The International Transmission of Bank Capital Requirements: Evidence from the UK[1]

Shekhar Aiyar[2], Charles W. Calomiris[3], John Hooley[4], Yevgeniya Korniyenko[5]

and Tomasz Wieladek[6]

[Preliminary – Please do not distribute and/or cite without the permission of the authors]

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. Previous work has examined the effect of capital requirements on domestic loan supply, but the international transmission of shocks to bank capital requirements – an urgent and ubiquitous policy concern – has not been studied to date. By examining a sample in which each recipient country has multiple relationships with UK-resident banks, we are able to control for demand effects as in Khwaja and Mian (2008). 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 between 3 and 5.5 percentage points. We also find that banks tend to favor their most important country relationships, so that the cross-border credit supply response in "core" countries is significantly less than in others. Furthermore, 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.

JEL Classification Codes: G21, G18, E51, E52, E44

Keywords: cross-border lending, loan supply, capital requirements, international transmission.

---

[1] We are grateful to Mark Robson and the other staff of the Bank of England's Monetary and Financial Statistics Division for making the data on UK banks available to us and for helping us to access the data. This working paper should not be construed as representing the opinions of the Bank of England, the IMF, or any other organization. All errors and omissions remain our own.
[2] International Monetary Fund. E-mail: saiyar@imf.org
[3] Columbia Business School. Email: cc374@columbia.edu
[4] Bank of England. Email: john.hooley@bankofengland.co.uk
[5] Bank of England. Email: yevgeniya.korniyenko@bankofengland.co.uk
[6] Bank of England. Email: tomasz.wieladek@bankofengland.co.uk

I. Introduction

It is well documented that globalized banks transmit balance sheet shocks across borders. Cetorelli and Goldberg (2012) show that during the global financial crisis, liquidity shocks to banking systems in advanced countries caused a contraction in lending to emerging markets. Aiyar (2012) documents that foreign banks withdrew funding from UK-resident banks during the crisis, causing 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 pre-crisis evidence from diverse episodes and settings is marshaled by contributions such as Peek and Rosengren (1997, 2000), 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 Van Hoose (2008) for a review).[1] A more recent literature focuses on a unique dataset 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 2012, Aiyar, Calomiris and Wieladek 2013, Francis and Osborne 2012, Bridges et al 2012, Noss and Tofano 2012). All of these papers share the trait that the credit supply response analysed is purely domestic.

But 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

[1] 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.

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) or reducing risk-weighted assets (Figure 3). 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.

These are not abstract concerns. In December 2011 the European Banking Authority (EBA) announced 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 this policy measure on bank credit supply, not just within the advanced European countries where most of the EBA banks are headquartered, but also in emerging European countries (many of which are particularly reliant on credit from foreign banks) and non-European countries. While the number of banks explicitly required to raise capital under this exercise was relatively small, a greater set of banks were incentivized to strengthen their capital positions ahead of stress tests in July 2011.[2]

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 incentivising banks to rein in excessive lending when the economy 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

[2] See the IMF's Global Financial Stability Report, April 2012 and BIS (2012) for a review.

banks under their purview. But such time-varying minimum capital requirements are likely to affect not just domestic credit supply, but also credit supplied abroad. Moreover, to the extent that macro-prudential policies are co-ordinated across several advanced countries, this could amplify financial spillovers to emerging markets which have relationships with several advanced country banking systems.

In this paper we examine whether a rise in minimum capital requirements on UK banks is transmitted to foreign economies through a change in the supply of cross-border credit. The UK provides an ideal testing ground for the analysis, for at least two reasons. First, UK-resident banks tend to be very globalised, not just through affiliated banks abroad, but also through cross-border lending and liabilities. In our sample of UK-owned banks and foreign subsidiaries resident in the UK, cross-border lending on average accounted for a substantial 24% of total lending over 1998-2006, and the average bank had cross-border credit outstanding in 180 countries. Figures 10-12 give some idea of the scale and geographic dispersion of cross-border lending by UK banks.

Second, during the 1990s and 2000s the UK regulator, the Financial Services Authority (FSA) imposed bank-specific, time-varying minimum capital requirements on the banks under its purview. This apparently unique regulatory regime is elaborated in Section II. 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 bank 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 each of 180 countries. The detailed recipient country-level data allows 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.

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 requirement is associated with a reduction in the growth rate of cross-border credit of between 3 and 5.5 percentage points. Overall, this seems smaller than 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, 2012). However, banks tend to favour their most important country relationships, so that the cross-border credit supply response in "core" countries is significantly less than in others. 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.[3] 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 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 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).

In the remainder of the paper, we proceed as follows: Section II briefly describes the bank-specific UK data base that we employ to measure changes in capital requirements and changes in loan supply and loan demand. Section III describes the regression framework that we will use in our investigation in greater detail. Sections IV presents the results. Section V concludes.

[3] The difference in risk-weights only applies to lending with greater than one-year maturity. See Avramova and Le Leslé (1990) for a discussion of risk weights under Basel I.

II. UK Capital Regulation, 1998- 2007

Our empirical analysis is made possible by a regulatory policy regime that set bank-specific, time-varying capital requirements. These minimum capital requirement ratios were set for all banks under the jurisdiction of the FSA – that is, 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 97 regulated banks (30 UK-owned banks and 67 foreign subsidiaries resident in the UK). 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.[4]

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 (2012).

As Table 2 and Figure 1 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 Figure 2 shows, changes in capital ratio requirements 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.

[4] The data used in this study exclude outliers based on the following criteria: (1) trivially small banks (with total loans less than £3,000,000 on average and/or with cross-border claims less than £300,000,000); and (2) observations for which the absolute value of the log difference of lending in one quarter exceeded 2.

Importantly, the FSA based regulatory decisions on organization structures, systems and reporting procedures, rather than high-frequency financial analysis. 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, 2012). 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 domestic portfolio. The FSA's approach to supervision was implemented via ARROW (Advanced Risk Responsive Operating frameWork). 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 securitisation (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 (2012) consider the extent to which capital requirements were binding on bank behaviour, based on 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 that they maintain. For all four groups of banks, the variation in minimum capital requirements was associated with substantial co-movement in actual capital ratios, confirming the conclusions of Alfon et al (2005), Francis and Osborne (2009), and Bridges et al. (2012) that capital ratio requirements were binding on banks' choices of capital ratios for UK banks during this sample period.

III. The International Transmission of Capital Requirements

We aim to estimate the following benchmark model (1), with lending by FSA-regulated bank *i* to country *j* as the dependent variable:

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

where Δl_{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. ΔKR_{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 sample design has one particularly noteworthy feature. F_{jt}, the country-specific time fixed effect is a way of asking whether the *same* country in the *same* time period borrowing from multiple UK-affiliated 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 analogue of the firm-specific fixed effect 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.

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 supplied to a country by the banking group (which could include credit extended through affiliated banks 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.

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

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

The only difference between model **(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 asses if 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 lending to a country is in the top (*CORE*) or bottom (*PERIPHERY*) 10% of all banks' cross-border lending relationships, and zero otherwise; ii) a dummy variable that takes the value of one when the destination country is the bank's home country and zero otherwise; and iii) a dummy variable that takes the value of one when the destination country is an OECD country and zero otherwise.

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 in 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)). Our prior is therefore that the interaction term will be positive (that is, lending growth will fall by *less* in 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. And lending to the home country may respond differently to capital requirement changes than lending to other countries.

Finally, we also look at which borrowers are subjected to a cutback in credit supply arising from an increase in UK capital requirement, dividing the recipients of cross-border credit into banks and non-banks. This difference in the identity of borrowers experience loan supply reductions relates to the mechanism through which the shock is transmitted to the foreign country. 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.

IV. Results

Prior to describing our regression results, a casual examination of the data reveals several interesting stylized facts. In levels, external assets and lending have substantially increased from 2002 onwards (Figures 4 and 5). But this masks an important difference: Figure 6 shows that larger banks were responsible for most of this increase in external lending. Interestingly, larger banks lend on average less to any given country (Figure 7), which is consistent with the idea that 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 (Figure 8) and lend on average less to each country (Figure 9).

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 (Figure 10). 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 (Figure 11). 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(Figure 12).

We now turn to a discussion of our regression results, which are presented in Tables 3-5. Other than for the dummy variables in Z_{ijt}, we report the sum of the coefficients associated with the contemporaneous and three lagged values for each of the variables listed in the tables. The figures in brackets are the p-values associated with F-test statistic for the null-hypothesis of no statistical significance. All standard errors are clustered by countries and time. Importantly, following the approach presented in Khwaja and 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.

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 -6.76pp over a four quarter period following a 100 basis points 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 -5.48pp (column 1a).

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 II, it is very unlikely that UK regulators were changing banks' capital requirements based on changes in external lending growth to any particular country.[5] 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, 2a, 2b, 3. Aiyar, Calomiris and Wieladek (2012) 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 2a. The estimated loan-supply effect of a 100 basis points change in the capital requirement of -4.66pp is slightly smaller but similar to the prior estimates. Once bank fixed effects are added in specification 2a, the stable funding and core-tier one ratios become insignificant. This is because bank fixed effects are likely to be collinear with these variables, since bank-country time series for many countries are short. Given that bank fixed effects are therefore likely capturing all of these other variables; we keep bank fixed effects in our baseline model and drop all of these other control variables in the remaining regression tables in this paper. Most importantly, the effect of changes in the capital requirement ratio on cross-border lending growth is substantially smaller in specification 2a. It is however important to point out that this decline in the magnitude of the effect appears to be driven by a reduction in the regression sample size (the number of observations fall from 52 thousands to 31 thousands) caused by the inclusion of leads and lags in changes in the write-off-to-risk-weighted asset ratio. When these leads and lags in changes in the write-off-to-risk-weighted asset ratio are excluded from the model in column 2b while the sample is kept similar the column 2a coefficient on change in the capital requirement remains almost unchanged pointing to the fact that the large drop in coefficient on change in the capital requirement between specifications 1a and 2b is solely driven by the sample size. When only the contemporaneous change in the write-off-to-risk-weighted asset ratio is included alongside bank

[5] 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.

fixed effects, which allows us to preserve the whole sample, the magnitude of the effect on loan supply is -5.38pp and this is statistically significant at the 1% level (specification 3). Overall, this suggests that a 100 basis points increase in capital requirements causes the affected bank to reduce its external lending supply growth by between 3 and 5.5pp.

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.

Finally, Table 5 estimates model **(2)** to examine whether the cross-border loan contraction differs by either bank or recipient country characteristics. Columns 1-3 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 when the size of lending to a country is in the top (*CORE*) or bottom (*PERIPHERY*) 10% of all banks' cross-border lending relationships, and zero otherwise; ii) a dummy variable that takes the value of one when the destination country is the bank's home country and zero otherwise; and iii) a dummy variable that takes the value of one when the destination country is an OECD country and zero otherwise. As discussed in the previous section,

one might expect lending to be cut back less in core countries, in OECD countries and in the home country, in response to a change in capital requirements.

The regression results in Table 5 show that only the interaction with the core dummy is highly statistically significant, with an expected positive sign. The sum of the coefficients on the change capital requirements in the same regression specification (column 1) is statistically significant and negative. 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 have shown any statistical significance. When all of them are included together in column 5, only the core interaction term remains 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.

V. 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.[6] In this paper we make a first step towards filling this gap.

[6] 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.

For this purpose, we exploit a unique 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 for these regulated banks, this allows us to examine the impact of changes in domestic capital requirements on cross-border loan supply. Since we observe lending by each bank to 180 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 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 between 3 and 5.5 percentage points. This is smaller than the 5.7 to 7.6 percentage points reduction reported in previous work focusing on the transmission to the domestic credit supply (Aiyar, Calomiris and Wieladek, 2012). Lending to core countries (defined by the relative magnitude of the lending relationship) tends to reduced by less, while there is little evidence that lending to OECD countries, despite lower risk-weights on bank lending that 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.

References

Aiyar, S. (2011), "How did the crisis in international funding markets affect bank lending? Balance sheet Evidence from the UK", *Bank of England Working Paper*, No. 424.

Aiyar, S., C. Calomiris and T. Wieladek (2012a), "Does Macro-Pru Leak? Evidence from a UK Policy Experiment", NBER Working Papers 17822, National Bureau of Economic Research, Inc.

Aiyar, S., C. Calomiris and T. Wieladek (2012b), " How Does Credit Supply Respond to Monetary Policy and Bank Minimum Capital Requirements?", *Bank of England Working Paper (forthcoming)*.

Aiyar, S., C. Calomiris and T. Wieladek (2012c), "Exploring the Variety of Macro-Prudential Leakages", Unpublished mimeo.

Avramova, S. and V. Le Leslé (1990), 'Revisiting Risk-Weighted Assets: Why Do RWAs Differ Across Countries and What Can Be Done About It?" *IMF Working Paper*, No. 12/90.

Ashcraft, A. and M. Campello (2007), "Firm balance sheets and monetary policy transmission", Journal of Monetary Economics, vol. 54(6).

Campello, M (2002), 'Internal capital markets in financial conglomerates: evidence from small bank responses to monetary policy', *Journal of Finance*, Vol. 57, No. 6.

Cetorelli, N and L. Goldberg (2008), 'Banking globalization and monetary transmission', *NBER Working Paper No. 14101*.

Cetorelli, N and L. Goldberg (2011), "Global Banks and International Shock Transmission: Evidence from the Crisis", IMF Economic Review, vol. 59(1).

De Haas, R and I. van Lelyveld (2010), 'Internal capital markets and lending by multinational bank subsidiaries', *Journal of Financial Intermediation*, Vol. 19, Issue 1.

De Haas, R and N. Van Horen (2013), "Running for the Exit? International Bank Lending During a Financial Crisis," *Review of Financial Studies*, vol. 26(1), pages 244-285.

Khwaja, A and A. Mian (2008), 'Tracing the effect of bank liquidity shocks: evidence from an emerging market', *American Economic Review*, Vol. 98(4).

Peek, J and E. Rosengren (1997), 'The International Transmission of Financial Shocks: The Case of Japan', *American Economic Review*, Vol. 87(4).

Schnabl, P (2012), 'The International Transmission of Bank Liquidity Shocks: Evidence from an Emerging Market', *Journal of Finance*, forthcoming.

Appendix 1: Figures and Tables

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), per cent of risk-weighted assets.	Bank of England reporting form BSD3.	
Bank size	Log of total assets of 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 deposits and all CDs.
Tier 1 ratio	Tier one capital as a per cent of total risk weighted assets.	Bank of England reporting form BSD3.	
Risk	Total risk-weighted assets as a per cent of total assets.	Bank of England reporting form BSD3.	
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.	
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.	

Figure 1: Histogram of minimum capital requirement ratio

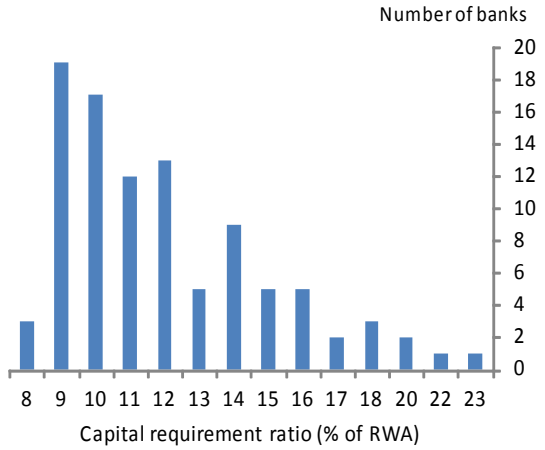

Figure 2: Time series average of capital requirement ratio (% of RWA)

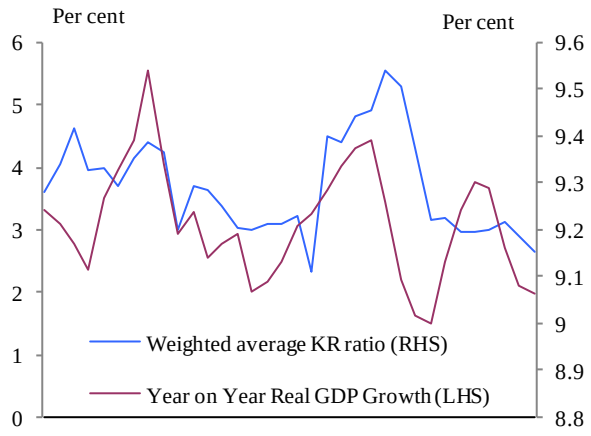

Figure 3: International transmission of changes in domestic capital requirements

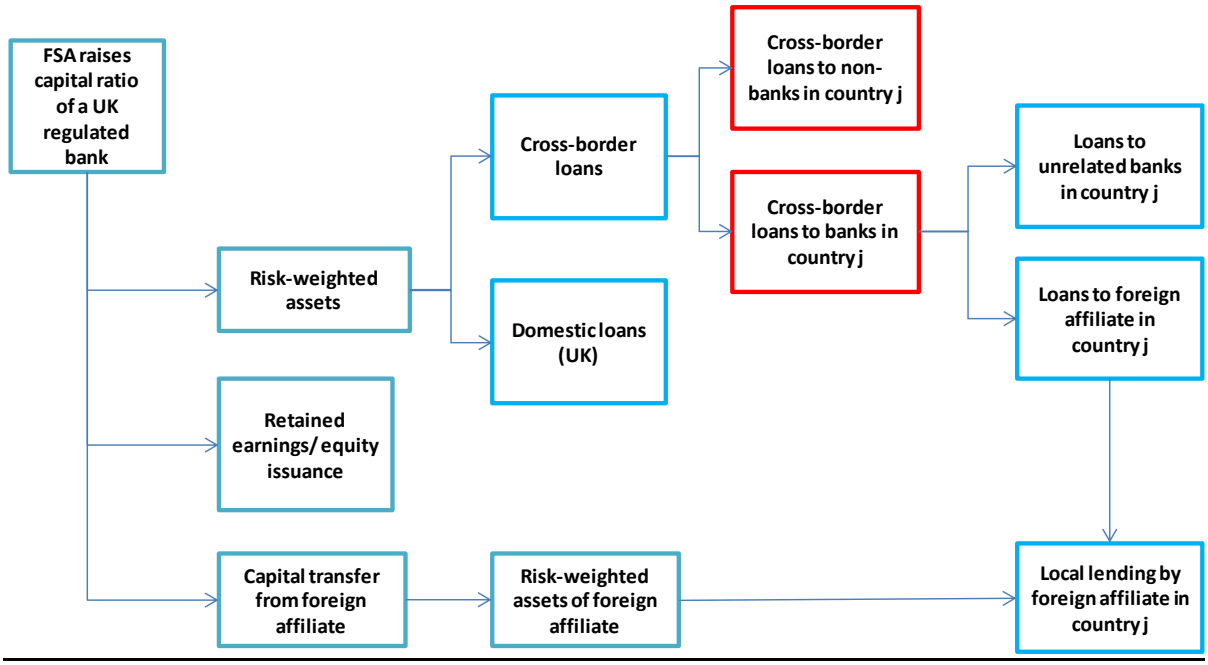

Figure 4: Cross-border assets by bank type

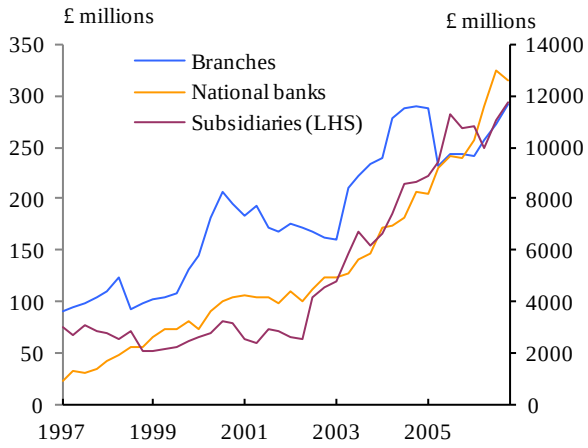

Figure 5: Cross-border lending by bank type

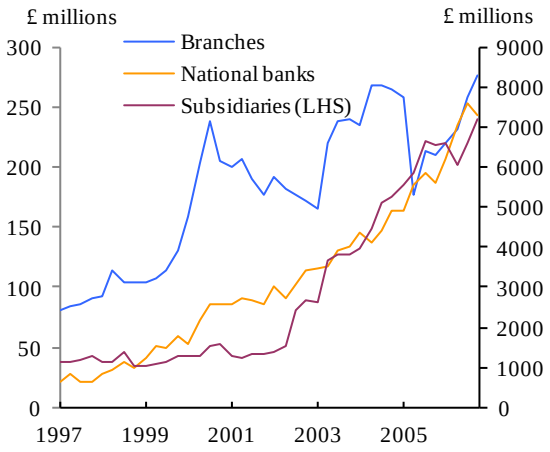

Figure 6: Mean growth of cross-border lending by bank i to country j (by bank size)

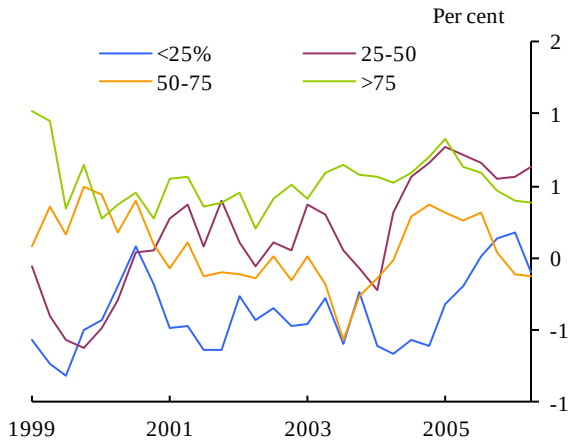

Figure 7: Mean share of country i in bank j's total cross-border lending (by bank size)

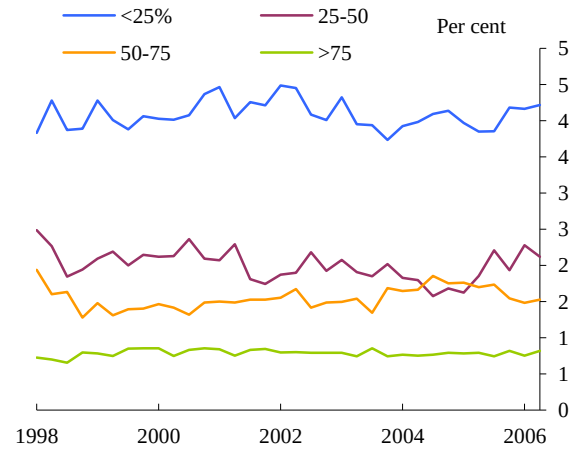

Figure 8: Mean number of lending destinations per bank

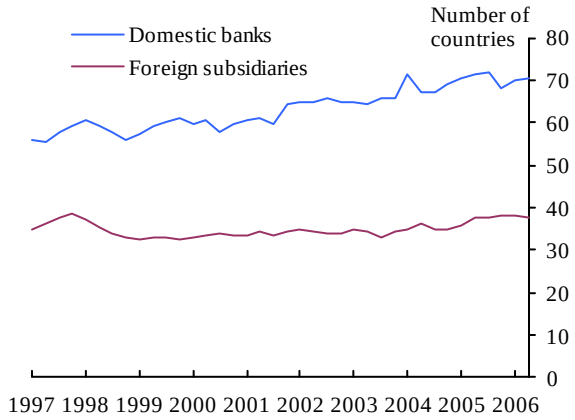

Figure 9: Mean share of country i in bank j's cross-border lending

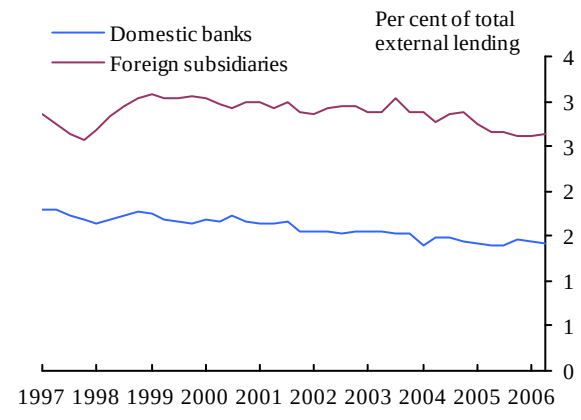

Figure 10: Total country share of UK regulated banks' total cross-border lending (2006)

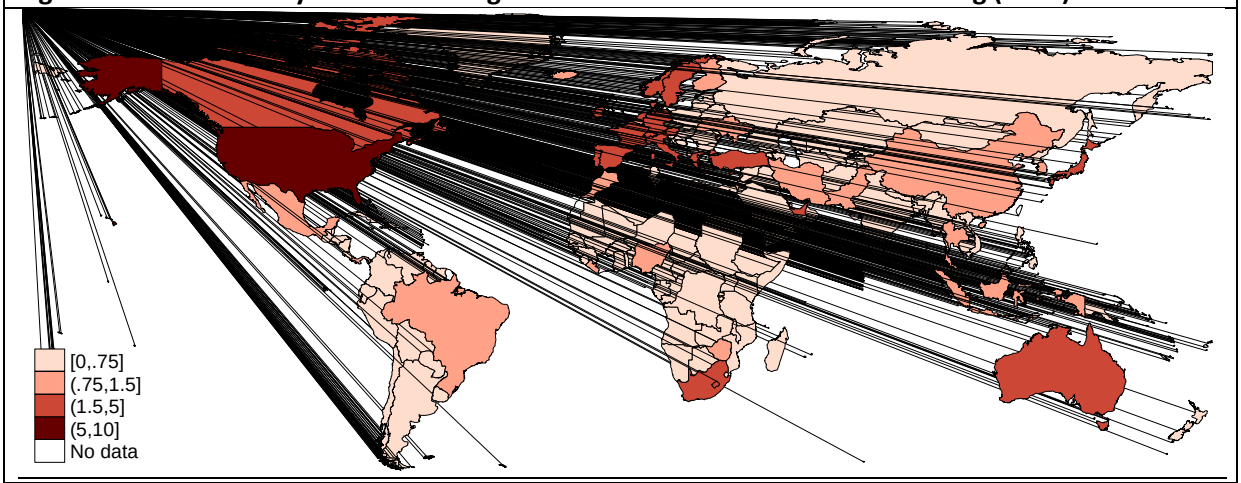

Figure 11: Mean country share (by bank) of UK-regulated banks' total cross-border lending (2006)

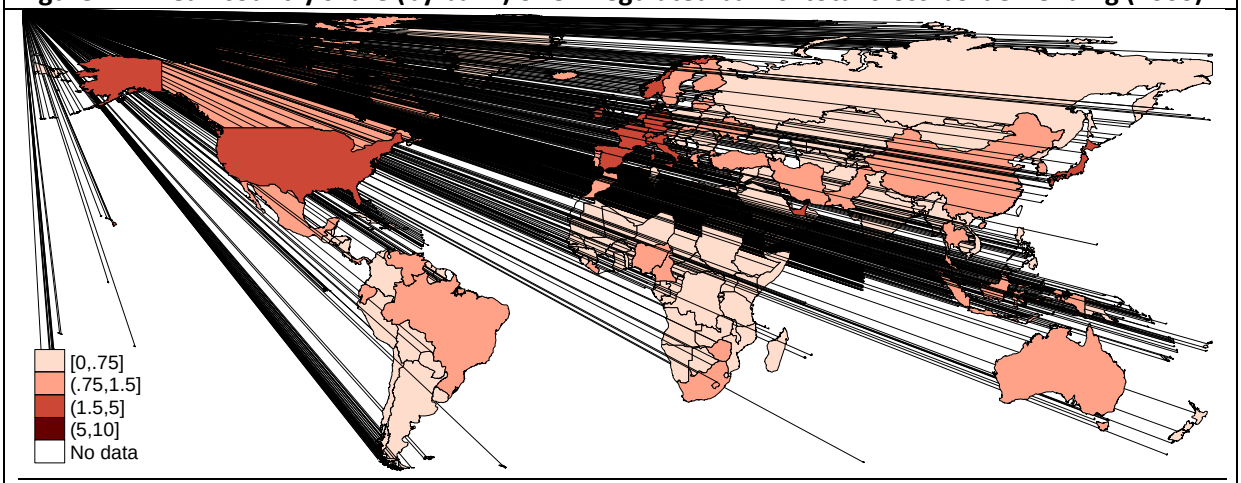

Figure 12: Growth in UK-regulated banks' total cross-border lending (1999-2006)

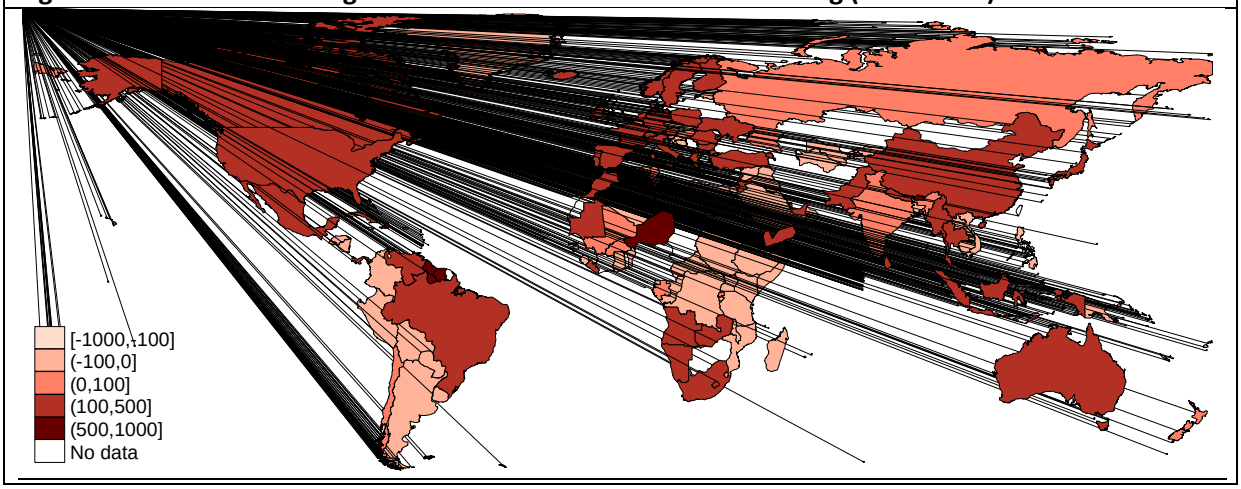

Table 2: Summary statistics

Variable	Entity	Units	Median	S.D.	Min	Max	Obs
Capital requirement ratio	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

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

Dependent variable: UK regulated banks' cross border lending growth	1	1(a)	2	2(a)	2(b)	3
Change in capital requirement ratio (DBBKR) (summed lags)	-6.760***	-5.475***	-4.664***	-3.167**	-3.317**	-5.328***
(Prob>F)	0.000	0.000	0.001	0.039	0.030	0.000
Bank size			0.280***	2.380**	2.360**	1.787**
(p-value)			0.009	0.011	0.012	0.015
Liquidity			-0.122	0.122	0.131	0.117
(p-value)			0.165	0.415	0.379	0.308
Stable funding			-0.026***	-0.013	-0.011	-0.012
(p-value)			0.000	0.557	0.590	0.423
Tier 1 ratio			-0.024**	-0.001	-0.000	0.016
(p-value)			0.031	0.962	0.975	0.105
Risk			-0.002	-0.004	-0.005	0.003
(p-value)			0.487	0.463	0.453	0.130
Lagged exposure			-0.225***	-0.215***	-0.214***	-0.127***
(p-value)			0.000	0.000	0.000	0.002
Change in write –offs (contemporaneous)						0.594***
(p-value)						(0.000)
Change in write –offs (summed leads)			1.499*	1.654*		
(Prob>F)			0.074	0.063		
Change in write –offs (summed lags)			2.949***	3.111***		
(Prob>F)			0.001	0.001		
Observations	52,683	52,683	31,704	31,704	31,704	52,683
R-squared	0.089	0.102	0.138	0.151	0.150	0.103
Quarter/Country FE	YES	YES	YES	YES	YES	YES
Bank FE	NO	YES	NO	YES	YES	YES

Notes: 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 total lending (meaning sum of lending to banks and non-banks) in 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.

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

Dependent variable: UK regulated banks' cross border lending growth	1 Cross-border lending to all non-residents	2 Cross-border lending to non-resident banks	3 Cross-border lending to non-resident non-banks
Change in capital requirement ratio (DBBKR) (summed lags)	-5.459***	-6.110**	-0.882
(Prob>F)	0.000	0.016	0.445
Observations	52,683	16,265	50,169
R-squared	0.102	0.162	0.109
Quarter/Country fixed effects	YES	YES	YES
Bank fixed effects	YES	YES	YES
Bank controls	NO	NO	NO

Notes: 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 (sum of bank and non-bank) lending (Column 1), banks only (Column 2) and non-banks only (Column 3) in country j. The other conventions are the same as in Table 3.

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

Dependent variable: UK regulated banks' cross-border lending growth	1	2	3	4
Change in capital requirement ratio (DBBKR) (summed lags)	-6.942***	-5.324***	-4.869***	-5.798***
(Prob>F)	0.000	0.000	0.002	0.000
Core market*DBBKR	6.707*			7.783**
(Prob>F)	0.052			0.026
Peripheral market*DBBKR	7.291			6.946
(Prob>F)	0.173			0.196
Home country*DBBKR		-9.440		-10.06
(Prob>F)		0.353		0.278
OECD*DBBKR			-1.454	-2.733
(Prob>F)			0.568	0.295
Core market	9.784***			10.057***
(p-value)	0.000			0.000
Peripheral market	-6.432***			-6.412***
(p-value)	0.000			0.000
Home country		-1.841		-5.710***
(p-value)		0.280		0.001
Observations	52683	52683	52683	52683
R-squared	0.112	0.102	0.102	0.112
Quarter/Country fixed effects	YES	YES	YES	YES
Bank fixed effects	YES	YES	YES	YES
Bank controls	NO	NO	NO	NO

Notes: 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 total lending (meaning sum of lending to banks and non-banks) in 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.

Appendix 2: 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.[7] All data are unconsolidated— they refer to individual authorised 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, was adjusted by the authors on a best endeavours basis. This data annex describes the data used and the adjustment procedures followed. The dataset 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 A1.

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 are included that have external claims above the reporting threshold of £300mn. [8]

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

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

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

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.

Treatment of mergers and acquisitions

Over the period analysed, 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.

Outliers

The data used in this study exclude outliers for which the absolute value of the log difference on lending in one quarter exceeded +/- 2.

Sensitivity of the results to the cleaning technique

Below we investigate how sensitive our results, to the cleaning assumptions that we have made. Due to high volatility of bank-country time series which lead to large country-specific growth rates of lending , we symmetrically restricted lending growth rates 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 with an interval of -200/+200%, which is equivalent to dropping 10% of the sample. Column 3 drops growth rates associated with high volatility and restrict distribution of the left had side variable to the 90 percent on both sides. Finally column 4 defines the dependent variable as the flow 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 oppose 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 presented in Table A1 show that the effects estimated in columns 1-3 are quite similar to each other. The estimate in column 4 is -0.09, but multiplied by 42, the average number of countries each bank lends to, the magnitude of the effect is not dissimilar to that presented in column 1. This suggests our results seem to be robust to different data cleaning techniques.

Annex Table A1: Robustness checks

Dependent variable: UK regulated banks' cross border lending growth	1 Base specification (used in Tables 3-5)	2	3	4
Change in capital requirement ratio (DBBKR) (summed lags)	-5.459***	-5.203**	-2.228*	-0.093**
(Prob>F)	0.000	0.002	0.087	0.055
Observations	52,705	61,980	41,435	80,304
R-squared	0.102	0.083	0.115	0.035
Quarter/Country fixed effects	YES	YES	YES	YES
Bank fixed effects	YES	YES	YES	YES
Bank controls	YES	YES	YES	YES

Notes: 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 cross-border total lending (meaning sum of lending to banks and non-banks) in country j. In Column 4, the dependent variable is the change (FX-adjusted) of bank i's cross-border lending to banks and non-banks in country j, as a percentage of the stock of bank i's total cross-border lending in the previous period. In each Column, a different cleaning method is used to exclude outliers from the dependent variable. In Column 1, observations for which the absolute value of the log difference of lending in one quarter exceeded 2 are excluded (+/-100%) (the same method as in Tables 3-5). In Column 2, observations for which the absolute value of the log difference of lending in one quarter exceeded 4 are excluded (+/- 200%). In Column 3, observations from the upper 10th percentile of each ij time series are excluded (i.e. highly volatile growth rates); in the remaining sample, 10% of the observations from each tail of the whole distribution were excluded. In Column 4, 1% of the observations from each tail of the distribution are excluded. 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. In Column 4, a comparable estimate of the impact of changes in minimum capital requirements on banks' cross-border lending growth to those in Columns 1-3 can be obtained by multiplying the coefficient on the summed lags of DBBKR by 42 (the average number of countries per bank per period in the sample). A constant is included but not shown.