4. THE IMPACT AND EFFECTIVENESS OF MACROPRUDENTIAL CAPITAL BUFFERS: EVIDENCE FROM LUXEMBOURG

Boubacar Diallo[144]

ABSTRACT

In this contribution, we examine several key questions such as: How effective are macroprudential capital buffers in Luxembourg? What are their effects on bank lending, risk-taking and efficiency in Luxembourg, if any? To answer these questions, we use the introduction of the capital conservation buffer (CCoB) and the other systematically important institutions (O-SII) capital buffer to investigate their individual effects on the relevant banks' total lending, mortgage lending, lending to non-financial corporations, lending to households and inter-bank lending activities. We also assess the effects of these buffers on banks' risk-taking and efficiency. Applying the difference-in-differences (DID) methodology to an unbalanced panel of 141 banks in Luxembourg over the period 2011-2018, we find the following results. The O-SII capital buffers decreased total lending and boosted bank soundness, as measured by the z-score; as well as bank efficiency. However, our results also suggest that the introduction of the CCoB in Luxembourg did not have any significant effect on lending. Robustness checks using several resampling approaches and the propensity score matching (PSM) suggest that the findings are corroborated.

INTRODUCTION

Macroprudential capital buffers are intended to increase bank resilience thereby allowing banks to absorb losses while maintaining the smooth supply of credit to the economy during crisis periods. On the research side, Cerutti *et al.* (2017), Jiminez *et al.* (2017), Altunbas *et al.* (2018), Cizel *et al.* (2019), Fraisse *et al.* (2020) among others, have published papers on the effectiveness of macroprudential policies with respect to both capital buffers and borrower-based measures at the country, regional and monetary union levels. However, experience with assessing their effects on different types of lending, bank soundness and efficiency remains limited. Therefore, the main goal of this contribution is to address this gap by providing answers to the following questions. What are the effects of macroprudential capital buffers in Luxembourg and what are their more specific effects on bank lending, risk-taking and efficiency? To answer these questions, we use the introduction of the capital conservation buffer (CCoB) and other systematically important institutions (O-SII) capital buffer and assess their effects on total lending, mortgage lending, lending to non-financial corporations households and other banks. In addition, we examine their potential effect on risk-taking and bank efficiency using an unbalanced panel of 141 banks over the period 2011-2018.

In Luxembourg, the capital conservation buffer (CCoB) and the other-systematically important institutions (O-SII) capital buffer were implemented in 2014 and 2016, respectively. The primary objective of the CCoB is to ensure that banks have sufficient capital to draw on in the event that they incur losses. This buffer helps to ensure that banks are able to avoid breaches of the minimum capital requirement because if a bank breaches the buffer it is subject to automatic restrictions on the amount of dividend and bonus payments.

144 Financial Stability Department, Banque centrale du Luxembourg.

In Luxembourg, the CCoB has been effective as of January 1, 2014 when it was set at 2.5 percent of Common Equity Tier 1 (CET1).[145] However, there is an exception from these requirements for small and medium-sized investment firms. Small and medium-sized investment firms are defined as those with a number of employees fewer than 250 persons, which have an annual income not exceeding 50 million euros or a total annual balance sheet not exceeding 43 million euros. In the analysis that follows, we exploit this heterogeneity and measure the ex-post effects of the CCoB on bank lending, risk-taking and efficiency.

The European regulation also foresees the activation of O-SII capital buffers in order to address the negative externalities associated with the failure of a systemically relevant bank and to protect the economy as a whole. According to the European Banking Authority (EBA), O-SIIs are institutions that are most likely to create risks and financial instability because of their systemic importance. In their search to maximize private benefits, these institutions may impose negative externalities on the banking sector and contribute to market failures. In following with the EBA guidelines, the O-SII capital buffers are calculated using a scoring method based on size, importance, complexity and interconnectedness in Luxembourg. The O-SII buffer rates were first effective on January 1, 2016. The Central Bank of Luxembourg (BCL) also applies an extended methodology to identify O-SIIs that may have important interconnections with the investment fund sector. The extended methodology complements the EBA approach and calculates scores that take into account the importance of a given bank in relation to its interlinkages with the Luxembourg investment fund sector.

Using the difference-in-differences (DID) empirical methodology we find that the introduction of the O-SII capital buffers decreased total lending for banks operating in Luxembourg. More precisely, the O-SII capital buffer decreased the total loan growth rate by roughly 20 percentage points over the period 2011-2018 (during which the CCoB was activated in 2014 and the O-SII buffer in 2016) compared to a scenario with no O-SII buffers. However, applying the same methodology to the implementation of the CCoB requirements suggests that the CCoB has not had any significant effect on bank lending. Importantly, O-SII capital buffers also increased bank soundness, as measured by the z-score, and bank efficiency. These results hold in the presence of several robustness tests to account for selection bias issues.

Our study is motivated by several strands of the literature on macroprudential policy. First, many papers in the literature have focused on the effects of capital requirements on lending. Using a panel data set covering 2800 banks across 48 countries over the period 2000-2010, Claessens *et al.* (2013) investigate the effectiveness of macroprudential policies on banks' balance sheets. Taking into account endogeneity concerns, they showed that, as macroprudential tools, borrower-based measures have a significant but limited impact on credit growth. In similar work, De Jonghe *et al.* (2020) look at how time-varying bank capital requirements affect balance sheet adjustments and lending standards for the non-financial corporate sector. Additionally, Fraisse *et al.* (2020) analyze the effect of bank capital requirements on firms' borrowing and investment, finding that a one percentage point increase in capital requirements reduces lending by 10 percent. However, bank capital requirements did not affect consumer loans.

Using the countercyclical capital buffer (CCyB) introduced in Switzerland in 2012, Auer and Ongena (2019) study the effects of macroprudential regulation on residential and commercial lending. Their findings suggest that the introduction of the CCyB for Swiss banks increased the growth in commercial lending for small firms. However, interest rates and fees charged to these small firms also increased. Conversely, in Spain, Jimenez *et al.* (2017) investigated the effects of provisioning and countercyclical

145 The implementation of the CCoB in Luxembourg is based on Article 59-5 of the Law of 5 April 1993 on the financial sector (LFS). The CCoB was activated in January 2014 and the exemption for small and medium-sized investment firms took place in 2015.

buffers on credit growth, finding little impact. Nevertheless, they found that countercyclical buffers help to reinforce the solvency of the banking sector. Gropp *et al.* (2018) identify the effect of higher capital requirements on firm lending, investment and growth using a difference-in-differences matching method. They use the 2011 European Bank Authority (EBA) capital exercise as well as the June 2011 stress test to assess the effect of these requirements in euro area countries. The objective of the stress test exercise was to ensure that banks had sufficient capital to insure against unexpected losses. They find that banks in the EBA sample increased their capital ratios by reducing their credit supply. In addition, the observed reduction in credit supply negatively affected investment and sales growth of firms.

With respect to the existing literature, our study adds several contributions compared to previous studies. First, it uses the implementation of the capital conservation and O-SII buffers in Luxembourg to assess the effectiveness of two macroprudential capital buffers, unlike previous studies. Second, it focuses specifically on Luxembourg, a financial center in which banks originating from different countries and in which a large continuum of business models operate. The results suggest that the O-SII buffer requirements result in a decrease in total lending growth over the period considered compared to a scenario in which no O-SII buffer was implemented.

Other studies look at how macroprudential policies can help to decrease bank risk-taking. For example, Altunbas *et al.* (2018) investigate the effects of macroprudential policies on bank risk-taking using a large panel of banking institutions operating in 61 advanced and emerging economies. Their findings suggest that macroprudential policies have a significant impact on bank risk-taking. Interestingly, the effects of these macroprudential policies on risk-taking depend on banks' characteristics, suggesting that small, weakly capitalized banks and institutions with important wholesale funding dependencies react more strongly to changes in macroprudential tools. Cappelletti *et al.* (2019) assess the impact of higher capital buffers on banks' risk-taking behavior in Europe. Using the EBA framework they study the effects of higher bank O-SII capital buffers on banks' lending and risk. Their results suggest that banks identified as O-SIIs reduced their credit supply to households and the banking sector in the short-term, and thereby shifted their lending to less risky counterparts within the non-financial corporate sector. Additionally, in the medium-term the soundness of O-SII banks increased. Lubello and Rouabah (2017) embedded a shadow-banking sector within a DSGE framework to investigate the effects of macroprudential policies on financial stability. They find that the introduction of capital requirements and caps to securitization are effective instruments for decreasing volatility in the financial system through the stabilization of output volatility. Our present research also looks at this question and estimates the effects of the CCoB and O-SII capital buffers on bank risk-taking measured by the z-score. Our results show strong and positive effects of the O-SII capital buffers on bank soundness. Consequently, unlike previous papers, we also investigate for the first time the effects of macroprudential policies on bank efficiency. These results also show consistent and positive effects of O-SII capital buffers in enhancing bank efficiency. This result is in contradiction with the findings of Curi *et al.* (2013) and Barth *et al.* (2013) who have both shown that strict banking regulation and supervision are negatively and significantly associated with bank efficiency.

Another strand of the literature in the effectiveness of macroprudential tools tries to disentangle their effects on lending according to a country's level of economic development. For instance, Cerutti *et al.* (2017) study the effects of several macroprudential tools on credit growth and house prices according to a country's level of economic development. More precisely, they define an aggregate measure of macroprudential instrument consisting of 12 specific tools from the Global Macroprudential Policy Instruments (GMPI) survey of the IMF. They find that macroprudential policies have significant mitigating effects on credit growth. However, these effects were much stronger for developing and emerging economies. Cizel *et al.* (2019), who showed that macroprudential instruments had a significant impact on bank credit growth in both advanced and emerging market economies, also obtained similar findings. In addition, they found some substitution effects for non-bank credit in advanced economies, thereby reducing the policies' effects on total credit. Lim *et al.* (2011), using a sample of 49 countries, find that macroprudential instruments reduced procyclicality. More specifically, macroprudential policies helped decrease the sensitivity of credit to GDP growth. Olszak *et al.* (2019) studied the effects of several macroprudential measures on bank lending for a sample of 60 countries, showing that macroprudential policies decrease the procyclical impact of capital and lending during both normal and bad times. Yet, the effects of these policies were stronger for larger banks. To alleviate concerns related to omitted variables issues, because of the observed heterogeneity across countries, focusing on a financial center such as Luxembourg allows us to obtain estimates that are not likely to suffer from this heterogeneity and measurement error given the absence of data issues such as different reporting requirements. More importantly, focusing on one country allows us to deal with the endogeneity related to national discretion as policymakers could use their supervisory judgment in implementing macroprudential tools as well as classifying a bank as an O-SII independent of its score.

On the effects of macroprudential policies in alleviating housing bubbles, Krznar and Morsink (2014) use Canadian data and find that the implementation of macroprudential policy tools decreases mortgage credit, and house price growth. Calem *et al.* (2017) analyze the effects of macroprudential policies on credit supply in the U.S., finding that the 2011 Comprehensive Capital Analysis and Review (CCAR) stress test had a negative effect on the share of jumbo mortgage originations and approval rates of banks participating in the stress test. They further found that banks with worse capital positions were more significantly and negatively impacted. Using a sample of 28 European countries over the period 1990-2018, Poghosyan (2019) investigated the effectiveness of lending restriction policies, namely loan-to-value (LTV) and debt-service-to-income ratios (DTI) on credit and house prices. The author found that, overall, lending restrictions have significant effects on credit and house prices. However, these effects are delayed and reached their peaks only after three years. Our results suggest that there was no specific impact of the CCoB or O-SII capital buffers on mortgage lending, thus validating the importance of implementing borrower-based macroprudential tools in order to address rising household indebtedness in relation to residential real estate vulnerabilities in Luxembourg.

In terms of data, Budnik and Kleibl (2018) built a new and comprehensive database on macroprudential policies for 28 EU countries over the period 1999-2014. This new database, named the Macroprudential Policies Evaluation Database (MaPPED), provides a detailed overview of the life-cycle of macroprudential policy tools, and classifies these instruments according to their macroprudential versus microprudential nature. Their findings indicate that capital buffers, lending restrictions and caps on maturity mismatches have significant impacts on the supply of credit to the non-financial private sector across EU countries.

Another line of research has recently suggested that there may be leakages associated with the effects of macroprudential policies. Ongena *et al.* (2013) are the first to show that tighter restrictions on bank activities and higher minimum capital requirements in domestic markets are associated with lower bank lending standards abroad. Aiyar *et al.* (2014b) and Reinhardt and Sowerbutts (2015) all show that the implementation of macroprudential tools by home authorities for domestic banks increases foreign borrowing. Precisely, Aiyar *et al.* (2014b) investigate the leakage effects of macroprudential policies in the U.K. They provide evidence that both types of regulated banks, i.e. UK-owned banks and foreign subsidiaries, decrease their lending in response to the introduction of macroprudential tools. However, unregulated banks, i.e. resident foreign branches, increase lending in response to tighter capital requirements. Still in the U.K., Danisewicz *et al.* (2017) studied the effects of cross-border spillovers of macroprudential measures on the organisational structure of banks' foreign affiliates. Their empirical results suggest that after a tightening of capital buffer requirements, branches of multinational banks reduce interbank lending growth by 6 percentage points relative to subsidiaries of the same banking group. However, there were no differences for non-bank lending. Interestingly, they found that a tightening in lending standards at home does not have differential effects on either interbank or non-bank lending in the U.K. This is in line with the findings of Cerutti *et al.* (2017) who provided some evidence on the effects of macroprudential policies on cross-border lending. Goodhart (2008) and the IMF also argue that increasing bank capital requirements may be associated with growth of the non-bank sector. In this study, to account for potential spillovers of macroprudential policies, we use data on foreign lending in the euro area by banks operating in Luxembourg. Our results do not show evidence for outward spillovers in lending.

The next section of this research deals with the identification methodology for O-SII banks. The remainder of this study is as follows. Section 2 presents the empirical approach. Sections 4 and 5 deal with the results and robustness tests, respectively. Finally, section 5 concludes and provides some potential guidance for decision-making.

O-SIIS IDENTIFICATION METHODOLOGY

The methodology in the EBA Guidelines allows the relevant authorities to identify O-SIIs and require each institution identified to maintain an O-SII buffer of up to 2 percent of the total risk exposure amount, consisting of Common Equity Tier 1 capital. The O-SII framework is based on a loss given default (LGD) approach, which is intended to reduce the negative externalities associated with the failure of a systemically important institution. In other words, it is intended to address losses in case of default and the scoring approach focuses on the various activities of banks rather than the amounts held. The Guidelines proposed by the EBA consist of a two-step identification process. During the first step, quantitative information on banks' size, interconnectedness, relevance for the economy and complexity are collected by the national authorities and classified in terms of scores that determine a bank's systemic importance.

Accordingly, banks scoring above a certain threshold (upper threshold) will be identified as O-SIIs, and those scoring below the threshold (lower threshold) will not be identified as OSIIs. In the second step, national authorities can still designate O-SIIs using their judgment. For example, judgment can be used to: (i) designate an institution as an O-SII (when appropriate) if its score is below the threshold , (ii) move a bank to a higher loss absorbency bracket (where appropriate), and (iii) remove a bank from the list (i.e. reverse previous judgment) if appropriate. The O-SIIs identification process in Luxembourg started in 2015 and repeats on an annual basis. The CET1 O-SII buffer requirement is reassessed on an annual basis.[146]

IDENTIFICATION STRATEGY

This section discusses the difference-in-differences (DID) econometric models. Because bank capital ratios and their capital levels prior to the implementation of macroprudential capital buffers might be correlated with other bank characteristics including lending, risk-taking and efficiency, we use the implementation of new macropudential tools in relation to pre-existing capital requirements to assess

146 For more details see the EBA score guidelines available at: https://eba.europa.eu/regulation-and-policy/own-funds/guidelines-on-criteria-to-to-assess-other-systemically-important-institutions-o-

their effects on bank lending, soundness and efficiency. First, we focus on the effects of the CCoB on banks in Luxembourg. More precisely, we define a dummy variable called Treat for treatment, which takes the value of 1 for all banks affected by the CCoB and 0 for small and medium-investment firms. We also define another dummy variable called Post that takes the value of 1 for the period following its implementation. One can now estimate the model as follows:

$$Bank\ Outcome_{i,t} = \beta_0 + \beta_1 Treat + \beta_2 Treat \times Post + X_{i,t-1} + \eta_t + \rho_i + \theta_i + \epsilon_{i,t} \qquad (1)$$

where *i,t* denote bank and period, respectively. The variable Bank Outcomeit consists of total, mortgage, non-financial corporation, household and bank loan growth rates; bank soundness i.e. insolvency and efficiency measured respectively by the z-score and the DEA approach[147] of bank *i* in period *t*. β_0 is the average of the outcome variable of the control group during the pre-treatment period. Therefore, this coefficient captures the average of the outcome variable for small and medium investment firms that are not affected by the CCoB. β_1 is the average of the outcome variable of the treatment group in the pre-treatment era minus the average of the outcome variable of the control group in the pre-treatment period. Put differently, *β*1 gives the coefficient of the mean difference in the outcome variable between the treatment and control groups prior to the implementation of the CCoB. β_2 is the average of the outcome variable of the control group in the post-treatment era minus the average of the outcome variable of the control group in the pre-treatment period. It is the expected mean change in the outcome variable from before to after the implementation of the CCoB implementation for the control group. β_3 is the coefficient of interest and is often called the DID estimate. It measures the true effect of the treatment and provides information on whether the expected mean change in the outcome variable from before to after the implementation of the CCoB is different in the two groups.

$X_{i,t-1}$ are lagged control variables at the bank and country levels consisting of bank size, capital and equity ratios, diversification, GDP and inflation. n_t controls for year-fixed effects, ρ_i and θ_i are banking business model and country of origin fixed effects, respectively. Banking business models are captured by six dummy variables, namely universal, retail and commercial banks, custodian and investment funds, private, corporate banking and others. In a similar vein, country of origin fixed-effects are measured by seven geographical dummy variables for Luxembourg, German, French, Swiss, Italian and Chinese and other segments, respectively.

Second, we follow the same approach as above and define two new dummy variables for the O-SII capital buffers. We define a dummy variable called "Treat" for treatment, which takes the value of 1 if a given bank is subject to an O-SII capital buffer in 2015, 2016, 2017 and 2018, respectively; and 0 otherwise. Since the O-SII capital buffers were effective as of January 1 2016, we define another dummy variable called "Post" that takes the value of 1 for the period following the intervention i.e. after 2015. The second econometric model is as follows:

$$Bank\ Outcome_{i,t} = \alpha_0 + \alpha_1 Treat \times Post + X_{i,t-1} + \eta_t + \rho_i + \theta_i + \epsilon_{i,t} \qquad (2)$$

Again, our coefficient of interest is α1, which measures the change in the outcomes of O-SII banks compared to other banks, conditional on a set of controls at the bank and country levels. With this model, one cannot add the single variables Treat and Post since the treatment takes the value of 1 when a bank is classified O-SII and only after the implementation of the policy. This suggests that the treatment occurs at different period of time, which leads to a variation in timing as argued by Goodman-Bacon (2018).

147 Diallo (2020) uses this approach to calculate bank efficiency for the Luxembourg banking sector.

Estimation method. To estimate equations (1) and (2), we use the population-averaged panel data model. This method fits generalized linear models and allows one to specify the within-group correlation structure for the panels. This technique deals with error correlations across individuals and groups due to the grouping of banking institutions. Furthermore, according to Bertrand *et al.* (2004) simple DID estimates and their standard errors generate many spurious correlations if one does not account for this serial correlation. In our case, we assume that the correlation structure follows an AR(1) process as in Bertrand *et al.* (2004). In order to get efficient estimates of the parameters of interest, we use the bias-corrected bootstrapped standard errors for statistical inference. More specifically, we use 1000 bootstrap replications to get the bias corrected estimates. The use of a large number of replications is motivated by the findings of Hall (1986) and Andrews and Buchinsky (2000, 2001) who showed that to obtain unconditional coverage probabilities of the estimates one needs to uses a large number of bootstrap repetitions.

Selection bias. Some challenges must be addressed before presenting the results of the DID technique. The most important one is the selection bias for the empirical specifications. The selection bias mostly refers to the fact that in order to be able to estimate the causal effects of macroprudential policies one must show that the evolution in the outcome variables for the treatment and control groups follow similar patterns before the changes occur. However, there is no specific econometric tool to test this assumption. Therefore, in our case we perform mean-comparison tests of the outcome variables, namely bank lending, soundness and efficiency before the implementation of the macroprudential tools. In terms of results, we do not find a statistically significant difference in the means of total, mortgage, non-financial corporation, household and bank lending, bank soundness and efficiency. For example, we find *p-values* of 0.197 and 0.846 for total lending using the CCoB and O-SII capital requirements, respectively. In addition, we employ two procedures to identify any potential concerns regarding the selection bias. The first approach to deal with the selection bias issue consists of using two resampling approaches. Moreover, we randomly construct the treatment group within banks in the sample and re-estimate the empirical models. Alternatively, since we have data on banks that are no longer operating in Luxembourg, we use these banks as a treatment group in the second robustness exercise and re-estimate the econometric model. The main idea is that we should find no effect if the selection bias is not a concern. Second, we follow the literature and use the propensity score matching approach. This approach allows us to match treated banks in relation to macroprudential policies with non-treated banks that may have a similar probability to be treated. Consequently, we compare pairs of banks that are exposed to a similar probability of being treated according to the buffers, respectively using bank-level characteristic variables. We match banks in the treatment group with banks in the control group based on the neighbor matching estimator with respect to several bank characteristics. Additionally, to control for changes in credit demand, our empirical strategies control for time, bank fixed-effects and GDP growth (Borio and Gambacorta (2017)). The inclusion of these effects permits us to take into account the demand-side bias and it increases the efficiency of the estimates

Data. The outcome variables consist of several types of annual loan growth rates, bank soundness and efficiency. We sequentially use the growth rates of total, mortgage, non-financial corporation, and household and bank loans, respectively. For bank soundness, we measure it using the z-score, which has been widely applied in the banking literature.[148] Specifically, it measures a bank's insolvency risk by taking the ratio between the sum of equity capital as a percent of assets and the return on assets and the standard deviation of the return on assets as a proxy for return volatility. Therefore, a higher z-score implies a lower probability of insolvency. Bank efficiency is calculated using the non-parametric Data

148 See for instance Boyd and Runkle (1993); Beck *et al.* (2007); Demirguc-Kunt *et al.* (2008); Laeven and Levine (2009), Cihak and Hesse (2010) and Diallo and Al-Mansour (2017).

Envelopment Analysis (DEA) method.[149] Besides these variables, we control all empirical specifications by adding a range of bank characteristic variables. More precisely, we include the lagged variables of the logarithm of total assets and its square to control for size, capital and equity ratios in terms of total assets, non-interest income in terms of total assets as a proxy for diversification, a measure of bank concentration in terms of total assets using the Herfindahl-Hirschmann index (HHI) and a measure of bank funding proxied by the ratio of total deposits to liabilities. At the macro level, we control for the lagged variables of the logarithm of per-capita GDP and the consumer price index for Luxembourg, respectively. The introduction of these two variables controls for demand-side effects as well as inflation. The introduction of the covariates is useful to capture the comparability between the treated and untreated groups before the implementation of the macroprudential capital buffers (Mayer (1995)). The data come from the Banque centrale du Luxembourg (BCL) and we use the GDP deflator of Luxembourg in 2010 for variables expressed in nominal terms. The final sample consists of 815 unbalanced bank-year observations over the period from 2011-2018. Taking the lag of the covariates and using the bootstrapping procedure decreases the size of the final sample according to the outcome variables.

149 Diallo (2020) provides detailed bank efficiency estimates for Luxembourg.

RESULTS

Capital Conservation Buffers (CCoB)

This section presents the main findings for the capital conservation buffer. In Table 1, we first estimate the main model by adding the confounding variables. Recall that the confounding variables are the first lag of the logarithm of total assets and its square, the capital and equity ratios in terms of total assets, bank concentration measured by the HHI index and diversification captured by the ratio of non-interest income and total assets, funding measured by the ratio of total deposits and liabilities, the logarithm of per-capita GDP and the consumer price index (CPI). In addition, we also add country of origin, banking business model and year fixed-effects. We can see that the coefficient of the interaction term remains negative for the lending outcome variables but is still statistically insignificant. This suggests that the CCoB requirements did not have any effect on lending, soundness and efficiency for banks operating in Luxembourg. Next, we present the results obtained for the O-SII capital buffers.

Table 1:

CCoB: Effects of macroprudential policies on bank lending, risk-taking and efficiency with confounding variables

	TOTAL LOANS	MORTGAGE	NON FIN. CORP.	HOUSE-HOLDS	BANKS	Z-SCORE	EFFICIENCY
Treat	-0.2237	-0.8660**	0.5252	0.7718***	0.0782	0.4013	-0.0109
	(0.1872)	(0.4327)	(1.1756)	(0.2860)	(0.0922)	(0.5235)	(0.0178)
Post	-1.5467	0.9748	-0.1985	-1.2030	-1.8049***	0.1657	0.0235
	(1.1423)	(2.1385)	(4.4414)	(2.5941)	(0.6371)	(0.6385)	(0.0309)
Treat×Post	-0.1484	0.0000	-0.8242	-0.4859	-0.0988	0.0799	0.0015
	(0.2027)	(0.0000)	(1.4512)	(0.3603)	(0.0935)	(0.2820)	(0.0098)
lag size	-0.7033**	1.6840	-2.7677*	-0.4435	-0.2947	0.1698	-0.0214
	(0.3352)	(1.1980)	(1.5993)	(0.7416)	(0.1967)	(0.6300)	(0.0442)
lag size^2	0.0217**	-0.0502	0.0800*	0.0152	0.0084	-0.0009	0.0006
	(0.0101)	(0.0355)	(0.0466)	(0.0223)	(0.0060)	(0.0196)	(0.0014)
lag capital ratio	0.0027	-0.4303	0.7513	-1.4156***	-0.1662	-0.2562	-0.0064
	(0.2802)	(0.2988)	(1.1903)	(0.5264)	(0.1181)	(0.2949)	(0.0145)
lag equity ratio	0.5214	-1.0447	-1.2059	2.1067	0.7388***	0.1443	0.0952**
	(0.4925)	(1.7067)	(1.6746)	(1.4396)	(0.2710)	(0.9143)	(0.0442)
lag HHI assets	0.5153**	0.1142	1.5547	0.5108	0.0518	-0.0638	-0.0264
	(0.2573)	(5.7543)	(1.0849)	(0.5416)	(0.2325)	(0.3018)	(0.0166)
lag diversification	0.3614	-1.7240	-8.7299	3.2360	0.3129	1.0019	-0.0848
	(1.4896)	(6.6991)	(10.9183)	(3.5191)	(1.0313)	(2.9790)	(0.0998)
lag funding	0.3136	-0.9263	-0.6050	0.5460	0.1824	-0.4476	0.0176
	(0.2701)	(1.5275)	(0.9830)	(0.6131)	(0.1468)	(0.6932)	(0.0314)
lag GDP	0.1466	-0.0440	0.2741	0.0211	-0.0087	0.0096	0.0041
	(0.1485)	(0.3793)	(0.7235)	(0.3975)	(0.0945)	(0.0590)	(0.0056)
lag CPI	0.1900	-0.0955	0.1931	0.1225	0.1311	-0.0275	-0.0011
	(0.1391)	(0.3147)	(0.6031)	(0.3543)	(0.0830)	(0.0480)	(0.0031)
Constant	-13.8736	-3.0219	2.7926	-10.3777	-10.7041	1.2630	1.0253**
	(14.1268)	(33.4120)	(67.0267)	(37.4278)	(8.7316)	(7.0887)	(0.4523)
Country of origin fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank business model fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number observations	657	200	374	465	643	676	676

*Source: BCL. Note that (***, ** and *) indicate significance at the 1 %, 5 % and 10 % levels, respectively. Bias-Corrected Bootstrapped Standard errors are in parenthesis. Source: Author's own estimations based on BCL data.*

Other Systematically Important Institutions (O-SII) Capital Buffers

This section focuses on the effects of O-SII buffers on bank lending, soundness and efficiency. The results are shown in Table 2 with confounding variables. The first column of Table 2 shows that when total lending growth is used as a dependent variable, the interaction term enters negatively and statistically significantly different from zero at the 5 percent level. In terms of the interpretation, this suggests that the O-SII capital requirements reduce total lending by 20 percentage points for banks subject to the buffer versus non-subject. However, the empirical results do not suggest any effect from the O-SII buffers on mortgage, non-financial corporation and bank lending. More importantly, the coefficient of the interaction term enters positively and significantly different from zero at the 10 percent level for bank soundness as captured by the z-score and efficiency. This suggests that the introduction of the O-SII capital requirements increased the soundness and efficiency of identified O-SII banks compared to non-OSIIs. In other words, O-SII capital requirements made banks more resilient to external shocks and more efficient. The mechanism through which O-SII capital requirements might affect bank efficiency is through credit intermediation, specifically they force banks to efficiently use and transform their inputs, namely deposits and labor in terms of outputs such as loans. Furthermore, in Column (1) of Table 2, which uses total loan growth as a dependent variable, one can notice the existence of an inverted U-shaped relationship between total lending growth and bank size, suggesting that larger banks in terms of assets offer more credit compared to smaller banks. Additionally, bank concentration increases lending since the coefficient associated with the lag of the Herfindahl-Hirschmann index enters positively and statistically different from zero at the 5 percent level.

Table 2:

O-SII Buffers: Effects of macroprudential policies on bank lending, risk-taking and efficiency with confounding variables

	TOTAL LOANS	MORTGAGE	NON FIN. CORP.	HOUSE-HOLDS	BANKS	Z-SCORE	EFFICIENCY
Treat×Post	-0.2038**	0.5361	-0.3089	-0.2786	0.2097	0.5976*	0.0110*
	(0.0952)	(0.5163)	(0.2798)	(0.3932)	(0.1360)	(0.3510)	(0.0061)
lag size	-0.6983**	2.1694*	-2.8099*	-0.5378	-0.2318	0.2580	-0.0168
	(0.3523)	(1.2654)	(1.5227)	(0.7684)	(0.2102)	(0.6435)	(0.0419)
lag size^2	0.0212**	-0.0651*	0.0815*	0.0185	0.0063	-0.0034	0.0005
	(0.0106)	(0.0372)	(0.0444)	(0.0232)	(0.0065)	(0.0198)	(0.0013)
lag capital ratio	-0.0270	-0.3587	0.7160	-1.4037***	-0.1716	-0.2609	-0.0068
	(0.2748)	(0.3025)	(1.3543)	(0.5426)	(0.1204)	(0.2857)	(0.0139)
lag equity ratio	0.5130	-1.5954	-1.1199	2.0520	0.6964***	0.1884	0.0937**
	(0.5460)	(1.7909)	(1.7406)	(1.4610)	(0.2683)	(0.9796)	(0.0460)
lag HHI assets	0.5216**	0.0532	1.6221*	0.3937	0.0532	-0.0771	-0.0261
	(0.2494)	(5.5586)	(0.9364)	(0.5024)	(0.2315)	(0.3177)	(0.0161)
lag diversification	0.2718	-0.7922	-7.5772	3.8154	0.2676	1.0366	-0.0856
	(1.5214)	(6.8821)	(10.9797)	(3.6803)	(0.9793)	(3.0761)	(0.0956)
lag funding	0.3346	-1.4078	-0.5127	0.4438	0.1381	-0.4866	0.0168
	(0.2823)	(1.5241)	(1.1267)	(0.5388)	(0.1445)	(0.7624)	(0.0316)
lag GDP	0.1458	-0.1228	0.2707	0.0165	-0.0068	0.0099	0.0042
	(0.1486)	(0.3339)	(0.7510)	(0.7165)	(0.1026)	(0.0621)	(0.0057)
lag CPI	0.1889	-0.1749	0.1876	0.1164	0.1301	-0.0301	-0.0010
	(0.1387)	(0.2843)	(0.6265)	(0.6515)	(0.0910)	(0.0479)	(0.0031)
Constant	-13.9359	0.8347	4.0538	-8.2738	-10.9686	1.1773	0.9824**
	(14.0281)	(29.0746)	(69.4595)	(67.4938)	(9.6068)	(7.4779)	(0.4488)
Country of origin fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank business model fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number observations	657	200	374	465	643	676	676

*Source: BCL. Note that (***, ** and *) indicate significance at the 1 %, 5 % and 10 % levels, respectively. Bias-Corrected Bootstrapped Standard errors are in parenthesis. Source: Author's own estimations based on BCL data.*

Robustness Checks

Bank branches and deposit insurance. In Luxembourg there are three types of banks divided as follows: (i) banks working under the Luxembourgish law for both domestic and foreign-bank subsidiaries; (ii) bank branches in Luxembourg but incorporated in other European Union (EU) countries, and (iii) bank branches in Luxembourg but incorporated in countries outside the EU. With this banking structure, it is important to adjust the findings for bank branches. Another reason for doing so is that Aiyar *et al.* (2014b) found that banks operating as branches or subsidiaries may behave differently when macroprudential policy is implemented. In fact, according to the European Systemic Risk Board (ESRB),[150] Luxembourg is one of the euro area countries where the market share of non-EU branches exceeds 1 percent. Moreover, it can be argued that if macroprudential policies are only applied to domestic banks, then foreign banks may increase their lending in host countries, and thus negate the reduction in credit from domestic banks. Furthermore, we also use the dummy variable deposit insurance as a confounding variable. This introduction is motivated by the findings of Diamond and Dybvig (1983) who argued that deposit insurance might prevent bank runs, and Cooper and Ross (2002) who found that deposit insurance alone is not sufficient to prevent bank runs; however, complementing it with capital requirements would help to efficiently prevent bank runs. Therefore, in Table 3, we adjust the findings for bank branching and deposit insurance. Again, the interaction term remains negative and significant at the 1 percent level when total loan growth rate is used as dependent variable. The magnitude of the DID coefficient, namely the interaction term, increased sharply for total lending growth. This suggests that the introduction of the O-SII buffers reduced total lending by 28 percentage points for O-SII banks compared to non-O-SIIs.

The role of mortgage banks. Because five banks account for around 90 percent of mortgage lending activity,[151] we adjust the main findings using a dummy variable that takes the value of 1 if a bank is part of these institutions and 0 otherwise. We then re-estimate the model and still find that the interaction term remains negative and statistically significantly different from zero at the 5 percent level, supporting the interpretation that the O-SII buffers decreased total lending for the banks concerned. In addition, we also show that the O-SII buffers increased bank soundness and efficiency.

150 Macroprudential policy implications of foreign branches relevant for financial stability (ESRB, December 2019).
151 See La Revue de Stabilité Financière (2019, 2020) (BCL).

Table 3:

O-SII Buffers: Effects of macroprudential policies on bank lending, risk-taking and efficiency with confounding variables bank branching and deposit insurance

	TOTAL LOANS	MORTGAGE	NON FIN. CORP.	HOUSE-HOLDS	BANKS	Z-SCORE	EFFICIENCY
Treat×Post	-0.2811***	0.5929	-0.3344	-0.2791	0.1894	0.5713*	0.0110*
	(0.1031)	(0.4393)	(0.3557)	(0.4203)	(0.1346)	(0.3441)	(0.0063)
Branch	-0.0208	0.6591	-0.6933	0.1158	0.0640	0.0008	0.0137
	(0.1121)	(0.8557)	(0.6056)	(0.4270)	(0.0865)	(0.3831)	(0.0206)
Deposit insurance	0.2837***	0.6209	-0.3939	0.2597	0.1204*	0.3353	0.0094
	(0.0873)	(0.7751)	(0.5443)	(0.1995)	(0.0657)	(0.3540)	(0.0127)
lag size	-0.8333**	2.5150**	-2.4852	-0.4957	-0.2768	0.2053	-0.0166
	(0.3364)	(1.0884)	(1.7105)	(0.8011)	(0.2128)	(0.6425)	(0.0417)
lag size^2	0.0251**	-0.0746**	0.0714	0.0172	0.0077	-0.0020	0.0005
	(0.0101)	(0.0320)	(0.0501)	(0.0240)	(0.0065)	(0.0197)	(0.0013)
lag capital ratio	-0.1083	-0.3732	0.7407	-1.4037**	-0.1951*	-0.2931	-0.0070
	(0.2524)	(0.3067)	(1.1737)	(0.5946)	(0.1179)	(0.2980)	(0.0143)
lag equity ratio	0.4654	-2.1396	-1.9189	1.8723	0.7305**	0.1204	0.0970**
	(0.5237)	(1.6708)	(2.0405)	(1.4362)	(0.2968)	(1.0243)	(0.0482)
lag HHI assets	0.6182**	0.0837	1.6132	0.4870	0.0809	-0.0487	-0.0263
	(0.2588)	(3.5568)	(1.0576)	(0.5671)	(0.2331)	(0.3074)	(0.0171)
lag diversification	0.2682	6.1148	-7.8810	4.2060	0.3027	1.1418	-0.0828
	(1.3789)	(7.1769)	(13.7145)	(3.8867)	(0.9708)	(3.0092)	(0.0930)
lag funding	0.4168	-1.1754	-0.9807	0.4568	0.1784	-0.4502	0.0179
	(0.2671)	(1.2599)	(1.2828)	(0.6316)	(0.1440)	(0.7509)	(0.0328)
lag GDP	0.1520	-0.1564	0.2604	0.0240	-0.0059	0.0145	0.0042
	(0.1418)	(0.2743)	(0.8500)	(0.4310)	(0.1000)	(0.0617)	(0.0056)
lag CPI	0.1908	-0.2101	0.1765	0.1203	0.1294	-0.0256	-0.0010
	(0.1340)	(0.2275)	(0.6855)	(0.3885)	(0.0883)	(0.0491)	(0.0031)
Constant	-13.1179	1.1030	3.0671	-9.0288	-10.5938	1.1185	0.9762**
	(13.5366)	(24.0119)	(74.8921)	(40.7952)	(9.2415)	(7.3353)	(0.4310)
Country of origin fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank business model fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number observations	657	200	374	465	643	676	676

*Source: BCL. Note that (***, ** and *) indicate significance at the 1 %, 5 % and 10 % levels, respectively. Bias-Corrected Bootstrapped Standard errors are in parenthesis. Source: Author's own estimations based on BCL data.*

Outward spillovers. Because Luxembourg is a financial center, it is important to investigate the role of outward spillovers in lending. Put simply, several foreign banks operate in the country and it shares borders with the first and second largest economies in the euro area, namely Germany and France. Consequently, it is worth assessing if banks located in Luxembourg would increase cross-border lending with the implementation of macroprudential policies. According to the ESRB report published in December 2019, the differences in the financial structures of home and host countries create additional considerations for authorities working on the adoption and activation of macroprudential measures. The literature on macroprudential policies has found evidence of spillover effects in lending. For instance, Buch and Goldberg (2017) define two possible types of policy spillovers: inward spillovers or leakages, which suggest that domestic macroprudential measures can give rise to policy "leakages" if bank activities migrate to areas/entities not subject to the measures such as foreign banks or non-bank financial institutions. Inward spillovers may render domestic macroprudential policy less effective.

The second type is called outward spillovers, suggesting that domestic macroprudential measures can induce externalities on other countries through adjustments in the lending behavior of domestic banks to foreign borrowers. For example, following a tightening of macroprudential policies at home, domestic banks may respond by increasing/decreasing their lending abroad via subsidiaries or through direct cross-border lending. On outward spillovers of macroprudential policy actions, findings in the academic literature are mixed regarding the impact on cross-border lending (Aiyar *et al.* (2014b), Ongena *et al.* (2013), Franch *et al.* (2020) and the literature within). Importantly, the potential for cross-border spillovers may be greater in national banking sectors with a strong presence of foreign banks according to the ESRB, which is the case of Luxembourg. In particular, foreign branches can contribute to macroprudential leakages, as they are typically not subject to measures targeting the domestic banking sector and are not under the direct supervision of the domestic authorities.

The results in table 4 account for these potential outward spillovers. We use the growth rates of total, mortgage, non-financial corporation, households and bank loans in the euro area (EA) as dependent variables. The findings do not indicate any outward spillover effects in lending as none of the coefficients is statistically significant, in line with Danisewicz *et al.* (2017).

Table 4:

Outward spillovers (O-SII Buffers): Macroprudential policies and lending

	TOTAL LOANS EA	MORTGAGE EA	NON FIN. CORP. EA	HOUSE-HOLDS EA	BANKS EA	Z-SCORE	EFFICIENCY
Treat×Post	0.2831	0.4425	0.2926	-0.1113	0.2823	0.5713*	0.0110*
	(0.2022)	(0.4587)	(0.2401)	(0.1308)	(0.2146)	(0.3441)	(0.0063)
lag size	-0.4469	-0.3871	-0.6614	0.3922	-0.0767	0.0008	0.0137
	(0.4662)	(1.1391)	(0.9778)	(0.7361)	(0.5351)	(0.3831)	(0.0206)
lag size^2	0.0127	0.0116	0.0162	-0.0095	0.0019	0.3353	0.0094
	(0.0138)	(0.0339)	(0.0286)	(0.0217)	(0.0161)	(0.3540)	(0.0127)
lag capital ratio	-0.2686	0.8048	-0.2652	-1.0453**	0.0407	0.2053	-0.0166
	(0.1680)	(0.9296)	(0.5078)	(0.5026)	(0.2734)	(0.6425)	(0.0417)
lag equity ratio	0.7430	-0.4757	-0.6544	1.2097	0.7657	-0.0020	0.0005
	(0.5078)	(2.2107)	(1.3207)	(1.9007)	(0.7548)	(0.0197)	(0.0013)
lag HHI assets	0.1001	1.1268	0.1025	0.4016	0.3376	-0.2931	-0.0070
	(0.2397)	(2.9859)	(0.3634)	(0.4605)	(0.4652)	(0.2980)	(0.0143)
lag diversification	0.0297	-8.5004	-10.7077	4.7496	1.2645	0.1204	0.0970**
	(1.7882)	(8.3608)	(7.0739)	(3.5787)	(1.8104)	(1.0243)	(0.0482)
lag funding	-0.1942	-0.0923	-0.1916	-0.3654	-0.1435	-0.0487	-0.0263
	(0.3459)	(1.1401)	(0.6883)	(0.8797)	(0.4433)	(0.3074)	(0.0171)
lag GDP	0.0577	-1.2900**	-0.1262	0.1608	-0.0055	1.1418	-0.0828
	(0.1175)	(0.5012)	(0.3949)	(0.2670)	(0.0372)	(3.0092)	(0.0930)
lag CPI	0.1438	-1.1345**	-0.1943	0.2025	0.0946	-0.4502	0.0179
	(0.1171)	(0.4584)	(0.3976)	(0.2436)	(0.0931)	(0.7509)	(0.0328)
Constant	-10.8453	120.6293**	26.6238	-24.4280	-8.8302	1.1185	0.9762**
	(10.3999)	(47.3009)	(41.3624)	(26.2227)	(10.1117)	(7.3353)	(0.4310)
Country of origin fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank business model fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	641	190	363	469	602	676	676

*Source: BCL. Note that (***, ** and *) indicate significance at the 1 %, 5 % and 10 % levels, respectively. Bias-Corrected Bootstrapped Standard errors are in parenthesis. Source: Author's own estimations based on BCL data.*

Further robustness tests.[152] In this section, we further investigate the robustness of the findings to selection bias issues for O-SII capital buffers using a resampling approach and the propensity score matching. According to Mayer (1995) the DID approach can be reinforced by the use of additional comparison groups. Since we have data on banks that are no longer operating in Luxembourg, we use these banks as a treatment group. In other words, we assume that these banks are affected by O-SII buffers and re-estimate the model. If our findings are not subject to selection bias we should find a statistically insignificant coefficient for the interaction term. However, if this is not the case then the estimates of the differences in outcomes between banks cannot be explained solely by the introduction of O-SII capital buffers. As expected, the coefficient of the interaction term enters insignificantly in all columns, providing more support for the non-selection bias issue. Finally, we perform a second robustness test by randomly constructing the treatment group within banks. Again, the coefficient of the interaction terms remains insignificant in all specifications. The findings of these two exercises support our main results as they account for potential concerns with respect to the identification strategy and selection bias issues.

Propensity score matching (PSM). We also use the propensity score matching in order to deal with the selection bias. This technique matches O-SII banks in relation to capital buffers with non-O-SIIs that may have similar probability to be treated. Concretely, we match banks in the treatment groups with banks in the control groups based on nearest neighbour matching with respect to several bank characteristics such as the logarithm of total assets, capital and equity ratios, concentration proxied by the HHI and income diversification based on the nearest neighbour matching estimator. We use two matches for the estimator since Abadie and Imbens (2011) and Gropp *et al.* (2019) found that this estimator provides a very good trade-off between bias and variance of the nearest neighbour matching estimator. The introduction of several covariates in the matching procedure is motivated by the fact that Heckman *et al.* (1997), Caliendo and Kopeinig (2008) among others showed that the omission of important covariates can increase the bias in the estimates. The results indicate that O-SII capital buffers decreased total loan growth but the coefficient of the interaction term entered insignificantly. However, we find that O-SII buffers boosted bank soundness and efficiency as the coefficient of the interaction term remains positive and statistically significantly different from zero at the 1 percent level.

Lastly, we test the robustness of the main findings by dropping a bank that recently acquired a branch status. However, before becoming a branch in 2017 that bank was identified as an O-SII financial institution in 2015 and 2016. Furthermore, the ESRB states that the systemic importance of foreign branches and subsidiaries is not taken into account when setting the consolidated O-SII buffer of the banking group. In particular, according to the EBA Guidelines on criteria for the assessment of O-SIIs, the consolidated position of the entire group is assessed in relation to the home banking system and without taking into account the systemic importance of the group in host member states. Therefore, it is generally possible that a smaller banking group established in a large economy would be of a little systemic importance, or would not be identified as an O-SII at all, but would have a dominant and highly systemic presence in other smaller economies. To avoid these shortcomings we re-estimate the model without this institution, finding that the sign and significance of the interaction term remain unaltered and the effects become a little bit stronger as the magnitude of the coefficient increased moderately.

CONCLUSION

This research studied the effectiveness of macroprudential policies in Luxembourg. Moreover, it used the timing of the introduction of the capital conservation and O-SII capital buffers and variation across

152 The results of these additional robustness tests can be seen in the long version of the Working Paper.

banks to investigate their effects on bank lending, risk-taking, efficiency and employment using an unbalanced panel of 141 banks over the period 2011-2018. Using the difference-in-differences (DID) methodology, the following findings emerge. The O-SII capital buffers decreased total lending and boosted bank soundness and efficiency. However, we did not find any such effects for the CCoB requirements. These findings remain robust when adjusting for bank branches and the presence of deposit insurance, the use of several resampling tests and the propensity score matching for the selection bias. In addition, we showed that the macroprudential instruments used in this study did not generate outward spillovers for banks operating in the country.

The results obtained in this research have relevant implications for Luxembourg. They suggest that macroprudential policies, in particular the O-SII capital requirements, have an effect on total lending, bank soundness and efficiency. However, this decrease in total lending might generate certain costs for the real economy. Such costs have to be weighed against the measures' ability to mitigate the adverse impact of future crises.

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