Cross-border effects of prudential regulation—Evidence from the euro area*

Fabio Franch† Luca Nocciola‡ Dawid Żochowski§

European Central Bank *Deutsche Bundesbank* *European Central Bank*

Abstract

We analyse the cross-border propagation of prudential regulation in the euro area. Using the Prudential Instruments Database (Cerutti et al., 2017b) and a unique confidential database on balance sheets items of euro-area financial institutions we estimate panel models for 248 banks from 16 euro-area countries. We find that domestic banks reduce lending after the tightening of capital requirements in other countries, while they increase lending when loan-to-value (LTV) limits or reserve requirements are tightened abroad. We also find that foreign affiliates increase lending following the tightening of sector-specific capital buffers in the countries where their parent banks reside and that bank size and liquidity play a role in determining the magnitude of cross-border spillovers.

Keywords: prudential policy, cross-border spillovers, international banking

JEL-Classification: G21, F34, F36

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†Currently at the Reserve Bank of Australia. Contributed while at the European Central Bank. E-mail: FranchF@rba.gov.au

‡E-mail: luca.nocciola@bundesbank.de

§Postal address: European Central Bank, Sonnemannstrasse 20, 60314 Frankfurt am Main; e-mail: dawid.zochowski@ecb.europa.eu (corresponding author)

1 Introduction

Our study measures cross-border externalities of prudential regulation by using individual euro-area bank data. This work is important for at least three reasons. First, cross-border spillovers may reduce (negative spillovers) or increase (positive spillovers) the efficacy of prudential policy[1] in containing systemic risk at home and/or abroad. Second, while achieving the same objectives, some (macro)prudential instruments can be more effective than others (ESRB (2014)). Third, cross-border spillovers may expand as financial markets and sectors become more integrated, as it has been the case in the euro area since the introduction of the single currency and is likely to be reinforced after the introduction of the banking union. Accordingly, finding sizable spillovers would highlight the need for coordination, in particular in a form of reciprocity arrangements, among macroprudential authorities, in order to limit negative spillovers and reap the benefits from positive ones (ESRB (2015)).

According to Buch and Goldberg (2017) cross-border spillovers can be classified according to their direction as inward, when banks (domestic and foreign-owned) placed in the host economy react to prudential policy changes abroad, and outward, when global banks respond to foreign prudential policy by changing their foreign activities or by reallocation of business through their foreign affiliates, i.e subsidiaries or branches. In this paper, we study inward spillovers broadly following the methodology developed by Buch and Goldberg (2017).[2] Drawing from Buch and Goldberg (2017) the inward transmission can operate via two different channels of propagation: first, the transmission of exposure-weighted foreign regulation to lending growth of domestically-owned banks[3] and, second, the transmission of home countries' regulation, i.e. the countries where the parent banks

[1] While the use of the instruments we study has been mostly microprudential purposes, the results can also shed light on the effects of macroprudential policy to the extent that the instruments used to achieve the macroprudential goal are the same, for instance capital or LTV regulation.

[2] We deviate from Buch and Goldberg (2017) in the following ways: we explicitly differentiate between branches and subsidiaries; we use total loan growth as a baseline dependent variable but we also use domestic loan growth in robustness checks; and we use country rather than bank-level weighting scheme for prudential indices.

[3] Following Buch and Goldberg (2017), this channel exists due to both direct cross-border exposures and exposures via foreign affiliates of home banks. Therefore, domestically-owned banks without foreign affiliates can still be affected by foreign regulation through direct cross-border exposures.

reside, to lending growth of foreign-owned banks placed in the domestic economy.[4] The first inward transmission operates via the adjustments of the balance sheet of home banks with foreign exposures. In reaction to the changes in the foreign prudential environment they can shift funds across borders. For instance, if the prudential policy tightens abroad they can increase domestic lending and reduce foreign lending. The second inward transmission operates via the impact of the home country regulation on the lending of foreign affiliates, i.e. branches or subsidiaries. Since in the EU branches are subject to parent's home country regulation, while subsidiaries are subject to the host country regulation, we identify the relevant regulation by selecting the parent country regulation for branches, and the host country regulation for foreign subsidiaries.[5] For instance, a tightening of home country regulation could lead to changes in the provision of credit from foreign branches and subsidiaries operating in that country.

To assess these two channels, we use a unique confidential database on balance sheet items (BSI) of 248 individual financial institutions from 16 euro-area countries over the period from 2007Q3 to 2014Q4.

Concerning the first, domestic channel, we find that euro-area domestic banks reduce on average lending after the tightening[6] of capital requirements in other EU countries, while they increase their lending when LTV limits or reserve requirements are tightened abroad (Table 3).

Turning to the second channel, which operates via foreign affiliates, we find that foreign affiliates increase lending when sector-specific capital buffers are tightened in the home countries for branches or host countries for subsidiaries (Table 5). This suggests that parent banks in the home economies shift their lending to their foreign affiliates placed in the jurisdiction where the regulation is relatively less binding, speaking for cross-border

[4]For a comprehensive description of cross-border propagation channels from macroprudential policy, see Fahr and Żochowski (2015).

[5] Danisewicz et al. (2017) show empirically the importance of this distinction.

[6]We refer to "tightening" or "tightened" in case of regulation changes, while we refer to "tighter" when we look at the cut-cumulative (at the second lag) indices of regulation. This is because while the first concerns the dynamics, the second reflects the level of stringency of regulation. The same applies to loosening.

negative spillovers.

Taking these findings together, we find that measures that are borrower-specific or operate locally (i.e. they affect lending in a specific jurisdiction, such as LTV limits), sector-specific capital buffers or reserve requirements, are prone to negative cross-border spillovers, as euro-area banks shift their lending to other jurisdictions. This can be explained by the fact that such measures are normally linked to the loan contract or borrower's characteristics, and are hard to circumvent. As a result, international banks shift their lending abroad, which also speaks for a portfolio rebalancing channel. Conversely, a tightening of prudential instruments which target lenders or act at the consolidated level, such as capital requirements (since they cannot be easily circumvented) is found to be associated with an overall decrease in lending by euro-area domestic banks, i.e. the prudential policy action is reinforced abroad.

We also find that bank characteristics play a role in the propagation of cross-border spillovers of prudential policy (Table 4): euro-area domestic banks that are less liquid reduce lending more than other banks when capital requirements are tightened abroad. Better capitalized banks also tend to increase lending more than other banks when sector-specific capital buffers are tightened, while larger (as measured by total assets) banks increase their lending more than smaller banks when LTV limits are tightened.

2 Related literature

The growing awareness of the importance of controlling potential unintended effects of prudential policy has recently triggered a strand of literature analyzing policy spillovers. The assessment of the cross-border impact of prudential regulation involves two dimensions of bank behaviour, that is the amount of credit and the quality of loans (i.e. risk taking behaviour) they provide. Using data across 16 countries, Ongena et al. (2013) focus on this second dimension and find that a tighter regulation does not necessarily reduce risk, but could reallocate it across countries through foreign branches or subsidiaries

of multinational banks. Aiyar et al. (2014b) focus on the first dimension and find that while loan supply from domestic banks decreases following a tightening in capital requirements, loan supply by foreign branches increases, providing evidence of regulatory leakage. The latter finding is also supported by Reinhardt and Sowerbutts (2015), who find that a tightening in capital regulation induces domestic non-banks to increase their borrowing from abroad. Moreover, Danisewicz et al. (2017) find that a regulatory tightening of capital requirements abroad disproportionately affects different types of foreign banks, impacting more branches than subsidiaries, thus highlighting the importance of the bank's organizational structure in the regulatory transmission.

Yet, there are studies which focus on cross-border lending instead of local lending through foreign affiliates. Aiyar et al. (2014a) find that an increase in capital requirements in the UK is associated with a reduction in cross-border credit growth. This is found to be true especially for interbank cross-border credit (to foreign affiliates) rather than cross-border credit to firms and households, reflecting the greater willingness or ability to cut back on shorter maturity (wholesale) lending and transmitting a liquidity shock to foreign banks. Bremus and Fratzscher (2015) also find that euro-area countries that experienced more stringent capital requirements after the crisis saw decreases in cross-border lending, arguing that this could be due to higher uncertainty, and increased information and funding costs associated with foreign lending. On the other hand, Cerutti et al. (2017a) find that the greater use of macroprudential policy is associated with more reliance on cross-border credit, in particular for open economies, suggesting that this policy should be considered simultaneously with capital flows management rules. Similarly, Houston et al. (2012) find that tighter regulation in the source country encourages credit outflows while tighter regulation in the destination country discourages credit inflows, speaking for regulatory arbitrage.

The studies most closely related to our were conducted in the context of the IBRN (Buch and Goldberg, 2017). We follow a similar methodology and use the same Prudential Instruments Database (Cerutti et al., 2017b). The meta-analysis of this international effort suggests that while spillovers vary across prudential instruments and are heteroge-

neous across banks, the effects of prudential instruments may sometimes spill over borders through bank lending. Consistent with our findings, the participants of the IBRN initiative find also that bank-specific factors like balance sheet conditions and business models drive the amplitude and the direction of the spillovers. For few inward transmission studies in the euro area conducted in the context of the IBRN initiative, our findings are consistent with Bonfim and Costa (2017), who find that tightening of capital requirements abroad reduces domestic credit growth in Portugal, while foreign banks operating in Portugal increase credit after the tightening of LTV ratios abroad. In line with our result for LTV cap, also in the context of the IBRN initiative, Ohls et al. (2017) find that German banks increase domestic lending in response to the tightening of foreign loan-to-value regulation. Concerning the LTV cap spillover to foreign banks, Hills et al. (2017) find the same direction of the spillover as in our and the Portuguese study, while spillovers from capital regulation to UK banks are found to be insignificant. Our findings are also in line with Berrospide et al. (2017), who find that a foreign country's tightening of limits on LTV ratios increases lending growth in the US. In a cross-country study using country level data from the BIS international banking statistics, Avdjiev et al. (2017) find, in line with our results for individual banks, that better capitalised banking systems reinforce international spillovers from prudential instruments. Takáts and Temesvary (2017) use also the IBRN data in a cross-country study to analyse the effect of macroprudential measures on cross-border lending during the taper tantrum. They find that macroprudential measures implemented in borrowers' host countries prior to the taper tantrum significantly reduced the negative effect of the tantrum on cross-border lending growth.

To our knowledge, this is a first cross-country study which analyses the cross-border spillovers from prudential regulations using cross-country, individual bank-level data of 248 euro-area credit institutions from the ECB MFIs statistics. The use of individual bank data from different countries is key to our identification strategy, which we elaborate on in section 4.

3 Data and stylized facts

We construct our panel using four datasets: a confidential bank-level database of MFIs BSI locational statistics from the ECB, the database on parent companies of MFIs, which we built using publicly available information, the IBRN Prudential Instruments Database (Cerutti et al., 2017b) and the database containing business and financial cycle variables from the BIS (BIS (2014) and Borio et al. (2012)). The final panel is an intersection of these four databases and includes $N_b = 248$ MFIs belonging to $N_c = 16$ euro area countries over the period 2007Q3-2014Q4. The next subsections present these datasets in detail.

3.1 Bank-level data

Our unbalanced bank-level dataset reports confidential locational BSI (assets and liabilities) statistics of 253 MFIs belonging to euro-area countries (excluding Latvia and Lithuania) starting from 2007M7 to 2014M12.[7] We reduce the frequency of the series from monthly to quarterly by simply picking the last month-value of the quarter. Nonetheless, we still have a number of missing observations which we however do not impute in order to be more confident in the goodness of our results. Balance sheet characteristics data are expressed as a percentage of total assets. As a response variable we use $\Delta ln(Y_{b,t})$, i.e. change in the natural logarithm of total loans. As control variables we use $ln(TA_{b,t-1})$, i.e. natural logarithm of a bank's total assets to take account that larger banks may be better linked with international capital markets, have a relatively larger international footprint and hence better equipped to relocate assets across portfolios and jurisdictions; $CR_{b,t-1}$, i.e. the capital ratio or percentage of bank's capital and reserves to asset ratio, given that banks with lower capital ratios may be more active in responding to policy shocks and be proactive in managing relatively lower capital stock; $IAR_{b,t-1}$, i.e. illiquid assets ratio or the percentage of a bank's portfolio of assets that is illiquid, since more liquid banks will have more leeway in managing their porfolios and in responding to policy innovations

[7] Five banks from Cyprus have not been considered in the analysis since the country's changes in regulation were not recorded in the IBRN Prudential Instruments Database.

and $DR_{b,t-1}$, i.e. the ratio of retail deposits to total liabilities or a percentage of a bank's balance sheet financed with retail deposits to capture the stability of banks' funding base, which in turn can determine the mobility and the velocity of the asset side. For a detailed description of the origin and the construction of the bank-level variables see Table 1A in the Annex.

In addition, we complement the BSI dataset with dynamic information on the ownership structure of the MFIs. We construct the database by tracking the domestic/foreign and branch/subsidiary, country and ownership status of an MFI and its owner over time. To this end, we relied on several information providers (public and private) and, when needed, also regulators' and banks' websites. Particular care was given to banks ownership changes, mergers and acquisitions especially in the aftermath of euro area sovereign debt crisis.[8] The distinction between branches and subsidiaries is relevant for the proper identification of the second channel operating via foreign affiliates. According to the EU law, subsidiaries are subject to the host country regulation, while branches are subject to the home country regulation.[9]

3.2 Country-level data

We consider two types of country data: prudential instruments changes from the IBRN Prudential Instruments Database (Cerutti et al., 2017b) and business and financial cycle time-series from the BIS dataset.

[8] Of those MFIs for which it was possible to identify ownership (90% of the total sample), roughly a quarter are foreign affiliates, i.e. a branch or a subsidiary.

[9] This distinction may be more subtle in practice. Some prudential instruments are locational measures, i.e. they target an exposure of a specific geographical location. For instance, sector-specific capital buffers, LTV limits and reserve requirements are locational measures in principle. This would suggest that both foreign subsidiaries and branches might be considered as subject to the respective host country regulations. However, we argue that branches do not have a legal entity status, but they are part of the balance sheet of the parent banks. As such they should be considered as subject to the home country regulation also for locational measures. On the contrary, subsidiaries, operating as a separate legal entity, are subject to the host country regulation.

3.2.1 Prudential instruments

The second dataset includes data on the use of prudential instruments collected by the IBRN team. The database covers eight instruments: capital requirements (*cap_req*), LTV limits (*ltv_cap*), sector-specific (*sscb*) and counter-cyclical capital buffers (*ccb*)[10], reserve requirements in local (*rr_local*) and foreign (*rr_foreign*) currencies, interbank exposure limits (*ibex*) and concentration ratios (*concrat*) for 64 countries for a period from 2000Q1 to 2014Q4. The authors of the database construct indices for each instrument using the following general coding rule: $P_{j,t}$={1,-1,0,*NA*} if country j tightens, loosens, does not modify the regulation at time t, respectively. Missing values (*NA*) are present in the dataset whenever the authors did not have enough information to determine whether a particular instrument in a specific period was tightened, loosened or remained unchanged. For all missing values we assume that the instrument was not changed at that given point in time and therefore we convert missing values to zeros constraining possible values of the index to: $P_{j,t}$={1,-1,0}.

In addition, the dataset contains an overall prudential policy index, *PruC*, which takes value one when the sum of all instruments at a given point in time is higher or equal to one, value minus one when the same sum is lower or equal to minus one, and zero otherwise.

3.2.2 Transformed prudential instruments

To assess the first channel of inward transmission, i.e. the reaction of lending of domestically-owned banks to exposure-weighted foreign regulation, we construct dynamic lender-based cross-border exposure-weighted indices using aggregate locational data on direct cross-border exposures[11]. The matrices $\mathbf{W}_t$ are of dimension $(N_c \times N_c)$ with weights based on EU countries bilateral exposures:

[10] Given that counter-cyclical capital buffers were enforced in the EU only in January 2016, the IBRN data does not contain any observations for this instrument in the time span we consider. As a result, we drop it from further analysis.

[11] Few residual missing data values are imputed using a random forest algorithm since this is needed to construct the weighted indexes.

$$\underset{(N_c \times N_c)}{\mathbf{W}_t} = \begin{bmatrix} w_{11,t} & \dots & w_{1N_c,t} \\ \vdots & \ddots & \vdots \\ w_{N_c1,t} & \dots & w_{N_cN_c,t} \end{bmatrix}$$

where $w_{ij,t} = 0$ if $i = j, \sum_{j=1}^{N_c} w_{ij,t} = 1$ for each $i, j = 1, \dots, N_c, N_c = 27$, and $t = 1, \dots, T, T = 30$ as the number of year-quarter pair considered in the sample. By setting the main diagonals to zero we consider only foreign regulation and by row-normalizing we relativize the weights to the EU indices to compute weighted averages of the original indices. We generate $\mathbf{W}_t$ for each time period, yielding a block diagonal matrix $\mathbf{E}$ of dimension $(N_cT \times \mathrm{N}_cT)$ with main diagonal composed of the single time-varying matrices $\mathbf{W}_t$ of exposure weights:

$$\underset{(N_cT \times N_cT)}{\mathbf{E}} = \begin{bmatrix} \mathbf{W}_1 & \dots & \mathbf{0} \\ \vdots & \ddots & \vdots \\ \mathbf{0} & \dots & \mathbf{W}_T \end{bmatrix}$$

Multiplying this matrix by the various vectors of instruments included in the sample, we obtain $EP_{j,t-l} = \mathbf{E} \cdot P_{j,t-l}$, where $l = \{0, 1, 2\}$ and $\cdot$ is the matrix multiplication operator. Since we only have aggregate information on cross-border loan exposures, we distribute the exposure-weighted regulation among banks belonging to the same country equally.[12]

To assess the second channel of inward transmission through foreign affiliates, we construct a new index conditional on whether the foreign affiliate is a branch or a subsidiary. This is relevant, since in the EU branches are subject to parent's home country regulation, while subsidiaries are subject to the host country regulation. To capture this, we select the home countries' regulation for foreign branches and the host countries' regulation for foreign subsidiaries, according to the following rule: $HP_{i,t} = \{P_{k,t}, P_{j,t}\}$ if $subs_t = \{0, 1\}$,

[12]This data limitation could weaken the potential richness of the network structure by cancelling the cross-sectional variability of the exposure-weights across banks belonging to the same country. Using supervisory data (FINREP/COREP) we concluded that the country-level data exposure weights are a good approximation of the bank-level exposure weights. The within-country standard deviation of banks' exposure to different countries (as percentage of total exposure) is on average slightly less than 0.06. Moreover, in 85% of the cases the range of the same cross-border exposures but across the available quarters is less than 10%, showing that bank-level exposures have been quite stable. Both findings suggest that this data limitation should have no significant effect on the results. These findings are also consistent with those using the BSI statistics and the EBA transparency data. The largest differences in exposures across the available quarters are concentrated on the domestic exposures.

respectively, where $subs_t$ is a binary variable taking value one if the bank is a subsidiary and zero otherwise (i.e. if the bank is a branch) at time t. This allows for a precise identification of the relevant regulation, embedded in $HP_{i,t-l}$, where $l = \{0, 1, 2\}$.

3.2.3 Macroeconomic cycles

The third dataset from the BIS includes country-level business and financial cycle variables to account for country-specific time-varying characteristics. As the literature suggests, these variables can be relevant controls for estimating the impact of prudential policy (Cerutti et al. (2017a) and Claessens et al. (2013)).

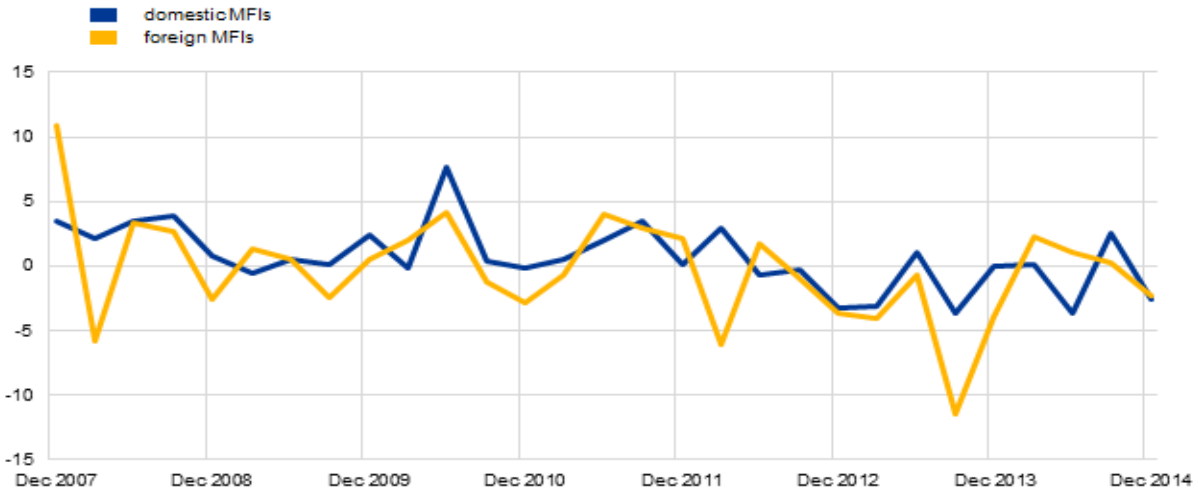
3.3 Stylized Facts

The volatility, as measured by the variance, of loan growth of euro area banks has been significantly greater for foreign banks over the past few years, speaking for a potential role of cross-border spillovers from shocks, some of which may be related to asymmetric changes in prudential policy (Figure 1).[13] At the beginning of the sample period domestic bank lending growth is shown to be persistently positive, but then decreases over time to become negative after 2011. While prudential policy could play a role exactly in periods of persistently high credit growth, lending growth measured at the country level could be influenced not only by national regulation but also by foreign regulation. This could be attributed to banks' cross-border lendings or lending via foreign affiliates.

To avoid inefficiency of the estimates of the impact of prudential measures, some minimum variation in the implemented policy is required. Table 2 in the Annex reports the number of changes in the prudential regulation both for the sample of EU countries used in analysing the first channel as well as for home (EU and non-EU) countries used in the

[13]The null hypothesis that the standard deviation of the loan growth of domestic and foreign banks is equal is rejected by the variance ratio F-test, which accounts for different sample sizes underlying the two lending indices.

Figure 1: MFIs total loan growth for domestic and foreign banks in the euro-area, (percent, 2007Q4-2014Q4)



second channel. For both channels, capital requirements, reserve requirements, loan-to-value limits and sector-specific capital buffers have been the most frequently used instruments at the country-time level, with at least ten changes during the sample period. Nevertheless, when deciding whether the number of changes is sufficient for estimation purposes, we consider transformed exposure-weighted indices. For the first channel these indices exhibit sufficient variation for all instruments. For the second channel, the host-home transformation leads to a lower increase in the number of observations for almost all tools. Therefore, when commenting the panel estimations we consider only those instruments for which more than 200 changes in policy for the first channel and 10 changes for the second is observed.[14] We report also the variation in the transformed indices at the bank-time level, which we ultimately used in the regressions.

Changes in all instruments are approximately uniformly distributed across euro-area countries, reflecting the increasing coordination among the countries sharing the single currency (Figure 2). However, the inclusion of non euro-area, EU countries increases the cross-sectional variability of regulation changes, which is necessary to estimate cross-border spillovers. In addition, the instruments are tightened or loosened not necessarily

[14]We drop reserve requirements (foreign) from further analysis, because of insufficient variation in this policy instrument.

in the same time period (Figure 3), which means that for each period the cross-sectional variability is actually higher than the aggregate one. The use of prudential policy has gradually increased over time for both EU and non-EU countries, in particular with respect to capital requirements (Figure 3).

Figure 2: Cross-sectional distributions of changes for prudential indices in euro-area countries (top panel) and non euro-area, EU countries (bottom left panel) and non-EU countries (bottom right panel) used in the estimation samples

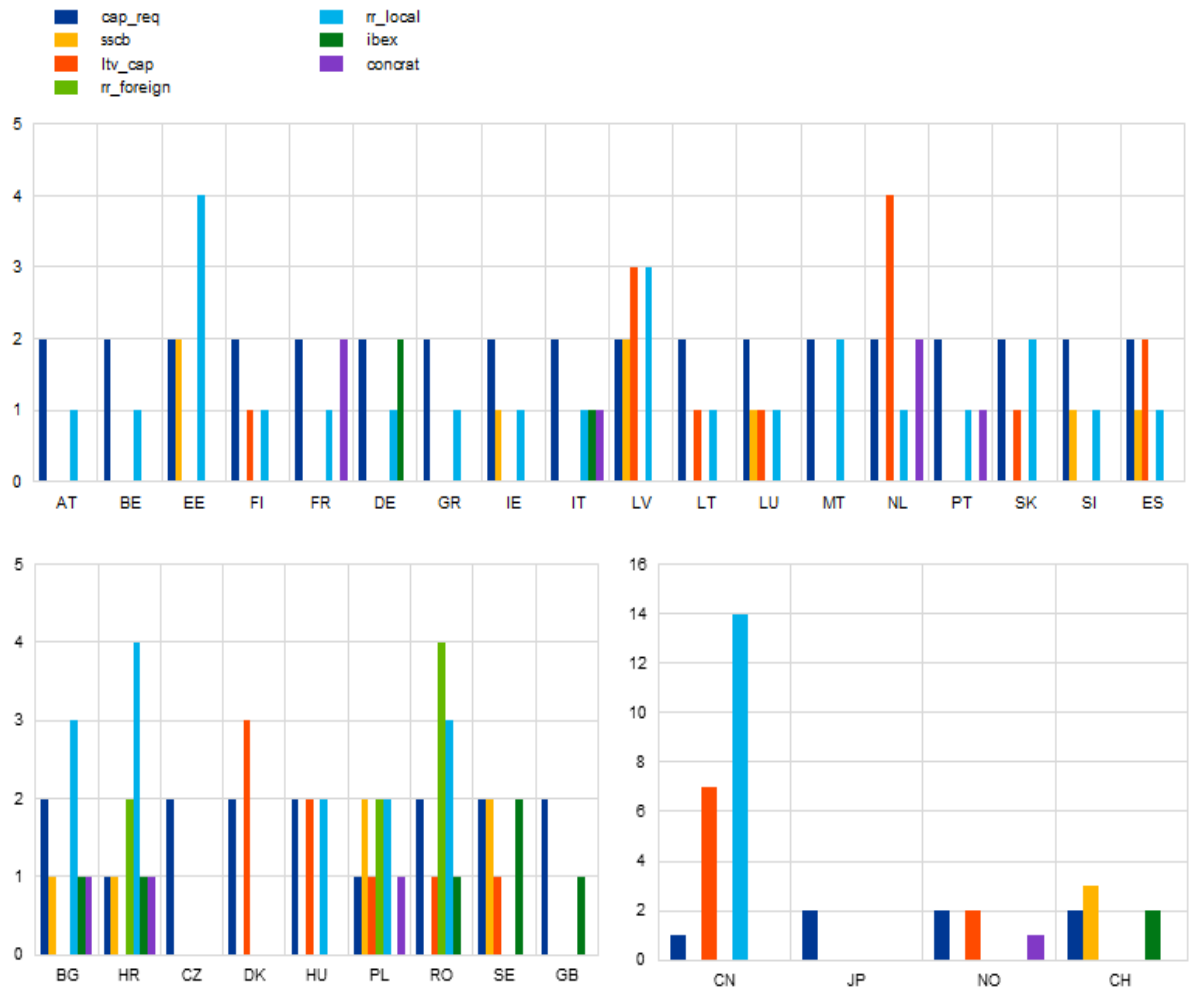
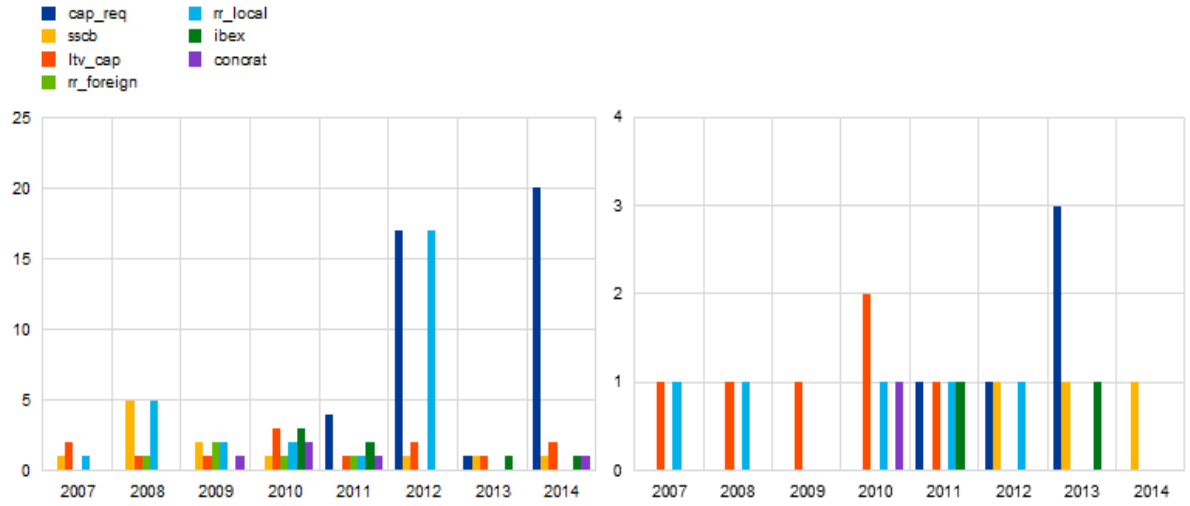


Figure 3: Time distribution of changes for prudential indices in EU countries (left panel) and non-EU countries (right panel) used in the estimation samples



4 Regression models and results

4.1 Regression models

The first inward transmission operates via the adjustments of the balance sheet of domestic banks through foreign exposures. To capture the foreign prudential policy impact on domestic banks we use lender-exposure weights as defined by matrices $\mathbf{W}_t$. In this way we measure exposure-weighted inward transmission of foreign prudential regulation on domestic banks.

We begin with the baseline specification:

$$\Delta ln(Y^d_{b,t}) = \alpha_0 + \sum_{l=0}^{2} \alpha_{l+1} EP_{j,t-l} + \alpha'_4 \cdot X^d_{b,t-1} + \alpha'_5 \cdot EZ_{j,t} + f_j + f^d_b + f_t + \epsilon^d_{b,t} \qquad (1)$$

where $\Delta ln(Y^d_{b,t})$ is the log change in total lending of domestic bank b at time t, α_0 is a constant representing the mean growth rate of lending by domestic banks when all other variables are zero, $X^d_{b,t-1} = \{ln(TA^d_{b,t-1}), CR^d_{b,t-1}, IAR^d_{b,t-1}, DR^d_{b,t-1}\}'$ is a vector of bank

control variables that captures the ex-ante balance sheet composition of domestic banks, $EZ_{j,t} = \{EFC_{j,t}, EBC_{j,t}\}'$ represents a vector of weighted financial and business cycles for country j, f_j are domestic country fixed effects to separate the effects of prudential regulation from common shocks at the country level, f_b^d are domestic bank fixed effects to capture all unobserved time-invariant cross-sectional factors that may influence lending growth from these banks, f_t are time fixed effect to control common (across banks) shocks in each time period which might affect the outcome variable and $\epsilon_{b,t}^d$ is a (domestic) bank-specific noise. The prudential policy changes are captured by EP, exposure-weighted changes in regulation recorded outside (but within the EU perimeter) the domestic economy.

This specification has the goal to assess the temporary cross-border impact of foreign prudential regulation by including indices in changes.

For the second channel, i.e. the inward transmission of home prudential policy via foreign branches, we estimate the following specification:

$$\Delta ln(Y_{b,t}^{br}) = \beta_0 + \sum_{l=0}^{2} \beta_{l+1} HP_{i,t-l} + \beta_4' \cdot X_{b,t-1}^{br} + \beta_5' \cdot Z_{i,t} + f_b^{br} + f_t + \epsilon_{b,t}^{br} \qquad (2)$$

where $\Delta ln(Y_{b,t}^{f})$ is the log change in total lending of foreign bank b at time t, β_0 is a constant representing the mean growth rate of lending by foreign banks when all other variables are zero, $X_{b,t-1}^{br} = \{ln(TA_{b,t-1}^{br}), CR_{b,t-1}^{br}, IAR_{b,t-1}^{br}, DR_{b,t-1}^{br}\}'$ is a vector of bank control variables that captures the ex-ante balance sheet composition of foreign banks, $Z_{i,t} = \{FC_{i,t}, BC_{i,t}\}'$ represents a vector of financial and business cycles for country i, the home country of the respective parent banks of the foreign affiliates, f_b^{br} are foreign bank fixed effects to capture all unobserved time-invariant cross-sectional factors that may influence lending growth from these banks, f_t are defined as before and $\epsilon_{b,t}^{br}$ is a (foreign) bank-specific error. The prudential policy changes are captured by HP, changes in regulation recorded in the home (EU and non-EU) countries.

Consistently with the first channel, this specification aims to assess the temporary cross-

border impact of prudential regulation implemented in the home countries by including indices in changes.

In all specifications we include quarterly dummy variables to control for seasonality.

The use of individual bank data from different countries is crucial for our identification of causal effects from policy instruments. In addition to ensuring the control of unobserved heterogeneity, the granularity of micro-level data makes the assumption about the exogeneity of the aggregate country-level policy changes to the individual bank reactions more plausible. Moreover, the cross-country nature of our study further strengthens our exogeneity hypothesis, as prudential policy changes in one country are likely to be exogenous to loans extended by banks with headquarters in other countries.

To rule out any potentially spurious inference, e.g. as may be introduced by non-stationarity of total assets, we carry out preliminary panel unit root tests on the residuals extracted from our baseline regressions. By using Fisher-type tests (both their augmented Dickey-Fuller and Phillips-Perron variants), we find that the null hypothesis that all panels contain unit roots is always rejected. Therefore we can rely on our specifications, in line with Buch and Goldberg (2017).

For both channels, we estimate the parameters of the equations by using the two-way least square dummy variable (LSDV) estimator. This is equivalent to use a two-way fixed effect (FE) estimator where the unobserved heterogeneity (f_b^d and f_b^{br}) is assumed to be potentially correlated with the control variables, i.e. endogenous. In doing so, we cluster standard errors by country to relax the strict $\epsilon_{b,t} \sim iid$ hypothesis and account for potential heteroscedasticity and correlation among banks belonging to the same country (Cameron and Miller (2015)).

Table 1A describes how the variables were constructed and which acronyms we used in the results tables. Table 1B provides the summary statistics for the dependent variable and for bank characteristics. Finally, Table 2 reports the summary statistics on prudential instruments.

4.2 Results

Before presenting the results reported in the Annex by transmission channel and by model specification, we emphasize that since the IBRN database simply reports episodes of tightening or loosening of prudential instruments, it is not possible to quantify their average magnitude. Hence, the magnitude of the parameters cannot be properly benchmarked. Nevertheless, we can still report the magnitude of cross-border effects of a tightening or loosening for any specific instrument on lending growth by euro-area banks, which should be interpreted as an average reaction to a tightening or loosening of an average magnitude by individual instruments.

Bearing in mind this caveat, considering the inward transmission of exposure-weighted regulation, we find that euro-area domestic banks reduce on average lending by about 5.2% with a two-quarter lag after the exposure-weighted tightening of capital requirements in foreign EU countries (equation (1), Table 3).[15] On the contrary, when LTV limits or reserve requirements are tightened, euro-area domestic banks tend, on average, to increase their lending, by 3.9% and 5.9%, respectively. The former finding is substantiated by a joint test of significance of the sum of the contemporaneous term and two lags' coefficients, which suggests that the cut-cumulative index is significant.[16] These findings are consistent with Bonfim and Costa (2017), who find that tightening of capital requirements abroad decrease growth of domestic credit in Portugal. They are also consistent with Ohls et al. (2017), who find that German banks increase domestic lending in response to the tightening of foreign LTV regulation.

These findings are broadly confirmed when considering the specification with interactions (equation (**??**), Table 4). Specifically, the effects are mostly absorbed by the coefficients on the interactions. The impact of LTV regulation is significant when interacting this variable with banks' size and capitalisation, while the impact of reserve requirements regulation

[15] Since the prudential variable is not log-transformed, while the dependent variable is in log differences multiplied by 100, a coefficient of about -5.36 implies that, on average, lending decreases by around 5.2%, as $e^{(-5.36/100)} - 1 = -0.052$, when the prudential index is tightened by one unit.

[16] With "cut-cumulative" indices we mean $EP_{cum2,j,t}$ and $HP_{cum2,i,t}$ in Tables 3, 4 and 5, i.e. the cumulative indices cut at the second lag.

is significant when interacting this variable with banks' capitalisation. This seems to support the portfolio rebalancing hypothesis, a course of action which is more likely to be followed by larger banks, although the role of capitalisation seems to be ambiguous (negative coefficient for LTV cap, positive for reserve requirements). Furthermore, in this specification, sector-specific capital buffers also tend to lead to an absolute increase in lending, similarly to the case of other requirements that put breaks on lending in specific jurisdictions. This effect is reinforced through the interaction with bank capital ratios, suggesting that banks with higher capital ratios increase their lending to an even larger extent. On the other hand, less liquid banks tend to reduce more their lending when capital requirements are tightened. In a similar vein, Avdjiev et al. (2017) find that better capitalised banking systems reinforce international spillovers from prudential instruments.

Turning to the second channel, which operates via the foreign affiliates' lending behavior, we also find that tightening of locational measures, namely sector-specific capital buffers, LTV cap and local reserve requirements leads to a lending surge of 5.3%, 3.9% and 3.9%, after a two-quarter lag, respectively (equation (2), Table 5). This is also confirmed for sector-specific capital buffers by the joint test of significance of the sum of the contemporaneous term and two lags' coefficients, which suggests that the cut-cumulative index is significant at the 5% level. This means that parent banks tend to shift their lending to their foreign affiliates after the tightening of home locational prudential measures, speaking for cross-border leakages from these instruments. The finding for LTV cap is consistent with Bonfim and Costa (2017) and Hills et al. (2017), who find that foreign banks operating in Portugal and the UK, respectively, increase credit after the tightening of LTV ratios abroad. The same result is also in line with Berrospide et al. (2017), who find that tightening of local reserve requirements leads to an increase in lending growth by foreign banks operating in the US. Changes of capital requirements in home economies do not seem to affect lending of foreign affiliates, as capital requirements restrict the entire balance sheet of the consolidated group, irrespective of the location of operations.

Taken together, these findings suggest that euro-area domestic banks react to stricter

capital requirements abroad by reducing total lending (including domestic). As measures operating at the consolidated level, such as capital requirements, are hard to circumvent, the tightening of capital requirements affects the entire consolidated balance sheet. Banks may also rebalance their cross-border portfolios in response to the tighter capital requirements abroad in favor of their foreign branches residing in the jurisdiction where regulation has become more stringent (Aiyar et al., 2014b; Reinhardt and Sowerbutts, 2015). Instead, when locational prudential instruments are implemented, they seem to encourage banks to increase lending in other jurisdictions, by rebalancing their lending portfolio in view of the changes in the relative capital-intensity of lending, in terms of the capital needed to hold certain exposures.

4.3 Robustness checks

We perform a series of robustness checks to test if our results hold under different assumptions. They include sensitivity analyses with respect to the dependent variable, the weighting scheme of cross-border linkages and various combinations of these two dimensions. In particular, we decompose the baseline response variable, total loans, across two dimensions: we split the series into foreign and domestic loans and into loans to financial sector and loans to non-financial sector. The latter allows us to rule out a potential contamination of our results with interbank lending (from parents to affiliates). We also vary the weighting scheme and consider a baseline dynamic form, a static form and, similarly to Hills et al. (2017), the one based on a four-quarter average of exposures prior to the regulatory change. These alternative weighting schemes aim at minimizing a bias from a plausible relation between exposures and policy changes.

More specifically, we use the following variations of the baseline specifications: total loans (growth) as a dependent variable with static lender-exposure weights, i.e. we use the same average weights across time (subscript: St); total loans as a dependent variable and the lender-exposure weights are computed as the average of the four quarters prior to the policy change (A); domestic loans as a dependent variable and dynamic weighting,

i.e. the lender-exposure weights are different for each time period (D); domestic loans as a dependent variable and static lender-exposure weights (DS); domestic loans as a dependent variable and the lender-exposure weights are computed as the average of the four quarters prior to the policy change (DA).

Furthermore, in order to highlight differences in the transmission channels, we run also all regressions using loans to financial companies (F) and loans to non-financial companies (NF) as dependent variables.

Concerning the first, domestic channel our finding that euro-area domestic banks reduce lending after the tightening of foreign capital requirements is confirmed when we replace total loans with domestic loans as response variable (Table 3). This strengthens our result and suggests that euro-area domestic banks restrict in particular their domestic lending after a tightening of capital requirements abroad. However, this finding is not confirmed by the other robustness checks. The results that when LTV cap are tightened euro-area domestic banks tend to increase their lending is confirmed when we employ a static exposure weighting scheme and loans to non-financial sector as a response variable. In other words, when we assume that linkages have not changed over the sample period or we focus on lending to the real sector, i.e. households or corporations, we find again that euro-area domestic banks increase their lending after an LTV cap tightening abroad. The case of loans to non-financial sector as a dependent variable is especially worth pointing out: the fact that the results hold even when we exclude loans to financial companies from the response variable rules out any possibility for contamination of the estimates due to the transfer of resources from parents to affiliates abroad in order to accommodate the shock.

Other robustness checks do not seem to confirm these findings. For instance, this finding is not confirmed for specifications with loans to financial sector as a dependent variable, but this reinforces our hypothesis. In other words, the lack of relation for that dependent variable means that the increase in lending by domestic banks following the LTV cap tightening abroad is a result of an increase of lending to the real sector and not to other banks.

When we consider interactions (Table 4), the findings on locational instruments, such as the LTV cap, are broadly confirmed when we split the dependent variable into loans to financial and non-financial sector. When we use this distinction, the impact of LTV cap is again significant when interacting it with the banks' size and capitalization. Larger euro-area domestic banks seem to increase lending to financial sector by more after a foreign tightening of LTV cap, while better capitalized euro area domestic banks seem to decrease lending to non-financial sector by more after the same policy innovation. Capitalization plays the same role in case of reserve requirements, meaning that euro area well-capitalized domestic banks decrease lending to non-financial sector by more after a foreign tightening of this instrument, in contrast to the case of total loans as dependent variable. The share of deposits plays instead a role for reserve requirements only, as banks with higher quota of deposits increase their lending to the financial sector by a larger extent after a policy change in that instrument abroad. Furthermore, when including interactions, sector-specific capital buffers lead to an absolute increase in domestic lending. This generally confirms our result for total loans as response variable, although, when using a static weighting scheme, this increase is partly compensated by a relative (through the interaction with capitalization) decrease in domestic lending.

Turning to the second channel, we also find that a tightening of locational measures, namely sector-specific capital buffers, LTV cap and local reserve requirements leads to a lending surge in case of loans to the financial sector (sector-specific capital buffers) and loans to non-financial sector (reserve requirements), confirming cross-border leakages from these instruments (Table 5). The fact that the results hold for the financial sector in case of *sscb*, too, strengthens our point on leakages. If these leakages where to happen, the funds must be transferred across borders to the subsidiaries and branches or *vice versa* through the interbank loans. Changes of capital requirements in home economies is in general confirmed not to affect lending of foreign affiliates, as capital requirements bind the entire balance sheet of the consolidated group, irrespective of the location of operations.

All in all, our findings are confirmed to a large extent by a number of robustness checks.

5 Conclusion

Using a panel of 248 euro area banks, we find evidence for inward cross-border spillovers from capital regulation (capital requirements and sector-specific capital buffers), liquidity measures (reserve requirements) and borrower-based measures (LTV limits), along the two channels of transmission.

Concerning the first channel, via changes of lending by domestic banks in reaction to changes in the prudential policy abroad, we find that euro-area domestic banks reduce on average lending following the exposure-weighted tightening of capital requirements in foreign EU countries. We also find that domestic banks increase their lending when facing tightened LTV limits or reserve requirements abroad.

Turning to the second channel, which operates via changes in lending of foreign affiliates, we find that foreign subsidiaries and branches increase lending when sector-specific capital buffers, LTV limits and local reserve requirements are tightened in the home countries where their parents reside. These findings speak for leakages from these instruments, which operate via foreign affiliates.

Taken together, these findings suggest that the sign of cross-border spillovers, i.e. whether the tightening of the instrument abroad/in the home country leads to an increase or decrease in bank lending is instrument-specific. It appears that instruments directed toward specific borrowers/sectors, such as LTV limits or sector-specific capital buffers, or acting locally, such as reserve requirements, are prone to negative cross-border spillovers, while tightening of tools which act at the consolidated level, such as capital requirements, exerts positive spillovers, i.e. it leads to a decrease in lending also abroad.

We also find that bank characteristics play a role in the propagation of cross-border spillovers for the first channel. In particular, we find that euro-area domestic banks which are less liquid reduce more their lending when the exposure weighted capital requirements are tightened. We also find that tighter LTV limits abroad are likely to lead larger euro-area banks (as measured by total assets) to increase lending more than other banks.

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A Annex

Table 1A: Construction of variables

Variable Name	**Description**	**Data Source**
TL	Loans_GG + Loans_HH + Loans_NFC_st + Loans_NFC_lt + Loans_OFI + Loans_MFI	Monthly BSI locational statistics (ECB)
IAR	Total Loans / Total Assets (in %)	Monthly BSI locational statistics (ECB)
TA	Total Assets	Monthly BSI locational statistics (ECB)
DR	(Dep_HH_st + Dep_HH_lt + Dep_NFC_st + Dep_NFC_lt + Dep_GG) / Total Liabilities (in %)	Monthly BSI locational statistics (ECB)
CR	(Capital + Reserves) / Total Assets (in %)	Monthly BSI locational statistics (ECB)
FC	Financial cycle indicator	BIS (2014) and Borio et al. (2012)
BC	Business cycle indicator	BIS (2014) and Borio et al. (2012)

Table 1B: Summary statistics on bank lending and bank characteristics

	All (N_b = 248, # obs = 7440)			**Domestic** ($N_{b,t}$ = 167, # obs = 4867)			**Foreign** ($N_{b,t}$ = 62, # obs = 1823)		
Variables	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Δ ln(Y)	0.26	0.19	8.52	0.37	0.2	8.50	-0.10	0.02	8.50
ln(TA)	10.41	10.51	1.47	10.74	10.78	1.36	9.79	9.858	1.434
CR(%)	7.94	6.373	13.95	7.691	6.32	6.15	7.08	5.02	26.60
IAR(%)	68.09	68.76	14.43	67.94	68.73	14.10	69.19	68.08	17.11
DR(%)	34.86	33.98	19.64	32.56	33.08	19.78	30.97	28.35	13.81

Notes: This table provides summary statistics for bank variables used in the estimation. Bank data comes from the BSI statistics (ECB) and are observed monthly, but reported on a quarterly basis, 2007Q3-2014Q4. Total number of banks and observations do not add up to the reported totals due to some banks changing ownership (domestic versus foreign) over the observed period, and missing details for a smaller set of banks. All regressions are run on observations where ownership information could be retrieved.

Table 2: Summary statistics on changes in prudential instruments

Domestic channel	**Base (country-time)**				**Exp-weighted (country-time)**				**Exp-weighted (bank-time)**			
Instrument	C	T	L	QNZ	C	T	L	QNZ	C	T	L	QNZ
PruC	119	81	38	0.15	667	407	260	0.82	4,720	2,882	1,898	0.84
cap_req	52	52	0	0.06	207	207	0	0.26	1,396	1,396	0	0.25
sscb	14	9	5	0.02	211	155	56	0.26	1,545	1,158	387	0.28
ltv_cap	21	14	7	0.03	353	231	122	0.44	2,544	1,629	915	0.45
rr_foreign	8	2	6	0.01	155	46	109	0.19	1,187	322	865	0.21
rr_local	39	5	34	0.05	344	67	277	0.42	2,462	461	2,001	0.44
ibex	9	8	1	0.01	138	122	16	0.17	936	846	90	0.17
concrat	9	8	1	0.01	175	149	26	0.22	1,134	948	186	0.2
Foreign channel	**Base (host country-time)**				**Home (country-time)**				**Home (bank-time)**			
Instrument	C	T	L	QNZ	C	T	L	QNZ	C	T	L	QNZ
PruC	82	49	33	0.09	96	74	22	0.07	338	265	73	0.12
cap_req	32	32	0	0.03	45	45	0	0.03	176	176	0	0.06
sscb	8	6	2	0.01	11	9	2	0.01	36	30	6	0.01
ltv_cap	10	7	3	0.01	22	16	6	0.02	74	51	23	0.01
rr_foreign	2	1	1	0	0	0	0	0	0	0	0	0
rr_local	45	6	39	0.05	35	10	25	0.03	117	21	96	0.04
ibex	5	5	0	0.01	8	8	0	0.01	37	37	0	0.01
concrat	8	8	0	0.01	7	7	0	0.01	34	34	0	0.01

Notes: This and the following tables show summary statistics on changes in prudential instruments for banks located in the EU less Cyprus (first channel) and EA countries plus China, Japan, Norway and Switzerland (second channel), both over the period 2007Q3-2014Q4. Data on the seven instruments come from the IBRN and are on the quarter-level. The number of changes in prudential instruments is reported on several dimensions, i.e. on the country-time and bank-time level. The last sub-column of each main column shows the share of prudential policy changes to total observations (i.e. the share of nonzero observations, QNZ). The columns Exp-weighted and Home are composed of counts computed after the respective transformation rules used in the two channels. C, T and L stand for number of changes, tightening and loosening, respectively. The reported data is based on the regression samples.

Table 3: Inward transmission of EU country exposure-weighted policy to domestic banks

$\Delta \ln(Y^d_{b,t})$	(1)	(2)	(3)	(4)
	Cap_req	Sscb	Ltv_cap	Rr_local
$EP_{j,t}$	-0.077	2.004	3.796**	5.792**
	(2.653)	(1.301)	(1.616)	(2.380)
$EP_{j,t-1}$	1.806	-2.113	1.646	1.229
	(1.901)	(1.996)	(3.520)	(3.345)
$EP_{j,t-2}$	-5.534**	1.366	5.572	0.868
	(2.086)	(2.407)	(4.574)	(1.704)
$EP_{cum2,j,t}$	-3.804	1.258	11.014*	7.890
	0.657	0.204	3.503	1.847
$ln(TA)_{b,t-1}$	-12.13***	-12.08***	-12.16***	-11.88***
	(1.483)	(1.486)	(1.469)	(1.397)
$CR_{b,t-1}$	-0.345**	-0.354**	-0.345**	-0.356**
	(0.154)	(0.159)	(0.155)	(0.152)
$IAR_{b,t-1}$	-0.325***	-0.330***	-0.326***	-0.333***
	(0.086)	(0.085)	(0.085)	(0.082)
$DR_{b,t-1}$	0.154*	0.156*	0.152*	0.162*
	(0.073)	(0.074)	(0.073)	(0.073)
Country controls	Y	Y	Y	Y
Country FE	Y	Y	Y	Y
Bank FE	Y	Y	Y	Y
Time FE	Y	Y	Y	Y
Seasonal dummies	Y	Y	Y	Y
Observations	1,701	1,701	1,701	1,701
Adjusted R^2	0.078	0.078	0.077	0.078
Clusters	11	11	11	11

Notes: This table reports the effects of changes in prudential regulation and bank characteristics on log changes in total loans. The quarterly data range from 2007Q3 to 2014Q4 for a panel of domestic banks. Foreign exposure-weighted regulation $EP_{j,t-l}$, l=$\{0,1,2\}$ is calculated as the weighted average of changes in foreign regulation, where the weights are based on bilateral exposures of 27 EU countries. For $EP_{cum2,j,t}$, the reported coefficient is the sum of the contemporaneous term and two lags' coefficients, with the corresponding F-statistics for joint significance below. Bank controls include: $ln(TA^d_{b,t-1})$, $CR^d_{b,t-1}$, $IAR^d_{b,t-1}$, $DR^d_{b,t-1}$. For more details on the variables' construction and their acronyms see Table 1A. Country controls include: . Each column gives the result for the regulatory measure specified in the column headline. All specifications include domestic country, time and bank fixed effects and seasonal dummies. Standard errors (in parenthesis) are clustered by country. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 5: Inward transmission of home-country policy to foreign branches

$\Delta \ln(Y^{br}_{b,t})$	(1) Cap_req	(2) Sscb	(3) Ltv_cap	(4) Rr_local
$HP_{i,t}$	-2.171	2.714	6.630	4.504
	(1.247)	(2.502)	(3.789)	(2.752)
$HP_{i,t-1}$	-2.426	4.185	5.188	3.333
	(1.324)	(3.715)	(3.103)	(2.842)
$HP_{i,t-2}$	2.169	4.180**	10.56**	3.660**
	(3.423)	(1.515)	(3.814)	(1.467)
$HP_{cum2,i,t}$	-2.428	11.079**	22.378***	11.497*
	0.333	8.059	20.31	5.200
$ln(TA)_{b,t-1}$	4.558	5.532	5.707	3.047
	(2.951)	(3.228)	(2.969)	(2.469)
$CR_{b,t-1}$	0.102	0.071	0.151	0.011
	(0.432)	(0.414)	(0.418)	(0.412)
$IAR_{b,t-1}$	-0.218	-0.219	-0.214	-0.225
	(0.197)	(0.195)	(0.186)	(0.207)
$DR_{b,t-1}$	0.036	0.023	0.070	0.053
	(0.221)	(0.235)	(0.221)	(0.237)
Country controls	Y	Y	Y	Y
Country FE	N	N	N	N
Bank FE	Y	Y	Y	Y
Time FE	Y	Y	Y	Y
Seasonal dummies	Y	Y	Y	Y
Observations	333	333	333	333
Adjusted R^2	0.096	0.092	0.101	0.097
Clusters	7	7	7	7

Notes: This table reports the effects of changes in the parent countries' regulation and bank characteristics on log changes in total loans. The data are reported on quarterly basis and range from 2007Q3 to 2014Q4 for a panel of foreign-owned banks. $HP_{i,t-1}$, 1=0,1,2, refers to the changes in regulation in the home (i.e. parent bank) countries of foreign branches and in the host countries of foreign subsidiaries. For $HP_{cum2,j,t}$, the reported coefficient is the sum of the contemporaneous term and two lags' coefficients, with the corresponding F-statistics for joint significance below. Bank controls include: $ln(TA^{f}_{b,t-1})$, $CR^{f}_{b,t-1}$, $IAR^{f}_{b,t-1}$, $DR^{f}_{b,t-1}$. Macro controls include: $FC_{i,t}, BC_{i,t}$. For more details on the variables' construction and their acronyms see Table 1A. Each column gives the result for the regulatory measure specified in the column headline. Standard errors (in parenthesis) are clustered by country. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 6: Inward transmission of EU country exposure-weighted policy to domestic banks

$\Delta \ln(Y_{b,t}^{d,domesticlending})$	(1)	(2)	(3)	(4)
	Cap_req	Sscb	Ltv_cap	Rr_local
$EP_{j,t}$	0.127	2.475	5.994	5.099
	(2.729)	(1.410)	(4.030)	(3.439)
$EP_{j,t-1}$	1.389	-3.899	0.052	4.111
	(2.165)	(2.964)	(4.312)	(3.707)
$EP_{j,t-2}$	-6.067**	1.761	2.781	4.794*
	(1.919)	(2.576)	(6.502)	(2.517)
$EP_{cum2,j,t}$	-4.552	0.336	8.827	14.004
	0.708	0.008	0.893	3.298
Bank controls	Y	Y	Y	Y
Country controls	Y	Y	Y	Y
Country FE	Y	Y	Y	Y
Bank FE	Y	Y	Y	Y
Time FE	Y	Y	Y	Y
Seasonal dummies	Y	Y	Y	Y
Observations	1,614	1,614	1,614	1,614
Adjusted R^2	0.090	0.091	0.089	0.091
Clusters	10	10	10	10

Notes: This table reports the effects of changes in prudential regulation and bank characteristics on log changes in domestic loans. The quarterly data range from 2007Q3 to 2014Q4 for a panel of domestic banks. Foreign exposure-weighted regulation $EP_{j,t-l}$, l={0,1,2} is calculated as the weighted average of changes in foreign regulation, where the weights are based on bilateral exposures of 27 EU countries. For $EP_{cum2,j,t}$, the reported coefficient is the sum of the contemporaneous term and two lags' coefficients, with the corresponding F-statistics for joint significance below. Bank controls include: $ln(TA_{b,t-1}^{d})$, $CR_{b,t-1}^{d}$, $IAR_{b,t-1}^{d}$, $DR_{b,t-1}^{d}$. For more details on the variables' construction and their acronyms see Table 1A. Country controls include: . Each column gives the result for the regulatory measure specified in the column headline. All specifications include domestic country, time and bank fixed effects and seasonal dummies. Standard errors (in parenthesis) are clustered by country. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.