is ideal for identifying the cross-border credit supply impact of minimum capital requirements. In particular, we can observe quarterly cross-border lending by each bank to up to 145 countries.[4] The detailed recipient country-level data allow us to control for demand with fixed effects—a variation of the firm-level approach developed by Khwaja and Mian (2008)—and therefore give a loan supply interpretation to our estimates.

[3] See the International Monetary Fund's (2012) Global Financial Stability Report for a review.

[4] The average bank in our sample has cross-border lending relationships with 65 countries.

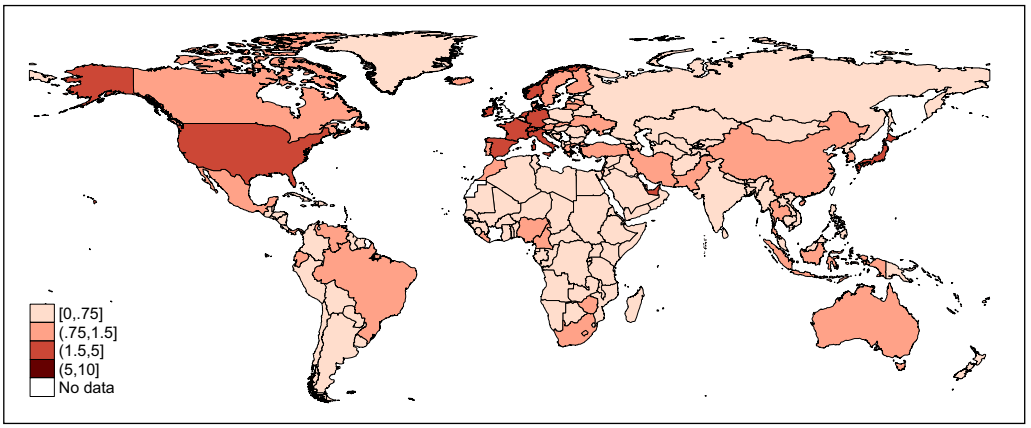


**Fig. 3.** Mean country share (by bank, percent) of UK-regulated banks' total cross-border lending (2006).

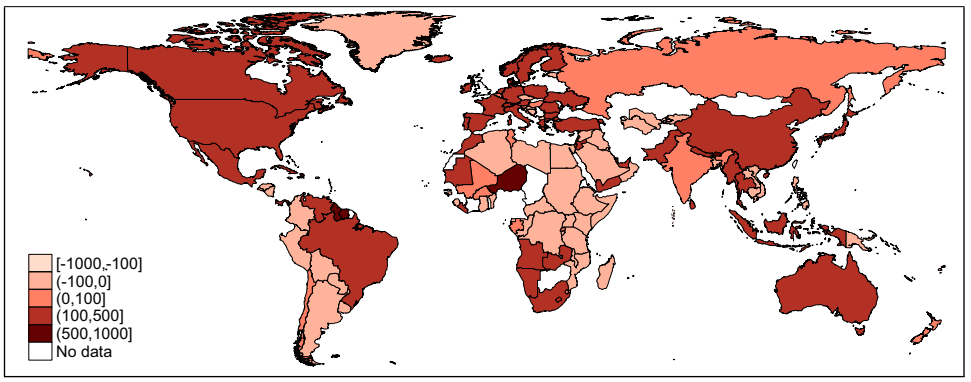


**Fig. 4.** Growth (percentage change) in UK-regulated banks' total cross-border lending (1999–2006).

To preview our main results, we find that a change in minimum capital requirements indeed elicits a robust cross-border supply response by affected banks: a 100 basis point increase in the capital requirement is associated with a reduction in the growth rate of cross-border credit of 5.5 percentage points. Overall, this is broadly similar to the effects of between 5.7% and 7.6% reported in studies that focus on the transmission to the domestic credit supply (Aiyar, Calomiris, and Wieladek, 2014a). We also find that banks tend to favor their most important country relationships, so that the cross-border credit supply response to "core" countries—defined as countries that tend to be important destinations for cross-border lending from the perspective of the individual bank—is significantly less than to other countries. While longer maturity bank lending to non-OECD countries carried a higher risk weight under Basel I, we do not find any evidence that banks cut bank lending more to these countries in response to a capital requirement change.[5] Together, these two findings suggest that banks' core market relationships are more important than differences in the regulatory treatment of loans for understanding which parts of the loan portfolio bear the brunt of adjustment to changes in home country regulatory requirements. Furthermore, we find that banks tend to cut back cross-border credit to other banks (including foreign affiliates) rather than to firms and households. That observation is consistent with a greater willingness, or ability, to cut back on shorter maturity, wholesale lending. This implies that an important part of the cross-border transmission of capital requirements occurs through a liquidity shock to foreign banking systems. We do not find a significant impact on direct cross-border credit to non-banks (i.e., firms and households). Although our empirical methodology and identification strategy differs somewhat from prior studies of domestic credit supply reactions to changes in capital requirements (e.g., Aiyar, Calomiris, and Wieladek, 2014a), the magnitude of response we find in cross-border loan supply is roughly comparable to the magnitude of response in the supply of credit to domestic non-bank borrowers for this particular time period.

In the remainder of the paper, we proceed as follows: Section 2 briefly describes the bank-specific UK database that we employ to measure changes in capital requirements and changes in loan supply and loan demand. Section 3 describes the regression framework that we use in our investigation in greater detail. Section 4 presents the results. Section 5 concludes.

[5] The difference in risk weights only applies to lending with greater than one-year maturity. See Avramova and Le Leslé (2012) for a discussion of risk weights under Basel I.

## 2. UK capital regulation, 1998–2007

Our empirical analysis is made possible by a regulatory policy regime that set bank-specific, time-varying capital requirements in the UK. These minimum capital requirement ratios were set for all banks under the jurisdiction of the FSA, that is, all UK-owned banks and resident subsidiaries of foreign-owned banks. 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 97 regulated banks (30 UK-owned banks and 67 subsidiaries of foreign-owned banks resident in the UK). Branches of foreign-owned banks resident in the UK do not maintain separate capital from their parent group and so are excluded from the sample. 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. Table 2 reports summary statistics.[6]

Discretionary regulatory policy played a much greater role in the UK'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. For more details on the manner in which trigger ratios were set, and the consequences for banks of that variation, see Francis and Osborne (2009) and Aiyar, Calomiris, and Wieladek (2014a).

As Table 2 and Fig. 5 show, the variation in minimum capital requirements as a share of risk-weighted assets over the sample period was large. The median capital requirement ratio was 11%, the standard deviation 3.1, the minimum value 8%, and the maximum value 23%. As Fig. 6 shows, changes in capital requirement ratios varied significantly over the business cycle, too. Average non-weighted capital requirement ratios ranged from a minimum of 11.4% in 1998 to a maximum of 12.2% in 2005. This is a striking amount of counter-cyclical variation given that the sample period was one of varying positive growth, but no actual recessions.

Importantly, the FSA seems to have based regulatory decisions more on organization structures, systems, and reporting procedures, than on credit risk factors. This institutional characteristic allowed us to treat changes in regulatory capital requirements as exogenous with respect to bank-specific domestic credit supply in earlier work (Aiyar, Calomiris, and Wieladek, 2014a). Of course, the argument for exogeneity is much more powerful with respect to *cross-border* lending to individual countries, since lending to any given foreign country is typically a small fraction of a UK-resident bank's portfolio. The FSA's approach to supervision was implemented via a regulatory framework known as Advanced Risk Responsive Operating frameWork (ARROW). In his review of UK financial regulation following the global financial crisis, Lord Turner, Chairman of the FSA, noted that most of the supervisory focus was on systems and processes rather than business risks and sustainability (Turner, 2009). Similarly, the inquiry into the failure of the British bank Northern Rock revealed that ARROW did not require supervisors to engage in financial analysis, defined as information on the institution's asset growth relative to its peers, its profit growth, its cost-to-income ratio, its net interest margin, or its reliance on wholesale funding and securitization (FSA, 2008). This approach to bank regulation suggests that bank-specific lending growth or loan quality were not the main determinants of FSA regulatory decisions about capital requirements.

Aiyar, Calomiris, and Wieladek (2014a) consider the extent to which capital requirements were binding on bank behavior, based on the comovements between weighted capital ratios and weighted capital ratio requirements over time, with banks sorted into quartiles according to the buffer over minimum capital requirements that they maintain. For all four groups of banks, the variation in minimum capital requirements was associated with substantial comovement between minimum requirements and actual capital ratios, confirming the conclusions of Alfon, Argimón, and Bascuñana-Ambrós (2005), Francis and Osborne (2009), and Bridges, Gregory, Nielsen, Pezzini, Radia, and Spaltro (2014) that capital ratio requirements were binding on banks' choices of capital ratios for UK banks during this sample period.

## 3. The international transmission of capital requirements

We aim to estimate the following benchmark model (1) on quarterly data, with lending by FSA-regulated bank $i$ to country $j$ at time $t$ as the dependent variable:

$$\Delta l_{ijt} = \sum_{k=0}^{K} \beta_{t-k} \Delta KR_{it-k} + \Psi G_{it} + \Lambda F_{jt} + e_{ijt}, \quad (1)$$

where $\Delta l_{ijt}$ is the growth rate of lending by bank $i$ to country $j$ at time $t$. This comprises bilateral cross-border lending by the UK-incorporated FSA-regulated entity. $\Delta KR_{it}$ is the change in bank $i$'s minimum capital requirement (in percent of risk-weighted assets) in quarter $t$. Several lags of this term are included to allow lending to adjust gradually to changes in the regulatory ratio. $G$ is a matrix of bank-specific characteristics such as size and liquidity. $F$ is a matrix of country-specific time fixed effects to account for demand shocks in each country.

This simple design has one particularly noteworthy feature. $F_{jt}$, the country-specific time fixed effects, is a way of asking whether the *same* country in the *same* time period borrowing from multiple UK-incorporated banks experiences a larger decline in lending from the bank facing a relatively greater increase in minimum capital requirements. This term is therefore the direct analog of the firm-specific fixed effects methodology pioneered by Khwaja and Mian (2008) to absorb changes in demand conditions. Since the comparison is across banks for the *same* country in a *given* time period, all demand shocks in country $j$ at time $t$ should be absorbed by this term.

[6] The data used in this study exclude outliers based on the following criteria: (1) trivially small banks that do not meet the reporting thresholds for either total assets (currently £3,000,000,000) and/or cross-border claims (currently £300,000,000); and (2) observations for which the absolute value of the log difference of lending in one quarter exceeded 2.

**Table 1**
Variable definitions.

| Variable | Definition | Source | Notes |
|---|---|---|---|
| Capital requirement ratio | FSA-set minimum ratio for capital-to-risk-weighted assets (RWA) for the banking book. Also known as 'Trigger ratio' | Bank of England reporting form BSD3 | |
| Total cross-border lending | Cross-border lending by UK-resident bank *i* to all residents in country *j* | Bank of England reporting form CC | Includes loans, claims under repos, and bills issued by non-residents |
| Bank cross-border lending | Cross-border lending by UK-resident bank *i* to banks resident in country *j* | Bank of England reporting form CC | Includes loans, claims under repos, and bills issued by non-resident banks |
| Non-bank cross-border lending | Cross-border lending by UK-resident bank *i* to non-banks resident in country *j* | Bank of England reporting form CC | Includes loans, claims under repos, and bills issued by non-resident non-banks |
| Core market | Dummy variable takes the value of one when the size of lending to a country is in the top 10% of all banks' cross-border lending relationships, and zero otherwise | Bank of England reporting form CC | |
| Peripheral market | Dummy variable takes the value of one when the size of lending to a country is in the bottom 10% of all banks' cross-border lending relationships, and zero otherwise | Bank of England reporting form CC | |
| Write-offs | Write-offs (gross), percent of risk-weighted assets | Bank of England reporting form BSD3 | |
| Bank size | Log of total assets of the UK-resident entity | Bank of England reporting form BT | |
| Liquid assets | Ratio of liquid assets to total assets | Bank of England reporting form BT | Liquid assets include cash, bills, commercial paper, and other short-term paper (in all currencies) |
| Stable funding | Ratio of stable funding to total non-equity liabilities | Bank of England reporting form BT | Stable funding includes resident sight and time retail deposits and all certificates of deposit |
| Tier 1 ratio | Tier one capital as a percent of total risk-weighted assets | Bank of England reporting form BSD3 | |
| Risk | Total risk-weighted assets as a percent of total assets | Bank of England reporting form BSD3 | |
| Destination country exposure | Cross-border lending by bank i to country *j*, as a percent of bank *i*'s total cross-border lending, lagged one period | Bank of England reporting form CC | |
| Foreign | Dummy variable takes the value of one when bank is a UK-resident subsidiary of a foreign bank, and zero otherwise | Bank of England | |
| Affiliate | Dummy variable takes the value of one when UK-resident bank *i* has a bank affiliate in country *j* and zero otherwise | SNL and banks' annual reports | |
| OECD | Dummy variable takes the value of one when country is a member of the Organisation for Economic Cooperation and Development, and zero otherwise | OECD | |
| Parent size | Ratio of assets of the parent bank to assets of the UK-resident entity | Bank of England reporting form BT, Bankscope, and banks' annual reports | |
| Parent capitalization | Ratio of capital of the parent bank to the capital of the UK-resident entity | Bank of England reporting form BT, Bankscope, and banks' annual reports | |

It should also be emphasized that this study focuses on changes to minimum capital requirements imposed on *UK-resident entities*. That is, we study regulatory changes imposed at an unconsolidated level, not at a consolidated (banking group) level. This focus reflects a limitation of our data, which permit us to study international transmission via the *cross-border* lending channel of UK-resident entities, rather than examining all the sources of credit

**Table 2**
Summary statistics.

| Variable | Entity | Units | Median | S.D. | Min | Max | Obs |
|---|---|---|---|---|---|---|---|
| Capital requirement ratio[a] | All UK-regulated banks | % | 11.0 | 3.1 | 8.0 | 23.0 | 2601 |
| | UK-owned banks | | 9.0 | 1.8 | 8.0 | 17.0 | 956 |
| | Foreign subsidiaries | | 12.5 | 3.0 | 8.5 | 23.0 | 1645 |
| Change in capital requirement ratio | All UK-regulated banks | Basis points | 0.0 | 38.0 | −500 | 500 | 2495 |
| | UK-owned banks | | 0.0 | 24.5 | −200 | 500 | 902 |
| | Foreign subsidiaries | | 0.0 | 44.1 | −500 | 500 | 1593 |
| Change in cross-border lending to all non-residents | All UK-regulated banks | % | 0 | 37 | −100 | 100 | 96402 |
| | UK-owned banks | | 0 | 35 | −100 | 100 | 52580 |
| | Foreign subsidiaries | | 0 | 39 | −100 | 100 | 43822 |
| Change in cross-border lending to non-resident banks | All UK-regulated banks | % | −1 | 46 | −100 | 100 | 43387 |
| | UK-owned banks | | −3 | 45 | −100 | 100 | 21248 |
| | Foreign subsidiaries | | 0 | 46 | −100 | 100 | 22139 |
| Change in cross-border lending to non-resident banks | All UK-regulated banks | % | 0 | 32 | −100 | 100 | 82171 |
| | UK-owned banks | | 0 | 30 | −100 | 100 | 49008 |
| | Foreign subsidiaries | | 0 | 33 | −100 | 100 | 33163 |

[a] The capital values are reported as a fraction of risk-weighted assets. They are not necessarily informative about the institution's capital to total asset ratio.

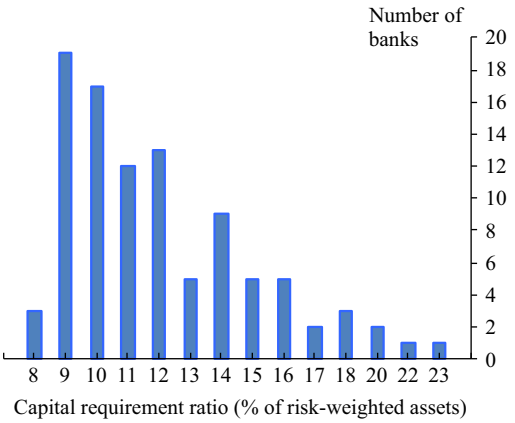


**Fig. 5.** Histogram of minimum capital requirement ratio for UK-regulated banks, 2006.

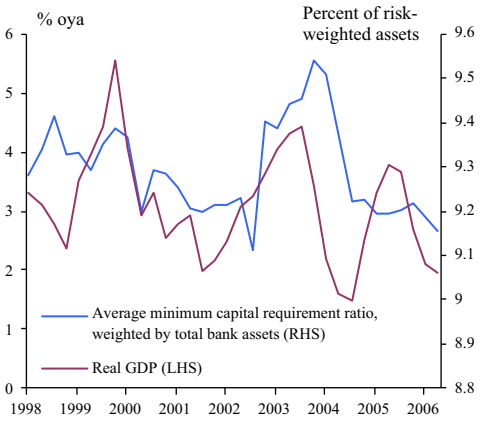


**Fig. 6.** Capital requirement ratio and GDP growth.

supplied to a country by the banking group (which could include credit extended by affiliated banks locally in the recipient country). Of course, the full extent of the financial spill-over to a recipient country would involve changes in both cross-border credit supply by the UK-resident bank *and* local credit supply by resident affiliates, if any. We also abstract from the issue of whether, from the recipient economy's point of view, cross-border lending by UK banks could be substituted by credit provision from other banking systems or by capital markets. Substitution by both unaffected banks and non-banks is of course possible, but a detailed investigation of this is outside the scope of this study. We do, however, explore the extent to which our estimated effects differ systematically for banks that have affiliated presence (including its headquarters) in recipient countries by including a dummy variable that takes the value of one when the destination country contains a bank branch or subsidiary that is affiliated with the bank operating in the UK. And we explore the extent to which the size and capital position of the parent bank might affect the credit supply response by the UK-incorporated bank.

In order to examine whether the impact of changes in capital requirements differs with recipient country and bank characteristics, we estimate model (2) below.

$$\Delta l_{ijt} = \sum_{k=0}^{K} \beta_{t-k} \Delta KR_{it-k} + \delta Z_{ijt-1} + \sum_{k=0}^{K} \gamma_{t-k} \Delta KR_{it-k} Z_{ijt-1} + \Psi G_{it} + \Lambda F_{jt} + e_{ijt}. \quad (2)$$

The only difference between models (1) and (2) is that $Z_{ijt-1}$ now enters in levels and as an interaction term with the change in the capital requirement ratio to assess whether the loan supply contraction varies with country and bank characteristics. $Z_{ijt}$ contains the following variables: (i) dummy variables that take the value of one when the size of a bank's lending to a country as a proportion of its total cross-border lending is in the top (*CORE*) or bottom

(*PERIPHERY*) 10% of *all* cross-border lending relationships in our sample, and zero otherwise[7]; (ii) a dummy variable that takes the value of one when the destination country is the bank's home country and zero otherwise; (iii) a dummy variable that takes the value of one when the destination country is an OECD country and zero otherwise; (iv) a dummy variable that takes the value of one when the bank is headquartered outside the UK and zero otherwise; and (v) variables measuring the size and capital position of the banking group to which the UK-resident bank belongs.

The interaction of changes in capital requirements and the variables contained in $Z_{ijt}$ allows us to explore if there is any heterogeneity in loan contractions by bank and country characteristics. In particular, it may be that the liquidity shock imposed by a capital requirement does not lead to a proportionate reduction in the bank's lending activities in all countries, but that lending to non-core countries is pared back first. This would be consistent with empirical evidence that banks scale back non-core lending disproportionately in response to liquidity shocks (Aiyar, 2011; De Haas and Lelyveld, 2010; Cetorelli and Goldberg, 2012). Our prior is therefore that the interaction term will be positive (that is, lending growth will fall by *less* to a core country relative to a non-core country, when the minimum capital requirement on bank *i* is raised). A different margin arises with respect to lending into OECD and non-OECD countries. Since longer maturity lending to banks in OECD countries carries a smaller risk weight than this type of lending to non-OECD countries, one might expect a larger cutback in lending to the latter. Lending to the home country may also respond differently to capital requirement changes than lending to other countries. The lending response may be different for foreign and UK-headquartered banks. Finally, many banks in our sample are part of larger banking groups, which may have operations in several jurisdictions outside the purview of the FSA. To the extent that such banking groups operate internal capital markets to smooth shocks to capital or liquidity between component parts (Cetorelli and Goldberg, 2011; De Haas and Lelyveld, 2010), it may be that banks belonging to larger and better capitalized banking groups need to adjust credit supply less in response to changing capital requirements.

We also look at which borrowers are subjected to a cutback in credit supply arising from an increase in UK capital requirements, dividing the recipients of cross-border credit into banks and non-banks. Differences in the magnitude of loan-supply responses for different types of borrowers may reflect differences in the strength of cross-border relationships (e.g., interbank relationships may be less valuable than non-financial relationships) or differences in maturity of lending (short-term loans can be rolled off more easily). Furthermore, it is useful to distinguish between the loan-supply responses for interbank and non-bank cross-border lending because the mechanisms through which these shocks are transmitted to the recipient foreign countries' economies will differ. If the cutback in lending is to non-banks (firms and households), the impact on credit supply in the foreign country is direct, whereas if the cutback in lending is to banks, then the transmission is indirect, via a liquidity shock to the foreign banking system.

Finally, because the presence of an affiliated bank in the destination country may affect the size of adjustment in credit supply for cross-border lending (as discussed above), we include a dummy variable to capture whether the loan-supply effect in cross-border lending from banks operating in the UK differs depending on whether the banking group operating a UK bank has a presence in the destination country.

## 4. Results

Prior to describing our regression results, a casual examination of the data reveals several interesting stylized facts. In levels, both external assets and lending substantially increased from 2002 onwards. But this masks an important difference: Fig. 7 shows that larger banks were responsible for most of this increase in external lending. Interestingly, larger banks lend on average a lower share of their external portfolio to any given country (Fig. 8), so

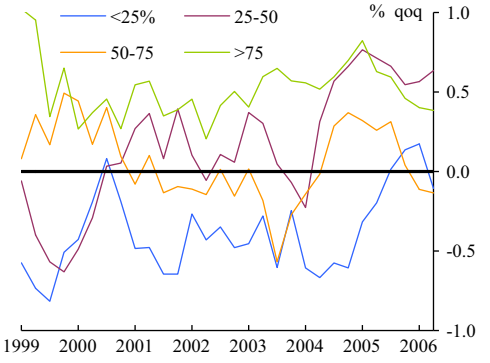


**Fig.7.** Cross-border lending growth by bank *i* to country *j* (by bank size, in percentiles).[a] ([a]Mean growth across the sample of bank-country pairs.)

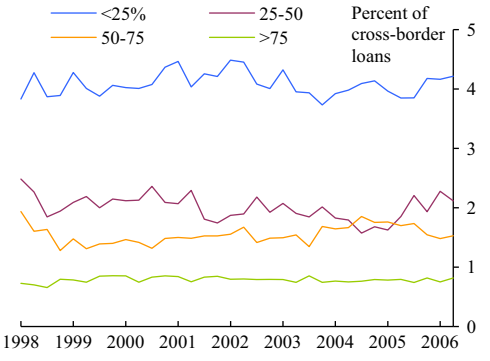


**Fig. 8.** Loans to country *j* as a share of bank *i*'s total cross-border loans (by bank size, in percentiles).[a] ([a]Mean shares across the sample of bank-country pairs.)

[7] The CORE dummy is constructed using the following three step procedure. For each bank *i*, the variable COUNTRYSHARE is defined as bank *i*'s lending to country *j* as a percentage of its total cross-border lending. The upper 10th percentile from the distribution of COUNTRYSHARE across all banks and countries is then used as a threshold to define the CORE dummy variable (4% in our data). Bank-country pairs are assigned the value one if COUNTRYSHARE is greater than 4% and zero otherwise.

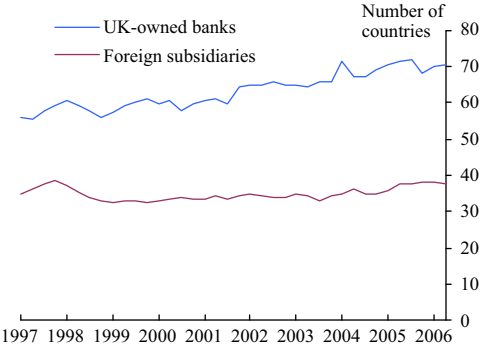


**Fig. 9.** Number of lending destinations per bank.[a]
([a]Mean number of destinations across the sample of banks.)

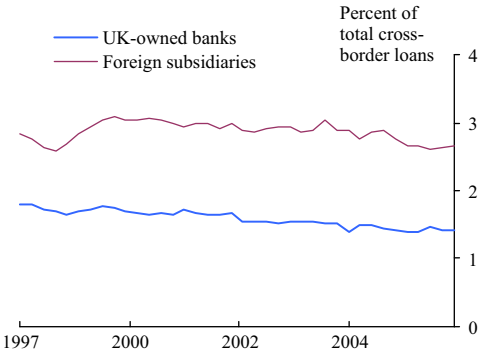


**Fig. 10.** Share of country *j* in bank *i*'s cross-border lending.[a]
([a]Mean shares across the sample of bank-country pairs.)

they tend to be more diversified. Similarly, UK-owned banks, which tend to be larger than foreign subsidiaries, tend to be exposed to more countries (Fig. 9) and lend on average less to each country (Fig. 10).

The geographical distribution of lending by UK-regulated banks reveals some additional interesting facts as well. Looking at the share of a given country in UK-regulated banks' total external lending in 2006, it seems that UK-regulated banks as a whole largely lend to North America, Western Europe, South Africa, Japan, and Australia (Fig. 2). On the other hand, the average exposure to a given country by a UK-regulated bank is concentrated mostly in the USA, Western Europe, and Japan (Fig. 3). This difference between average and total lending suggests that lending to South Africa, Canada, and Australia seems to be driven by a few large banks that are regulated in the UK. These were also the countries which experienced some of the largest growth in the period between 1999 and 2006 (Fig. 4).

Fig. 11 provides a graphical illustration of the way UK banks in our sample responded—along various dimensions—to an increase or decrease in their minimum capital ratio requirements. In constructing the graph, we capture the responses of risk-weighted assets, domestic loans, cross-border loans, and the capital buffer (the difference between the actual capital ratio and the required ratio) to changes in capital requirements. The responses to capital requirements are normalized for graphical purposes into responses to a positive 100 basis point-equivalent change.

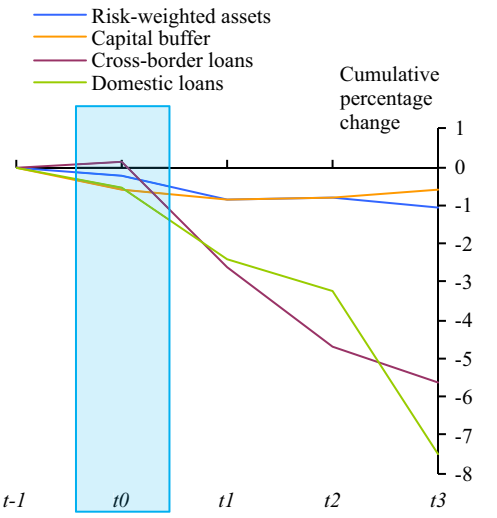


**Fig. 11.** Cumulative changes in selected balance sheet variables following a 100 bp increase in capital requirements. *Notes*: the figure shows cumulative percentage changes in domestic private sector loans, cross-border loans, risk-weighted assets, and the cumulative percentage point change in the capital buffer, in the three quarters following a change in capital requirements (at *t*0). The lines show the median response across banks, to changes in capital requirements, normalized to a 100 bp increase.

For example, we multiply the responses to a negative 100 basis point change by minus one, and we multiply the responses to a 50 basis point increase by two. As Fig. 11 shows, both cross-border and domestic loans fall when capital requirements are raised. The capital buffer also falls, by more than half the size of the capital requirement increase. Risk-weighted assets (RWA) fall slightly, with most of the adjustment within risk-weighted assets occurring in lending. Both domestic and cross-border lending decline sharply.[8] We emphasize that this is a descriptive graph, not a regression. The graph cannot be used to derive causal inferences (it is not an impulse response function in the conventional sense). Still, these patterns are roughly consistent with earlier research and with our own regression findings reported below.[9]

We now turn to a discussion of our regression results, which are presented in Tables 3–5. For our main variable of interest, the change in capital requirements, we report the sum of the coefficients associated with the contemporaneous and three lagged values. The figures in brackets for this variable are the *p*-values associated with *F*-test statistic for the null-hypothesis of no statistical significance. All standard errors are clustered by bank and time.[10] Importantly, following the approach presented in Khwaja and

[8] Note that, based on the median 11% capital requirement, a 100 basis point increase is roughly a 9% increase; if all the adjustment were occurring in risk-weighted assets, with no decline in the buffer, and no increase in capital, the total decline in risk-weighted assets would have to be about 9%.

[9] See Aiyar, Calomiris, and Wieladek (2014b) for a panel Vector Autoregression (VAR) analysis of domestic loan growth and changes in capital requirements.

[10] All results are robust to an alternative clustering of standard errors by country and time.

**Table 3**
The effect of changes in minimum capital requirements on UK-regulated banks' cross-border lending growth.

This table presents results from fixed effects panel regressions of UK-regulated banks. The dependent variable is the quarterly growth rate (*FX*-adjusted) of bank *i*'s total cross-border lending (sum of lending to banks and non-banks) to country *j*. The contemporaneous value of the change in capital requirements (DBBKR) is used, along with three lags. The table entry for DBBKR shows the sum of these four coefficients, together with the probability that the sum is significantly different from zero according to the *F*-test statistic. A similar convention is followed for changes in write-offs in columns 2 and 2(a). The remaining coefficients are shown together with *p*-values. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. A constant is included but not shown.

| Dependent variable: UK-regulated banks' cross-border lending growth | 1 | 1(a) | 2 | 2(a) | 2(b) |
|---|---|---|---|---|---|
| Change in capital requirement ratio (DBBKR) (summed lags) | −6.760*** | −5.475*** | −5.362*** | −3.077* | −3.291* |
| (prob > *F*) | (0.000) | (0.001) | (0.003) | (0.097) | (0.085) |
| Bank size | | | 1.566 | 2.229** | 2.217** |
| (*p*-value) | | | (0.111) | (0.044) | (0.047) |
| Liquidity | | | 0.099 | 0.127 | 0.135 |
| (*p*-value) | | | (0.476) | (0.405) | (0.371) |
| Stable funding | | | −0.022 | −0.003 | −0.002 |
| (*p*-value) | | | (0.290) | (0.927) | (0.941) |
| Tier 1 ratio | | | 0.015* | 0.003 | 0.003 |
| (*p*-value) | | | (0.074) | (0.823) | (0.822) |
| Risk | | | 0.002 | −0.002 | −0.002 |
| (*p*-value) | | | (0.373) | (0.730) | (0.729) |
| Destination country exposure | | | −0.147*** | −0.203*** | −0.202*** |
| (*p*-value) | | | (0.000) | (0.000) | (0.000) |
| Change in write-offs (summed leads) | | | | 2.463* | |
| (prob > *F*) | | | | (0.061) | |
| Change in write-offs (summed lags) | | | 1.472 | | |
| (prob > *F*) | | | (0.106) | | |
| Observations | 52,683 | 52,683 | 46,946 | 34,854 | 34,854 |
| *R*-squared | 0.089 | 0.102 | 0.115 | 0.135 | 0.134 |
| Quarter/Country fixed effects | YES | YES | YES | YES | YES |
| Bank fixed effects | NO | YES | YES | YES | YES |

Mian (2008), we include country-time fixed effects in each specification to absorb demand conditions in each country. The adoption of this framework therefore allows us interpret the estimated sum of coefficients on the change in the capital requirement ratio as a loan supply effect.

It should be noted that we regress credit growth on the change in minimum capital requirements expressed in basis points, not the percentage change in the minimum capital requirement. That is, an increase in the requirement from 11% to 11.5% of RWA is measured on the right-hand side of our equations as a 50 basis point increase, rather than as a 4.5% increase. Moreover, an increase in the requirement from 11% to 11.5% is treated the same as, say, an increase in the requirement from 2% to 2.5% (which is, of course, a much larger *percentage* increase in the requirement). There are a couple of reasons for this choice. First, policymakers are typically interested in the credit supply impact of raising or lowering capital requirements by a certain amount of basis points rather than in the elasticity per se. Second, and more important, in practice minimum capital requirements do not range freely from zero to 100; they are quite tightly distributed within a range of about 8% to 15% of RWA (Table 1). So as a practical matter, an identical change in capital requirements in basis points for two banks is likely to be very similar in percentage terms too. We check this by running all key specifications in elasticity terms (available on request), and confirming that the results are very similar, but focus here on presenting the results in more intuitive units.

The regression results for model (1) are shown in Table 3. The sum of coefficients on the change in capital requirements in column 1 is −6.76, which is statistically significant at the 1% level, suggesting that total foreign lending growth falls by −6.76 percentage points over a four-quarter period following a 100 basis point rise in the banks' capital requirement. Once bank fixed effects are added, which proxy for unobservable time-invariant bank-specific characteristics, this effect falls to −5.48 pp (column 1(a)).

While country-specific demand shocks and bank-specific shocks should be picked up by the country-time fixed effects and bank fixed effects, two other standard potential problems in estimating loan supply responses to bank-specific regulatory changes remain: reverse-causality and omitted variables bias. An important advantage of our econometric approach is that concerns on the first score are largely eliminated. As discussed in Section 2, it is very unlikely that UK regulators were changing banks' capital requirements based on changes in external

**Table 4**
The effect of changes in minimum capital requirements on UK-regulated banks' cross-border lending growth: all loans/banks/non-banks.

This table presents results from fixed effects panel regressions of UK-regulated banks. The dependent variable is the quarterly growth rate (*FX*-adjusted) of bank *i*'s cross-border lending to all non-residents (sum of bank and non-bank) (columns 1, 1(a)), banks only (columns 2,2(a)), and non-banks only (columns 3,3(a)) in country *j*. The affiliate dummy takes the value one where bank *i* has an affiliate bank (branch or subsidiary) in country *j* and zero otherwise. The other conventions are the same as in Table 3.

| Dependent variable: UK-regulated banks' cross border lending growth | 1 Cross-border lending to all non-residents | 1(a) Cross-border lending to all non-residents + affiliate dummy | 2 Cross-border lending to non-resident banks | 2(a) Cross-border lending to non-resident banks + affiliate dummy | 3 Cross-border lending to non-resident non-banks | 3(a) Cross-border lending to non-resident non-banks + affiliate dummy |
|---|---|---|---|---|---|---|
| Change in capital requirement ratio (DBBKR) (summed lags) (prob > *F*) | −5.475*** (0.001) | −4.908*** (0.004) | −6.110** (0.012) | −5.363** (0.035) | −0.882 (0.569) | −1.007 (0.530) |
| Affiliate dummy × DBBKR (prob > *F*) | | −5.106 (0.172) | | −4.823 (0.356) | | 0.716 (0.830) |
| Affiliate dummy (*p*-value) | | 0.721 (0.144) | | 0.237 (0.800) | | 0.514 (0.239) |
| Observations | 52,683 | 52,683 | 16,265 | 16,265 | 50,169 | 50,169 |
| *R*-squared | 0.102 | 0.102 | 0.162 | 0.162 | 0.109 | 0.109 |
| Quarter/Country fixed effects | YES | YES | YES | YES | YES | YES |
| Bank fixed effects | YES | YES | YES | YES | YES | YES |

lending growth to any particular country.[11] However, we also test for this by regressing changes in capital requirements on changes in total-cross lending by bank *i* to country *j* at time *t*, including three lags. As expected, there is no significant relationship between these variables in the opposite direction. But omitted variable bias could still contaminate our inference. For this reason we include a large number of bank balance sheet control variables in columns 2, 2(a), and 2(b). Aiyar, Calomiris, and Wieladek (2014a) found that changes in write-offs and their leads (as a proxy for loan quality) are important control variables, when attempting to identify the loan-supply response to changes in capital requirements. Lags and leads of changes in the write-off-to-risk-weighted asset ratio are therefore also included in specifications 2 and 2(a). The inclusion of leads of write-offs, however, substantially reduces the sample size for estimation. For that reason, we only include leads in one specification to investigate whether its inclusion affects the estimated coefficient of interest on the capital requirement change. As a comparison of the coefficients on the change in capital requirements in columns 2(a) and 2(b) shows, the coefficient of interest is not affected by the inclusion of leads of write-offs; the decline in the magnitude of the capital requirement coefficient in columns 2(a) and 2(b), therefore, is the result of the substantial reduction in the sample size that occurs when leads of write-offs are included.

The significance of the capital requirement coefficient is also robust to different exclusion criteria for outliers and alternative clustering techniques (see Appendix A).

Our data also allow us to split total cross-border lending into two parts: loans to banks, and loans to non-banks. Table 4 presents regressions using different definitions of the dependent variable: total cross-border lending, bank-to-bank cross-border lending, and cross-border lending to non-banks, which are shown in columns 1, 2, and 3, respectively. It should be noted that there is a substantial loss of observations when one switches from studying total lending to studying lending to banks or to non-banks separately. There are two reasons for this. First, there is a large number of zero stock observations for both bank and non-bank lending, which result in missing values for loan growth rates. Second, our specifications require multiple lags for the explanatory variables, which tends to amplify the number of observations that must be dropped due to any data gaps in the time series. With that caveat in mind, only cross-border lending to banks shows a negative and statistically significant response to changes in the capital requirement. This suggests that the overall contraction in cross-border lending is driven by lending to banks, not direct lending to firms and households. One explanation for this pattern is that bank to bank lending is typically of much shorter maturity than bank-to-non-bank lending, and hence easier to cut back.[12]

[11] Indeed, the ARROW framework suggests that minimum capital requirements were varied based on operational and managerial criteria rather than considerations of even domestic loan growth, let alone consideration of cross-border loan growth to a particular foreign country.

[12] In an attempt to conserve observations while splitting the sample, we experimented with an alternative formulation; one in which the dependent variable is defined as, respectively, the increase in lending to non-banks as a proportion of *all* cross-border lending in the previous period, and the increase in lending to banks as a proportion of *all* cross-border lending in the previous period. Because the denominator is the

**Table 5**
The effect of changes in minimum capital requirements on UK-regulated banks' cross-border lending growth with interaction terms.

This table presents results from fixed effects panel regressions of UK-regulated banks. The dependent variable is the quarterly growth rate (*FX*-adjusted) of bank *i*'s total cross-border lending (sum of lending to banks and non-banks) to country *j*. Interaction terms between changes in capital requirements (DBBKR) and various bank and country characteristics are also included. The other conventions are the same as in Table 3.

| Dependent variable: UK-regulated banks' cross-border lending growth | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Change in capital requirement ratio (DBBKR) (summed lags) | −6.942*** | −4.195 | −5.324*** | −4.869*** | −4.951* | −5.758*** | −4.979* | −5.693* |
| (prob > *F*) | (0.000) | (0.120) | (0.001) | (0.008) | (0.083) | (0.004) | (0.053) | (0.067) |
| Core market × DBBKR | 6.707* | | | | 7.608** | | | 9.176 |
| (prob > *F*) | (0.057) | | | | (0.031) | | | (0.228) |
| Periphery market × DBBKR | 7.291 | | | | 6.760 | | | 6.440 |
| (prob > *F*) | (0.199) | | | | (0.229) | | | (0.414) |
| Foreign bank × DBBKR | | −1.499 | | | −1.035 | | | 0.646 |
| (prob > *F*) | | (0.646) | | | (0.753) | | | (0.918) |
| Home country × DBBKR | | | −9.440 | | −9.791 | | | −5.783 |
| (prob > *F*) | | | (0.336) | | (0.271) | | | (0.748) |
| OECD × DBBKR | | | | −1.454 | −2.573 | | | −4.390 |
| (prob > *F*) | | | | (0.612) | (0.382) | | | (0.366) |
| Parent size × DBBKR | | | | | | 0.0851 | | −0.0792 |
| (prob > *F*) | | | | | | (0.257) | | (0.716) |
| Parent capitalization × DBBKR | | | | | | | 0.0762 | 0.225 |
| (prob > *F*) | | | | | | | (0.653) | (0.553) |
| Core market | 9.784*** | | | | 10.040*** | | | 9.951*** |
| (*p*-value) | (0.000) | | | | (0.000) | | | (0.000) |
| Periphery market | −6.432*** | | | | −6.412*** | | | −6.207*** |
| (*p*-value) | (0.000) | | | | (0.000) | | | (0.000) |
| Foreign bank | | −2.202 | | | −1.676 | | | 0.376 |
| (*p*-value) | | (0.275) | | | (0.404) | | | (0.815) |
| Home country | | | −1.841 | | −5.637*** | | | −5.281*** |
| (*p*-value) | | | (0.262) | | (0.001) | | | (0.006) |
| Parent size | | | | | | 0.013** | | 0.010 |
| (*p*-value) | | | | | | (0.015) | | (0.308) |
| Parent capitalization | | | | | | | 0.012 | 0.008 |
| (*p*-value) | | | | | | | (0.118) | (0.396) |
| Observations | 52,683 | 52,683 | 52,683 | 52,683 | 52,683 | 45,733 | 39,853 | 39,853 |
| *R*-squared | 0.112 | 0.102 | 0.102 | 0.102 | 0.112 | 0.116 | 0.129 | 0.139 |
| Quarter/Country fixed effects | YES | YES | YES | YES | YES | YES | YES | YES |
| Bank fixed effects | YES | YES | YES | YES | YES | YES | YES | YES |

In columns 1(a), 2(a), and 3(a) of Table 4 we test to see whether the loan supply effect differs between destination countries that contain affiliates of banks with UK operations. Unfortunately, our data do not separate cross-border lending to banks into lending to affiliate vs. unrelated banks. We therefore collect information on the locations of foreign affiliates for the banks in our sample and construct an 'affiliate' dummy variable which takes the value one if the bank has an affiliate bank (either subsidiary or a branch) in country A, and zero otherwise. We find no significant interaction effect associated with the presence of affiliates. This suggests that banks do not differentially adjust their cross-border lending depending on the global structure of their banking groups. One possible reason for this is that cross-border lending to related and unrelated banks received the same risk weight under Basel I.

Finally, Table 5 estimates model (2) to examine whether the cross-border loan contraction differs by either bank or recipient country characteristics. Columns 1–4 include both the level and the interaction term with the change in the capital requirement ratio of the following variables: (i) dummy variables that take the value of one

(*footnote continued*)
same for lending-to-banks and lending-to-non-banks, this avoids a loss of observations across subsamples. However, many of the observations in the lending-to-banks sample are zeros, and it is well-known that ordinary least squared (OLS) estimates become severely biased in this situation. In the empirical trade literature, researchers often adopt the Poisson pseudo-maximum likelihood (PPML) estimator (Santos Silva and Tenreyro, 2006, 2011; Westerlund and Wilhelmsson, 2011). Unfortunately, to the best of our knowledge, techniques have not been developed to apply the PPML in conjunction with two-way fixed effects, as required in our work.

when the size of a bank's lending to a country as a proportion of its total cross-border lending is in the top (*CORE*) or bottom (*PERIPHERY*) 10% of *all* cross-border lending relationships in our sample, and zero otherwise; (ii) a dummy variable that takes the value of one if the bank is a subsidiary of a foreign bank in the UK and zero otherwise; (iii) a dummy variable that takes the value of one when the destination country is the bank's home country and zero otherwise; (iv) a dummy variable that takes the value of one when the destination country is an OECD country and zero otherwise. Columns 6–7 include both the level and the interaction term with the change in the capital requirement ratio of the variables measuring the size and capital position of the banking group to which the UK-resident bank belongs. As discussed in the previous section, one might expect lending to be cut back less in core countries, in OECD countries, to the home country, and from larger and better capitalized banks in response to a change in capital requirements.

The regression results in Table 5 (columns 1 and 5) show that the interaction with the core dummy is statistically significant with the expected positive sign. This suggests that the cross-border loan supply contraction to 'core' countries is smaller, in accordance with our prior. None of the other interaction terms are statistically significant. The lack of statistical significance on the OECD interaction term is particularly interesting, as risk weights on lending to banks in OECD countries are smaller. Overall, this suggests that the most important source of heterogeneity in country-specific loan supply responses seems to be the magnitude (and hence relative importance) of the lending relationship with a particular country, as opposed to regulatory incentives such as risk weights. Columns 6, 7, and 8 examine the impact of parent banks' size and capitalization. The variable *Parent size* is the ratio of the assets of the whole banking group to the assets of the UK-incorporated bank, while *Parent capitalization* is the ratio of the banking group's total capital to the eligible capital of the UK-incorporated bank. While the positive sign of these interaction terms is consistent with the operation of an internal capital market—belonging to a large and better capitalized banking group reduces the credit supply impact of changes in capital requirements— these estimates are not significant.[13]

## 5. Conclusion

Economists have been interested in the international transmission of domestic economic policy decisions since at least Smith (1776). There is indeed a large academic literature examining the cross-border spillover effects of monetary and fiscal policy. But the cross-border impact of a key prudential instrument—bank minimum capital requirements— has not yet been explored, despite the well-documented globalization of banking systems. This gap in our knowledge assumes even greater importance with the advent of Basel III, under which central banks and regulators around the world will impose time-varying capital requirements as a new policy instrument.[14] In this paper we make a first step towards filling this gap.

For this purpose, we exploit a unique micro-prudential regulatory environment extant in the UK prior to the global financial crisis: To account for deficiencies in Basel I, UK regulators adjusted capital requirements by bank and over time. Together with country-specific external lending data which cover the period 1999Q1 to 2006Q4 for these regulated banks, this allows us to examine the impact of changes in domestic capital requirements on cross-border loan supply. Because we observe lending by each bank to up to 145 different countries at each point in time, we follow the approach in Khwaja and Mian (2008) and include country-time fixed effects in each specification to absorb changes in demand conditions in each country.

We find that a 100 basis point increase in the minimum capital requirement is robustly associated with a reduction in cross-border credit growth of 5.5 percentage points. This is of a similar magnitude to estimates reported in other studies focusing on the transmission to domestic credit supply to private non-financial corporations (PNFCs) (Aiyar, Calomiris, and Wieladek, 2014a; Bridges, Gregory, Nielsen, Pezzini, Radia, and Spaltro, 2014).[15] Lending to core countries (defined by the relative magnitude of the lending relationship) tends to be reduced by less, while there is no evidence that lending to OECD countries, despite lower risk weights on bank lending than in non-OECD countries, is differentially preserved. This suggests that business model considerations dominate pure regulatory arbitrage incentives. Furthermore, banks tend to cut back cross-border credit to other banks (including foreign affiliates) rather than to firms and households, suggesting that cross-border spillovers are transmitted primarily through a liquidity shock to the foreign banking system.

[13] Note that in specifications 6 through 8, the CORE interaction becomes insignificant. This may be related to the fewer observations in these specifications, and specifically, to a disproportionate reduction in the number of smaller UK banks in the sample. This arises because data on the size and capital position of banking groups are obtained from Bankscope, which lacks data on some smaller UK banks. If smaller banks tend also to be less diversified, then core countries might be more important for this set of banks (as opposed to larger, more diversified banks).

[14] Strictly speaking, we consider a bank's reaction to changes in only its own (micro-prudential) capital requirement. This is different from the approach in Basel III, where all banks will be subject to the same (macro-prudential) capital requirement. This may make a difference for the transmission to domestic credit supply, as other domestic banks which are unaffected by the micro-prudential, but would be affected by the macro-prudential, change can become a source of substitution. But this distinction is much less likely to matter for cross-border credit supply, since it is unlikely that many domestic banks compete with each other in a given recipient country.

[15] The econometric model used in Bridges et al. (2014) implies that a 100 basis points rise in capital requirements on private nonfinancial corporation (PNFC) lending over one year, which corresponds to the specification in this paper, is about 5.6%. This is obtained by weighting their estimates of the impact on commercial real estate(CRE) and non-CRE PNFC lending by their corresponding shares.

## Appendix A

### A.1. Data

The data used in this paper are based on the statistical returns submitted to the Bank of England by the entire population of UK-resident deposit takers, including building societies.[16] All data are unconsolidated—they refer to individual authorized banks irrespective of whether they are part of a larger banking group operating in the United Kingdom. Bank nationality is determined by where its ultimate parent (e.g., holding company) is located and not by the nationality of the largest shareholder. For example a 'UK-owned' bank simply means its ultimate parent is incorporated in the United Kingdom.

The data are processed by the Bank of England Statistics and Regulatory Data Division who conduct a methodical data interrogation process, designed to identify misreporting or errors which materially affect the data. Despite this, some minor data issues remain on a bank-by-bank basis. The raw reporting data, therefore, were adjusted by the authors on a best-endeavours basis. This data annex describes the data used and the adjustment procedures followed. The data-set used is quarterly from end-1998 Q3 through to end-2006 Q4. A full description of the variables used, together with the relevant reporting forms, is provided in Table 1.

#### A.1.1. External lending data

The main variable of focus, external lending by bank *i* to country *j*, is defined as cross-border lending from the UK-resident entity to both the financial and non-financial sectors in the foreign country. It includes lending to other banks within the same banking group (intragroup) but excludes any lending in local currencies done by bank *i*'s foreign affiliate in country *j*. Lending is in all currencies and comprises loans and advances, and claims under sale and repurchase agreements. The whole population of UK-regulated banks (i.e., UK-owned banks and foreign subsidiaries) are included that have external claims above the reporting threshold of £300mn.[17]

The raw external lending data were adjusted to account for the following: (i) exchange rate movements; (ii) mergers and acquisitions, and (iii) outliers:

#### A.1.2. Foreign currency adjustment

Information on the currency composition of the main variables of interest was used to adjust the flows data for exchange rate movements. External lending is measured in sterling. Amounts outstanding data are reported in sterling which are then converted into the 'original' foreign currency using the appropriate end-quarter exchange rates. Changes in these amounts outstanding, expressed in their 'original currency,' are then converted back into sterling using the average exchange rate for the quarter.

#### A.1.3. Treatment of mergers and acquisitions

Over the period analyzed, a number of the banks in the sample were involved in mergers or acquisition activity. Bank mergers were dealt with by creating a synthetic merged series of the merging banks' balance sheets over the entire period. The acquired bank was then removed from the data set.

#### A.1.4. Outliers

The data used in this study exclude outliers for which the absolute value of the log difference of lending in one quarter exceeded $\pm 2$.

### A.2. Sensitivity of the results to different cleaning techniques

Below we investigate the sensitivity of our results from Table 3 to the cleaning assumptions that we have made. Due to extremely high volatility of some bank-country

**Table A1**
Robustness checks.This table presents results from fixed effects panel regressions of UK-regulated banks. In columns 1, 2, and 3, the dependant variable is the quarterly growth rate (FX-adjusted) of bank *i*'s total cross-border lending (sum of lending to banks and non-banks) to country j. In column 4, the dependent variable is the change (FX-adjusted) of bank *i*'s total cross-border lending to country *j*, as a percentage of the stock of bank *i*'s total cross-border lending to all countries in the previous period. In each column, a different cleaning method is used to exclude outliers from the dependent variable (see the description in Section A.2 of Appendix A). The other conventions are the same as in Table 3.

| Dependent variable: UK-regulated banks' cross-border lending growth | Base specification (used in Tables 3–5) | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Change in capital requirement ratio (DBBKR) (summed lags) | −5.475*** | −5.208*** | −2.350*** | −0.092** |
| (Prob > *F*) | 0.005 | 0.002 | 0.006 | 0.045 |
| Observations | 52,683 | 61,944 | 34769 | 78,134 |
| *R*-squared | 0.102 | 0.083 | 0.14 | 0.036 |
| Quarter/Country fixed effects | YES | YES | YES | YES |
| Bank fixed effects | YES | YES | YES | YES |

[16] A full description of these forms can be found at: http://www.bankofengland.co.uk/statistics/Pages/reporters/default.aspx.

[17] Banks omitted from the sample tended to be small or domestically focussed (e.g., building societies).

time series, we symmetrically restricted the growth rate of cross-border lending to country $j$ by bank $i$ in any given quarter to lie within the interval of $-100/+100\%$. This is equivalent to discarding approximately 15% of the sample. The result, based on this data cleaning approach, is presented in column 1 of Table A1. Column 2 of Table A1 shows results for the same regression, but includes observations for the dependent variable within a wider interval of $-200/+200\%$, equivalent to dropping 10% of the sample. Column 3 truncates the distribution of the dependent variable symmetrically at the 90$^{th}$ percentile. Finally, column 4 defines the dependent variable as the flow of cross-border lending to country $j$, by bank $i$, at time $t$ divided by the stock of bank $i$'s total cross-border lending at time $t-1$ (as opposed to bank $i$'s stock of lending to country $j$ at time $t$). To account for the outliers we drop $-1/+1\%$ of the distribution. The results show that the effects estimated in columns 1–3 are broadly similar to each other. The smaller estimated coefficient in column 4 is not comparable with the estimates in columns 1–3. Instead, it must be multiplied by the average number of countries each bank lends to (65 in our sample), yielding a value of $-5.98$, which is not dissimilar to our baseline estimate in column 1. These findings suggest our results are robust to different data cleaning techniques.

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