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Aurora Abbondanza, Ugo Albertazzi,
Aurea Ponte Marques, Giulia Leila Travaglini

The impact of capital requirements on bank capital

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Abstract

This paper presents the first causal evidence on how banks adjust their voluntary capital buffers (the capital headroom above the required level) in response to changes in capital requirements. Using granular euro area data and exploiting the threshold-based assignment of Other Systemically Important Institution (O-SII) buffers within a regression discontinuity design, we study the liability side of banks' balance sheets, complementing the asset-focused literature on lending and risk-taking. This allows us to assess whether capital regulation is effective in enhancing bank resilience, arguably its main objective. We find that banks offset about half of higher capital requirements by cutting their voluntary buffers rather than raising new equity. The offsetting effect is more pronounced among banks with weaker balance sheets, particularly those with higher levels of non-performing loans. These results indicate that regulation aimed at strengthening resilience may be only partially effective, as banks use existing voluntary buffers when subject to higher requirements.

Keywords: Macroprudential policy, Capital buffers, Higher requirements, Voluntary buffer
JEL Codes: E44, E51, E58, G21, G28

Non-Technical Summary

This paper studies the transmission mechanism of the other systemically important institutions (O-SII) buffer. The Global Financial Crisis revealed limitations in the supervisory framework's ability to ensure the banking system's resilience to severe macro-financial shocks. In response, the euro area centralised its banking supervision, while, at the same time, the European Union (EU) built up the macroprudential policy toolkit to address systemic risks. One macroprudential measure emerging from these reforms is the introduction of the O-SII buffer. This capital buffer specifically targets banks whose size and importance mean their distress could jeopardise the broader economy. The O-SII buffer is intended to address the tendency for risk-taking in "too big to fail" banks by requiring them to hold additional capital, thereby increasing shareholders' exposure to losses and discouraging excessive risk.

Our paper analyses the mechanisms underlying the pass-through of capital regulation and of the O-SII buffer specifically, studying whether banks respond to higher capital requirements by altering their total capital levels. This represents a novel perspective compared to existing research and touches upon a crucial yet unanswered question, which our paper aims to address for the first time. In the wake of the Global Financial Crisis, existing literature has primarily focused on how tightening capital requirements affects banks' loan supply. This emphasis stems from the dual perspective that curbing banks' risk-taking was either a primary objective of capital regulation or an unintended consequence, leading to discussions of 'bad deleveraging' versus 'good deleveraging'.[1] Our study takes a novel approach by studying the liability side of banks' balance sheets to determine whether banks facing higher capital requirements adjust their actual capital levels (not just ratios) by reducing their voluntary capital buffers (the capital headroom maintained above the regulatory requirement). From a policy perspective, this question is increasingly relevant as banks' balance sheets are characterised by growing levels of voluntary capital buffers. This makes the impact of capital requirements on banks' assets less relevant, and at the same time raises issues whether macroprudential policy can remain effective by influencing banks' overall level of capitalisation. Indeed, a third option for banks to accommodate a tightening in capital requirements is by adjusting the capital headroom banks hold on top of the regulatory requirement, therefore reducing the impact on banks' total capital levels, even without cuts to loan supply. This angle adds an important perspective often missed in previous studies, which tended to focus on banks' asset-side adjustments.

We focus on O-SII buffers for two reasons: first, to assess this significant yet underexplored macroprudential policy, and second, to exploit the institutional framework for the setting of this requirement which allows some neat identification strategy. The European Banking Authority (EBA) assigns O-SII buffers through a scoring process that automatically designates banks with scores above a predetermined threshold as systemically important.[2] The EBA scoring process is a source of exogenous variation in capital requirements, equivalent to a randomised experiment near the threshold, allowing to identify the effect of higher capital requirements by comparing outcomes for banks just above and below the cutoff, through a regression discontinuity design. Adopting a sharp identification strategy is crucial in this context, precisely because the designation of O-SII

[1] For further discussion, see Enria, A. "Supervisory policies and bank deleveraging: a European perspective", 21st Annual Hyman P. Minsky Conference on the State of the U.S. and World Economies: Debt, Deficits and Financial Instability, 11th April 2012.

[2] A bank is designated as O-SII if the score is equal to or higher than 350 basis points, as per Article 131(3) of Directive 2013/36/EU ('CRD IV') and the EBA Guidelines (EBA/GL/2014/10). The procedure also incorporates some supervisory expert's judgment that may qualify some banks below the threshold as systemically important. This will also be taken into account in the methodology. Moreover, we will also consider the presence of additional thresholds used to assign different levels for the O-SII buffer within the group of systemically important institutions.

is not random and is likely correlated with the level of voluntary buffers these institutions endogenously decide to maintain. The availability of comprehensive, detailed, and confidential datasets is crucial for implementing this method and assessing the usability of banks' voluntary buffers.

Our study establishes two main findings. First, banks subject to O-SII buffers partially use their voluntary buffers to comply with the additional capital requirement, rather than raising new equity, which decreases their adjustment costs. Second, banks with a larger stock of non-performing loans are more prone to use their voluntary buffers to offset an increase in capital requirements. These banks, often perceived as less efficient, face greater challenges in raising new equity.

Our results have important implications for the design of macroprudential policy. It should be noted that even in the extreme case of a complete offset of the voluntary buffer, increasing prudential buffers may still enhance banks' resilience by ring-fencing capital that might otherwise be distributed prior to adverse shocks. Thus, higher capital requirements, while ring-fencing resources that could protect against adverse shocks, do not always translate into higher actual capital held by banks. In effect, part of the intended safety margin is offset, which could dilute the effectiveness of macroprudential policy should adverse conditions materialise. These results are accompanied by possible adverse effects on the real economy due to banks' deleveraging and derisking, extensively documented in the literature (e.g., Admati et al., 2018 and, for the euro area, Cappelletti et al., 2024 and Ponte Marques et al., 2024).[3] In terms of policy implications, our findings support the view that capital requirements aimed at strengthening banks' capital positions may require targeting the absolute amount of new capital to be raised, as suggested by Hanson et al. (2011) and Gropp et al. (2019).

[3] Whether the impact of stricter capital requirement on lending and risk taking is a side effect or instead an intended consequence depends on the objective associated to the prudential policy. Repullo (2004) and Gersbach and Rochet (2017) stress that this is part of the transmission mechanism as stricter capital requirements mitigate capital misallocation, increase expected output and social welfare.

1 Introduction

The Global Financial Crisis emphasised that the supervisory framework existing at that time could not ensure adequate resilience of the banking system to adverse macro-financial shocks. It was acknowledged that the supervisory and regulatory framework failed to address system-wide risks, prompting a comprehensive reform of both microprudential supervision and macroprudential policy. In the euro area, for instance, this reform led to the centralisation of banking supervision and the introduction of a new macroprudential policy toolkit to tackle systemic risks. More broadly, the post-Global Financial Crisis regulatory reforms largely relied on an enhanced regulatory regime for bank capital, including both micro- and macroprudential requirements.

This paper presents the first evidence on the causal impact of capital requirements on bank capital, specifically studying whether banks adjust their voluntary buffer — the capital headroom in excess of the required level — in response to changes in capital requirements. This analysis contributes to the literature regarding the mechanisms underlying the pass-through of capital regulation on banks and ultimately on the real economy. The bulk of the literature assessing the impact of capital regulation has studied mainly the implications for banks' risk-taking and lending (denominator of the bank capital ratio). Exploring the impact on bank voluntary buffers (numerator of the bank capital ratio) allows a better understanding of the transmission of bank regulation and helps to reconcile some inconsistent findings documented in the literature, as reviewed in Section 2. More broadly, this analysis is crucial to assess whether capital requirements are effective in making banks more solid by increasing capital, bank shareholders' skin in the game, arguably the main objective of micro- and macroprudential capital regulation. This question is highly relevant in a context where banks' balance sheets are characterised by increasing levels of voluntary capital buffers, which weakens transmission through banks' assets.

Banks maintain voluntary buffers primarily for two reasons and the extent to which they offset changes in capital requirements by compressing such buffers is likely to depend on the underlying motivation for holding capital in excess. First, due to market discipline, banks set target capital ratios above regulatory minimum levels, as maintaining voluntary buffers improves credit ratings (Andreeva et al., 2020), which reduces funding costs and improves profitability (Gambacorta and Shin, 2018). A second important motivation relates to a precautionary motive. Banks are reluctant to approach the regulatory minimum, as violations may trigger supervisory interventions or even trigger resolution (Drehmann et al., 2020). Exhausting all buffers could expose banks to significant risks, especially in combination with high uncertainty about the future economic path (Lewrick et al., 2020).[4] If banks hold capital in excess primarily for precautionary reasons, they may be reluctant, at the margin, to offset an increase in capital requirements by reducing their voluntary buffers. If banks do so because of market discipline, they may be willing to offset changes in capital requirements by reducing voluntary buffers.[5] Studying whether banks adjust their voluntary buffers in response to capital

[4] In the EU, such breaches could lead to restrictions on capital distributions and management remuneration, limit banks' ability to pursue profitable business opportunities, or require the disposal of non-core assets. Directive 2013/36/EU, Articles 102, 104, 141, and 142.

[5] More specifically, from a theoretical viewpoint, Repullo and Suarez (2013) and Borsuk et al. (2020) stress that banks hold endogenous capital buffers as a precaution against shocks that impair their future lending capacity. Intuitively, this theory implies that, at the margin, changes in capital requirements are associated with one-to-one changes in capital ratios, as this leaves the precautionary buffers intact. Flannery (1994), Myers and Rajan (1998), Diamond and Rajan (2000) and Allen et al. (2015), instead, develop more elaborate theories of optimal bank capital structure, in which capital requirements are not necessarily binding. From this perspective, marginal changes in capital requirements represent shifts in non-binding constraints which should leave the optimisation problem unaffected. Other authors stress how banks' decisions to hold voluntary capital buffers could be influenced by other factors such as the business cycle (Ayuso et al., 2004; Stolz and Wedow, 2009; Jokipii and

requirement changes can be seen as a test of the Lucas critique within the macroprudential framework (Wagner, 2014; Horváth and Wagner, 2016).

Assessing the causal impact of capital requirements on banks' voluntary buffers is therefore an empirical question made difficult by the presence of thorny identification issues. In particular, the level of regulatory capital requirements cannot be considered to be unrelated to the level of voluntary buffers, especially for bank-specific regulatory requirements, leading to potential endogeneity issues. This holds true regardless of the type of capital requirements, whether micro- or macroprudential. Our study addresses this challenge by employing a regression discontinuity design approach. This analysis is made possible by the availability of a unique and confidential granular dataset containing observations on a large set of euro area banks subject to additional capital requirements — namely, the other systemically important institutions (O-SII) buffers. The assignment of such extra capital requirements is based on a scoring system envisaging thresholds, which we exploit for identification within a regression discontinuity framework. The institutional setup is described in detail in Section 3.

Our main contribution is to provide novel empirical evidence that may prove useful in the debate on the effectiveness of macroprudential policies for banks with large capital headroom. For that, we look at O-SII buffers and, following the design of Cappelletti et al. (2024), we address the non-random assignment between treatment and control groups, by employing a regression discontinuity design (RDD), enabling us to select comparable banks across both cohorts and causally identify the impact of an exogenous increase in capital requirements on banks' voluntary buffers.

Our results indicate that, on average, banks do use their voluntary buffers to partly offset higher capital requirements. This offsetting behaviour is quantitatively significant and heterogeneous, being more pronounced in banks with higher non-performing loans ratios. Baseline results show that banks just above marginally higher thresholds (i.e., those receiving slightly higher capital buffers) hold, on average, voluntary buffer ratios that are about 0.30 percentage points lower than those of banks just below the threshold. An increase of about 0.5 percentage points in capital requirements — reflecting the typical O-SII buffer for banks marginally above the threshold — is therefore associated with a 0.3 percentage point reduction in the voluntary CET1 capital buffer. The fact that banks rely on voluntary buffers to offset around half of the higher capital requirements, rather than raising new equity, suggests that the intended objective of macroprudential policy may not be fully achieved. In the case of O-SIIs, the objective is for banks to maintain sufficient capital to ensure a minimal risk of failure. This is particularly important given the negative externalities that bank failures can impose on depositors and the potential for moral hazard, especially due to the risk of triggering systemic disruptions with severe consequences for the real economy.

From a policy perspective, our results support the view that effective capital regulation should focus on targeting the absolute amount of capital, rather than solely aiming at capital ratios, as suggested by Hanson et al. (2011) and Gropp et al. (2019).

The remainder of this paper is organised as follows. Section 2 reviews the related literature. Section 3 describes the identification process of O-SIIs, as established in the European Banking Authority (EBA) guidelines, presenting the data and descriptive statistics. Section 4 outlines the empirical strategy. The results of our analysis are presented in Section 5. Section 6 reviews the validity of our empirical approach, providing several robustness checks to ensure the reliability of our findings. Section 7 concludes.

Milne, 2008; Repullo and Suarez, 2013; Hanson et al., 2011), participation in trading activities, the composition of debt, and reliance on market-based funding.

2 Literature review

This paper relates to the large body of empirical literature on the effects of capital requirements. A first stream of research emphasizes how capital requirements support financial stability (Crockett, 2000; Caruana, 2010, 2010b; Gropp and Heider, 2010; Acharya et al., 2011; Calomiris and Herring, 2013; Hart and Zingales, 2011; Hanson et al., 2011; Perotti and Suarez, 2011; Elliott et al., 2012; Admati et al., 2013; Berger and Bouwman, 2013; Acharya and Thakor, 2016; Bui et al., 2017; Cappelletti et al., 2024; Ponte Marques et al., 2024). Other studies have taken a similar perspective and assess to what extent capital buffers succeed in enhancing banks' capacity to absorb losses and therefore in stabilising lending activity under adverse conditions (Berrospide and Edge, 2010; Buch and Prieto, 2014). An overview of the earlier literature is provided in Martynova (2015).

A second stream of work has mostly focused on the implications of the phase-in of capital requirements for the asset side of banks' balance sheet and in particular on the supply of loans. This literature broadly suggests that higher capital requirements may restrict lending, as banks often respond by deleveraging to comply with the increased regulatory measures (Thakor, 1996; Peek and Rosengren, 1997; Gambacorta and Mistrulli, 2004; Bolton and Freixas, 2006; Francis and Osborne, 2009 and 2012; Bridges et al., 2014; Aiyar et al., 2014 and 2016; Noss and Toffano, 2016; De Jonghe et al., 2020). More recently, also Gropp et al. (2019) and Fraisse et al. (2020) stressed that banks constrained with higher capital requirements tend to increase their capital ratios not by raising their level of equity but by reducing their credit supply. This literature is generally ambiguous about whether the impact on loan supply of the phase-in of capital requirements is to be seen as a side effect or instead an intended objective.

There is some evidence on the effects on lending of capital buffer release. Sivec et al. (2019) present empirical evidence from a policy experiment in Slovenia, showing that capital buffer releases had a positive impact on loan supply. Andreeva et al. (2020), using a correlation-based analysis, find that when capital buffers are released, banks are often reluctant to use them due to financial market pressures, limiting the effectiveness of such measures. Couaillier et al. (2025), looking at lending by euro area banks in the aftermath of the Covid outbreak, document that the release of capital buffers did not support lending as intended. More broadly, several studies have identified market expectations and the risk of penalties as primary factors behind the limited usability of regulatory capital buffers (e.g., BCBS, 2022; Abad and Garcia Pascual, 2022; Andreeva et al., 2020).

Another body of literature, closer in spirit to this paper, looks empirically at the determinants of banks' target capital ratios. Gropp and Heider (2010) find that bank fixed-effects are ultimately the most relevant determinant of banks' leverage ratios which they interpret as indicating that banks' capital structures are shaped primarily by bank-specific targets. Capital regulation is seen instead as a second-order importance factor in shaping banks' capital structure. Ediz et al. (1998), Francis and Osborne (2009, 2012) and Memmel and Raupach (2010) exploit panel data to infer individual banks' (unobservable) target capital ratios and generally show, instead, that this tends to rise in response to increases in capital requirements. In the same spirit, Couaillier (2021) uncovers similar findings for a sample of banks that report their target capital ratios.

This paper contributes to the latter body of literature by empirically testing the effects of capital requirements on banks' voluntary buffers. Instead of considering estimated or self-reported target capital ratios, it does so based on an empirical framework that can arguably identify the causal effects of higher capital requirements on the observed levels of voluntary buffers. The paper also contributes by focusing on an important but under-explored capital requirement in place, the O-SII buffer. Another distinct feature of this analysis is that it considers a sample characterised by a high level of voluntary buffers. Under these circumstances, a tightening in capital requirements is not operating via its impact on lending supply (Behn et al., 2020). An increase in capital requirements can play a role only insofar as it leads to higher capital, therefore contributing to further enhancing the resilience of the banking sector. This is what is being tested in this paper.

3 O-SII framework and data

3.1 O-SII identification framework

In this paper, the focus is on the macroprudential measure related with other systemically important institutions capital buffer (O-SII) which aims to reduce moral hazard and misaligned incentives by strengthening the resilience of "too big to fail" institutions. This additional capital requirement cushions the systemic impact of misaligned incentives by strengthening the resilience of systemic banks in absorbing losses (ESRB Handbook, 2018).

As of 1 January 2016, the EU member states' designated authorities started to implement stricter requirements, in the form of CET1 capital buffers, following the EU legislation.[6] The O-SII identification framework is described in Directive 2013/36/EU ("CRD IV"), Article 131(3), and in the EBA guidelines (EBA/GL/2014/10).[7] This framework establishes a two-step procedure for identifying O-SII. In the first step, national authorities calculate a score for each relevant entity, at least at the highest level of consolidation of the banking group under their jurisdiction. The score is established in the EBA guidelines, and it is based on four mandatory indicators that should capture the systemic footprint of each institution (Table 1). In detail, a bank is designated as O-SII if its score is equal to or higher than 350 basis points.[8] This automatic rule ensures homogeneity of the group of O-SII resulting from the scoring process.

The threshold for the calibration of the O-SII buffer requirement depends on each EU country. The national authorities can deviate from the suggested buckets to accommodate differences between the European States' banking systems. Higher thresholds also imply an increase in the marginal O-SII buffer requirement. A representation of the O-SII buffer requirements by bucket across countries is presented in Figure 1.

In the second step, national authorities employ a supervisory overlay, whereby it is assessed whether further institutions are systemically relevant to be also qualified as O-SII. The assessment is based on other optional indicators detailed in the EBA guidelines, which are considered more adequate in capturing systemic risk in the domestic banking sector or economy.[9] The supervisory overlay is typically applied to banks which fall under the automatic score, but national authorities can still identify those institutions as O-SII given their systemic footprint within the national banking system.[10]

[6] In few countries (Estonia, the Netherlands and Slovakia) the O-SII surcharge was complemented with the introduction of the systemic risk buffer.

[7] The EBA guidelines are consistent with the Basel Committee on Banking Supervision framework for domestic systemically important banks. Although the EBA guidance is not compulsory, almost all countries follow the guidelines. At the same time, the strict application of the EBA protocol might not always reflect the specificities of the different EU countries.

[8] To account for the specificities of each EU member state's banking sector and the resulting statistical distribution of scores, national authorities may increase the threshold up to 425 basis points or decrease it to 275 basis points.

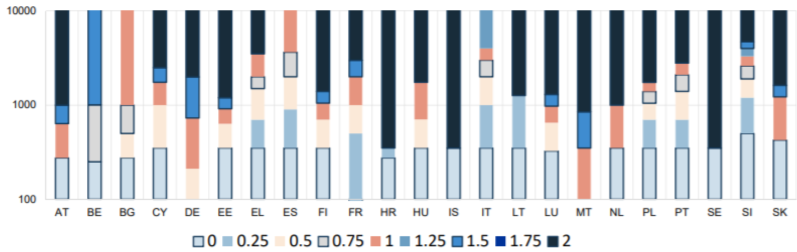
[9] According to the EBA guidelines, national authorities should publicly disclose information of the methodology applied to assess banks' systemic importance.

[10] However, institutions with a score not exceeding 4.5 basis points should not be designated as O-SII.

Table 1: O-SII scoring: indicators and criterion (EBA, 2014)

Criterion	Indicators
Size	Total assets
Importance (including substitutability/financial system infrastructure)	Value of domestic payment transactions
	Private sector deposits from EU depositors
	Private sector loans to recipients in the EU
Complexity/cross-border activity	Value of OTC derivatives (notional)
	Cross-jurisdictional liabilities
	Cross-jurisdictional claims
Interconnectedness	Intra-financial system liabilities
	Intra-financial system assets
	Debt securities outstanding

Figure 1: O-SII buffer rates and buckets width by country



Sources: Figure taken from the EBA report (EBA, 2020) based on a survey of national authorities in 2020; 2018 year-end data. *Notes*: y-axis (log transformation of scores) starting at 100 bps. Darker shades of blue and grey correspond to higher buffer rates. Some authorities have declared applying first buckets of O-SII score at 0 bps; the bucket of 0 bps for the O-SII buffer rate regards all non-O-SIIs banks.

The EBA guidance does not provide a method for the calibration of the O-SII buffer, therefore the different EU countries have used various methodologies to calibrate the O-SII capital surcharge.[11] Yet, the EU legislation provides some constraints: a cap for the O-SII buffer of 2 percent, and, for subsidiaries, the additional capital requirement cannot exceed the greater of 1 percent and the global systemically important institutions (G-SII) or O-SII buffer applicable at the consolidated level. Also the timing of the introduction of the measure is heterogeneous among the EU member states. There is considerable variation in the first year regarding the implementation of the policy measure, with several countries deciding to defer the start of the execution of a positive O-SII capital surcharge beyond 2016. Cyprus, Germany, Ireland, Greece, Lithuania, Portugal and Slovenia delayed the activation of the buffer beyond 2016. In addition, different multi-year linear phase-in periods have been adopted, with Estonia, Finland, Lithuania and Slovenia being the only countries that required fully loaded implementation already from the first year. Finally, it is worth mentioning that national competent or designated authorities need to notify their intention to the ECB prior to deciding to request new capital requirements, including O-SII buffers. The ECB may object, stating

[11] For example, the EU member states considered, together with the score, the banks' size, lending activity and other optional indicators such as historical losses and the gross domestic product.

its reasons (Article 5(1) of the SSM Regulation). The ECB can still apply higher requirements for capital buffers than those applied by the national authority (Article 5(2)), though this "top-up" power has never been enforced so far.

3.2 Data

In this section, we outline our primary data sources. We rely on two data sources: the EBA's implementing technical standards on supervisory reporting (i.e., Common Reporting Framework, Corep and Financial Reporting Framework, Finrep) and the notifications from national authorities on the O-SII buffer.

In particular, the centralised European supervision setting is exploited by using:

(1) A quarterly confidential supervisory dataset, between 2014 Q4 and 2018 Q3, with 278 euro area banks at consolidated level from 19 euro area countries (Table 2), which includes both O-SII banks and non-systemically important banks (non-OSII banks). Data includes information on volumes of exposures, risk-weighted assets, non-performing loans, assets, return-on-assets, and capital indicators such as the CET1 ratio, the total capital ratio, and the voluntary buffer. Our database is meticulously constructed using a diverse array of thresholds and assigned O-SII buffers, as officially announced by the respective national regulatory authorities. This approach ensures that our dataset accurately captures the multi-cutoff regulatory landscape across different jurisdictions, reflecting the nuanced capital requirements specific to each country's financial system. The compilation of this information has been ongoing since 2014 when it became publicly available.[12] Out of 278 entities in the sample, 105 banks (at consolidated level) were identified as O-SII.[13] The remaining 173 banks (the control group) are not subject to O-SII buffers.

(2) A unique internal dataset on O-SII banks, which includes, for example, information on the required capital buffer levels and the dates of O-SII notifications. By complementing confidential supervisory data with information provided by national authorities, we are able to estimate the overall scores of banks in the sample and calculate their distance from the threshold for automatic identification as O-SII.[14]

To identify how banking groups adjust their capital buffers in response to higher capital requirements, different indicators are considered. The main variable of interest is the banks' capital headroom ("voluntary buffer"), in excess of regulatory requirements.[15] Our study uses as dependent variable the voluntary buffer both in levels and ratio. To capture possible bank deleveraging or derisking we control for the risk-weighted assets. The return-on-assets ratio is also included to measure banks' profitability. The descriptive statistics of the main variables are presented in Table 3, below, and in Figures 3 and 4 in the Appendix.[16] The banks' assets (in millions of euros) are used as a variable to measure the size of the banks. Finally, the non-performing loans ratio is also used to proxy the health of banks' balance sheets.

[12] Documents are available at `https://www.esrb.europa.eu/national_policy/systemically/html/index.en.html`

[13] In Austria, Raiffeisen Zentralbank is not considered in our sample as it merged with Raiffeisen Bank International. In Germany, Volkswagen Financial Services AG has been excluded given the very specific business model. In Ireland, DePfa Bank plc is excluded due to the buffer assignment of zero. In Slovenia, 3 banks identified as O-SIIs were less significant institutions (LSI), and some supervisory data were incomplete. 9 institutions were excluded because they were identified not as banks but rather as financial institutions. Additionally, 5 banks were excluded due to their concurrent designation as G-SII.

[14] The relevant threshold considered depends on the home country of the reporting bank.

[15] The CET1 voluntary buffer is the amount by which a bank's CET1 capital exceeds its regulatory requirements, including Pillar 2 Guidance.

[16] For standard approach (STA) exposures the risk-weights are defined according to external ratings or level of collateralisation, as detailed in the Regulation (EU) No 575/2013 ('CRR'). For internal ratings based approach (IRB) exposures the risk-weights are calculated according to Articles 153 and 154 of the CRR.

Table 2: O-SII buffer implementation

	Number of Banks (1)		Average Score		Year of Notification
	O-SII (2)	Not O-SII	O-SII	Not O-SII	
Austria	8 (6)	14	768	102	{2015, 2018}
Belgium	8 (7)	4	1,075	129	{2015}
Cyprus	12 (6)	1	1,882	81	{2015, 2017, 2018}
Germany	16 (14)	34	449	67	{2015}
Estonia	4 (4)	4	2,293	122	{2016, 2017}
Spain	6 (4)	18	981	297	{2015, 2016}
Finland	4 (4)	9	885	594	{2015}
France	6 (4)	13	1,153	498	{2015}
Greece	4 (4)	2	2,461	38	{2015}
Ireland	7 (6)	4	697	235	{2015, 2016}
Italy	4 (3)	33	1,222	235	{2016, 2017}
Lithuania	4 (4)	2	2,166	82	{2015}
Luxembourg	9 (9)	5	368	94	{2015, 2017}
Latvia	6 (6)	8	1,262	167	{2016}
Malta	3 (3)	1	1,358	299	{2015}
Netherlands	5 (5)	11	1,633	39	{2015, 2017}
Portugal	6 (6)	6	1,417	105	{2015}
Slovenia	8 (5)	2	1,575	109	{2015}
Slovakia	5 (5)	2	884	64	{2015}
Total	125 (105)	173			

Notes: The table summarises the implementation details of O-SII buffers across various countries and across years (2015, 2016, 2017, 2018). The first two columns present the total number of banks in the sample, categorised into O-SII and non-OSII banks, while the subsequent columns provide the average score for each group (not including the banks designated as O-SIIs when subject to supervisory judgment). (1) The banks selected in the sample are considered at the consolidated level to ensure consistency with the consolidation level of the treated group. (2) The number of banks identified as O-SII is displayed without brackets, while the number of banks available/identified as O-SII with a buffer higher than zero is displayed in brackets (). Finally, the "Year of Notification" column specifies the initial notification date of the O-SII buffers. In Austria, Raiffeisen Zentralbank is not considered in our sample as it merged with Raiffeisen Bank International. In Germany, Volkswagen Financial Services AG has been excluded given the very specific business model. In Ireland, DePfa Bank plc is excluded due to the buffer assignment of zero. In Slovenia, 3 banks identified as O-SIIs were less significant institutions (LSI), and some supervisory data were incomplete. 9 institutions were excluded because their were not identified as banks but rather as financial institutions. Additionally, 5 banks were excluded due to their concurrent designation as G-SII.

Table 3 reports the mean (μ) and standard deviation (σ) of the main variables in the sample, calculated separately for banks below and above the threshold (identifying systemic importance) under the O-SII capital requirement. The table shows that, on average, voluntary buffers are smaller for O-SII banks. However, this cannot obviously be taken as reflecting the causal effects of the O-SII capital requirements, given that other possibly unobservable features may correlate with both aspects. Appendix A (Figures 3 and 4) also presents the distributions of the main variables.

Table 3: Descriptive statistics

	Voluntary buffer (percentage of RWA)	Voluntary buffer (million euros)	RWA (million euros)	ROA (percentage of assets)	NPL (percentage of loans)	Assets (million euros)	CET 1 ratio (percentage of RWA)
Non-OSII							
μ	6.80	695	17,879	0.31	9.34	46,018	16.94
σ	(8.334)	(1,850)	(52,620)	(1.046)	(11.226)	(154,849)	(8.673)
N	2,233	2,233	2,235	1,965	1,865	1,965	2,233
O-SII							
μ	5.57	3,526	89,492	0.28	11.2	228,727	17.99
σ	(6.002)	(5,369)	(141,479)	(0.638)	(14.994)	(391,152)	(9.900)
N	751	751	753	744	708	744	751
All banks							
μ	6.49	1,408	35,926	0.28	9.85	96,197	17.20
σ	(7.831)	(3,364)	(89,873)	(0.953)	(12.403)	(256.948)	(9.007)
N	2,984	2,984	2,988	2,709	2,573	2,709	2,984

Notes: Data spans between 2014 Q4 and 2018 Q3. The table provides summary statistics — mean (μ), standard deviation (σ), and the number of observations (N) — for all institutions, as well as separately for banks categorised as eligible (O-SII) and non-eligible (non-OSII) as systemically important institutions. The dependent variable, representing the banks' voluntary buffer, is presented in both millions of euros and as a ratio, and the CET 1 ratio is presented as percentage. Also, the table presents the mean and standard deviation values for relevant bank characteristics, used as control variables, such as the risk-weighted assets (RWA) and assets, expressed in millions of euros, as well as the return-on-assets (ROA) and non-performing loans (NPL), expressed as percentages.

4 Empirical strategy

4.1 A regression-discontinuity approach to derive exogenous variation in capital requirements

The fact that the national authorities assign a capital requirement (i.e., O-SII buffer) based on an automatic calculation of a score and given thresholds, provides a natural setting for a regression discontinuity design. Banks have to comply with the additional capital requirement when their score passes a threshold. National authorities define buckets, each corresponding to a 0.25 percentage point increase in the O-SII capital buffers, as can be seen in Figure 1. The approach allows us to identify the random variations in treatment, as very similar banks with very similar scores may end up falling just below or just above the threshold and, as such, randomly receive different capital requirements. This is discussed in more detail in Section 3.1.

The underlying idea is that banks with a score slightly higher than the threshold are considered systemically important institutions, but they are not materially different from those banks slightly below the threshold, which are therefore not classified as systemically important. Based on Cattaneo et al. (2020a and 2020b), the underlying assumption is that the treatment assignment is unrelated to other covariates in a window around the cutoff, and the potential outcomes are allowed to depend directly on the score.[17]

[17] A difference-in-differences approach is not as good as the regression discontinuity design in taking account of these issues because observed and unobserved bank characteristics may affect both the adoption of the policy and the trends of the potential outcomes. This approach would be invalidated if banks of different sizes followed different trends before the adoption of the measure.

Thus, the automatic calculation provides a randomised experiment allowing us to implement a regression discontinuity design.[18] In other words, the EBA assessment protocol induces a randomised experiment in the neighborhood of the threshold, allowing us to causally identify the effect of higher capital requirements on banks' voluntary buffers by comparing the change in the outcome of banks just above and below the cutoff.

We also explore how the marginal effect of the O-SII buffer varies with bank-specific characteristics. The model used includes control variables, as well as time and country fixed-effects. To ensure the validity of the regression discontinuity design, we perform a series of robustness tests (Section 6).

4.2 Baseline specification

The regression discontinuity design relies on the assumption that unobservable characteristics do not vary discontinuously around the cutoff. This makes the institutional decision rule provide exogenous variation in the treatment as banks close to the threshold randomly end up just below or just above the threshold. We extend the standard regression-discontinuity approach to leverage the exogenous variation across the multiple thresholds that define the various buckets in our sample, as presented in Figure 1. This enhanced approach allows us to assess the impact of higher capital requirements (O-SII buffer) on banks' voluntary buffers using the following baseline specification:

$$Y_{i,t} = \beta_0 + \beta_1 Treated_{i,t} + \beta_2 Score_{i,t} + \beta_3 Treated_{i,t} Score_{i,t} + \sum_{k=1}^{K} \beta_{2,k} X_{i,t,k} + u_{t,c(i)} + \varepsilon_{i,t} \quad (1)$$

Where $t = 1,...,T$ and $i = 1,...,N$ are quarter and bank subscripts, respectively. $Y_{i,t}$ is the outcome variable under consideration. $Score_{i,t}$ is the score of bank i at time t, in difference from the closest thresholds. $Treated_{i,t}$ is a dummy denoting observations with $Score_{i,t-1} > 0$. $X_{i,t}$ is a bank characteristic used as control variable ($k = 1, ..., K$). $u_{t,c(i)}$ are country*time fixed effects absorbing the effect of domestic time-varying macroeconomic conditions. $\varepsilon_{i,t}$ is the individual error term. To account for multiple buckets, each bank's score is measured relative to the nearest threshold. The dummy variable $Treated_{i,t}$ is therefore defined to reflect a bank's score relative to the banks around the closest O-SII threshold. In jurisdictions where the O-SII framework is not in place during a given period, $Treated_{i,t}$ is set to 0 for all domestic banks.

Under mild regularity assumptions on the standardised score, it is possible to use the standard sharp regression discontinuity design (Cattaneo et al., 2020a and 2020b). The adopted specification considers a local polynomial regression. A linear specification is adopted, for robustness. Equation (1) therefore requires the estimation of a linear model in the running variable ($Score_{i,t}$), where both the intercept and slope are allowed to vary between the two sides of the cutoff. The coefficient of interest is β_1. In order to focus on the comparison between data points just below a threshold and those just above it, a triangular kernel is used as a weighting scheme. This approach assigns greater weight to observations closest to the cutoff in the running variable, gradually decreasing the weight for those further away. Regarding the choice of the bandwidth, that is the choice of the set of data points around the cutoff receiving a positive weight, we rely on a data-driven selection approach. Different bandwidths are presented, where the smaller ones reduce the

[18] The original motivation for a local randomisation approach was given by Lee (2008) and has been bolstered by several studies showing that regression discontinuity designs can recover experimental benchmarks (e.g., Green et al., 2009; Calonico et al., 2014a, 2014b, 2015, 2016 and 2019). Thistlethwaite and Campbell (1960), Hahn et al. (2001), Lee and Lemieux (2010), Leonardi and Pica (2013), Grembi et al. (2016) and Imbens and Lemieux (2008) also use the regression discontinuity design.

misspecification error of the local polynomial approximation, but at the same time increase the variance of the estimated coefficients due to the lower number of observations. [19]

Since the actual introduction of the O-SII capital buffers has often been postponed in time and phased in over several time periods, in our setup the beginning of the treatment corresponds to the date in which the bank is assigned the capital requirement, as opposed to the earlier moment in which the designation is communicated to the ECB. Moreover, in a few other cases, national authorities designated banks as systemic even when their score was below the threshold, i.e., via the expert supervisory judgment. We removed these banks when estimating our baseline specification, though we also present an alternative approach that takes into account the fuzziness in the assignment rule (Appendix Table 14.)

The baseline specification focuses on the implications for voluntary buffers of (marginally) higher capital requirements, from one bucket to the next one, typically involving a 25 bp increase in O-SII buffers or multiples of it, with an average of about 50 bps. An alternative approach is also implemented by testing a different specification that focuses on the effect of the implementation of the O-SII buffer versus not being identified as O-SII. In this case, the probability of a bank being designated as O-SII increases significantly and discontinuously if a bank receives a score above the threshold. In Appendix E, the results relying on a fuzzy regression discontinuity design are presented.

4.3 Heterogeneous effects

To study the presence of possibly heterogeneous effects, we enhance the baseline specification as follows.

$$Y_{i,t} = \beta_0 + \beta_1 Treated_{i,t} + \beta_2 Score_{i,t} + \beta_3 Treated_{i,t} Score_{i,t} + \beta_{2,j} X_{i,t,j} + \beta_3 Treated_{i,t} X_{i,t,j} + u_{t,c(i)} + \varepsilon_{i,t,k} \quad (2)$$

Equation (2) differs from Equation (1) only in the fact that we interact the running variable ($Treated$) with the control variables $X_{i,t,j}$. We replicate this analysis for each j and the result are presented in Table 6. Equation (3) instead presents the multivariate model where we include all interaction terms (one for each

[19] We employ a range of data-driven optimal bandwidth selection procedures, based on minimising either the mean squared error (MSE) of point estimates or the coverage error rate (CER) of confidence intervals. We consider all those produced in the STATA package ”rdrobust” for this purpose. MSE-optimal bandwidth selectors are designed to minimise the expected squared error of the estimator. The MSEsum-optimal bandwidth selects a single bandwidth that minimises the MSE of the sum of the regression estimates on both sides of the cutoff, rather than their difference. The MSErd-optimal bandwidth — the default in most empirical applications — chooses a single bandwidth that minimises the MSE of the treatment effect estimator, that is, the difference in regression estimates at the cutoff, and is therefore the standard for estimating the local average treatment effect in RDD. The MSEtwo-optimal bandwidth allows for different bandwidths on each side of the cutoff, adapting to possible asymmetries in data density or variance, and can thus improve estimation by minimising MSE separately on each side. The MSEcomb1-optimal bandwidth takes the minimum of the MSErd and MSEsum bandwidths, providing a conservative choice that guards against selecting an excessively large bandwidth and potential bias. The MSEcomb2-optimal bandwidth selects, for each side of the cutoff, the median value among the MSEtwo, MSErd, and MSEsum bandwidths, offering a robust compromise among the main MSE-optimal selectors. CER-optimal bandwidth selectors are specifically designed for inference, aiming to minimise the error in the coverage probability of confidence intervals, which is particularly important when using robust bias-corrected inference. The CERsum-optimal bandwidth selects a single bandwidth to minimise the CER for the sum of regression estimates at the cutoff, analogous to MSEsum but focused on inference. The CERrd-optimal bandwidth minimises the CER for the treatment effect estimator, directly paralleling MSErd for inference purposes. The CERtwo-optimal bandwidth allows for different bandwidths on each side, each chosen to minimise the CER for the treatment effect estimator, mirroring the logic of MSEtwo. The CERcomb1-optimal bandwidth takes the minimum of CERrd and CERsum, providing a conservative inference-oriented choice, while the CERcomb2-optimal bandwidth selects, for each side, the median of CERtwo, CERrd, and CERsum, offering a robust compromise for inference. These bandwidth selection strategies are grounded in the methodological literature, particularly the work of Calonico, Cattaneo, Farrell, and Titiunik (2016, 2019), and have become standard practice in contemporary RDD analysis due to their data-driven nature and strong theoretical justification.

control variable) in a unique specification. The results are presented in Table 6.

$$Y_{i,t} = \beta_0 + \beta_1 Treated_{i,t} + \beta_2 Score_{i,t} + \beta_3 Treated_{i,t} Score_{i,t} + (\sum_{k=1}^{K} \beta_{2,k} X_{i,t,k} + \beta_{3,k} Treated_{i,t} X_{i,t,k}) + u_{t,c(i)} + \varepsilon_{i,t} \quad (3)$$

5 Results

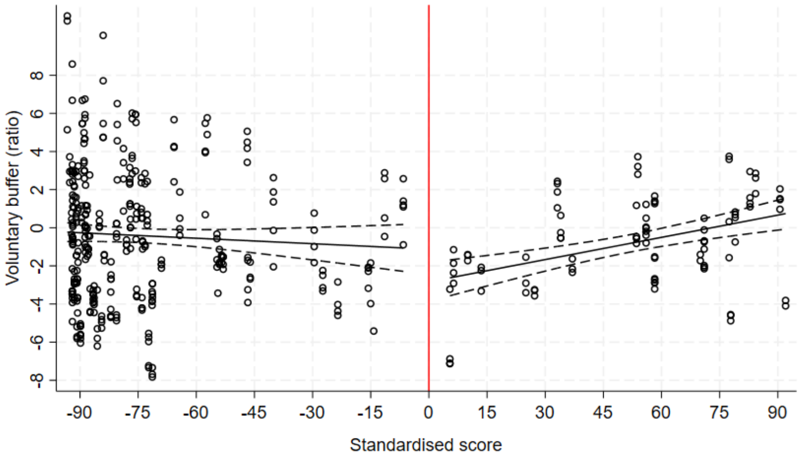
5.1 Main findings

The objective of this paper is to study the implications of (marginally) higher capital requirements for voluntary buffers. Figure 2 illustrates graphically the approach we follow. Banks are grouped into buckets depending on their score and the interval in which this is included. Each dot in the chart is an observation (a bank in a given period). The level of the corresponding bank voluntary buffer ratio is represented on the y-axis, in deviation from the corresponding buckets' average (for comparability, buckets are assumed to be country-specific). The level of the corresponding bank score is represented on the x-axis, in deviation from the cutoff (the threshold for the score defining banks that are assigned a positive O-SII buffer rate). For banks in the several jurisdictions adopting multiple buckets for the O-SII calibration, we consider as relevant cutoff the closest one. This means that banks with a score between two cutoffs can have either a positive or a negative standardised score. In this way we can visualise the effect on the voluntary buffer ratio of having a score just above a given cutoff level, as opposed to being just below, that is the effect of a small but positive level of the standardised score as opposed to a small but negative level. And we can do so while taking into account that there are several cutoffs and that banks in different buckets can exhibit structural differences including in the level of voluntary buffers, which is why we consider the voluntary buffer ratio in deviation from the corresponding bucket's average. The visual inspection highlights a significant degree of dispersion across banks in the voluntary buffer ratio, even with relatively similar levels of (standardised) score. Yet, the chart is consistent with a moderate decline in the voluntary buffer ratio for banks just above the unique relevant cutoff level for the standardised score, which is at 0, as indicated by the vertical red bar.[20]

A more formal assessment is presented in Table 4. As in Figure 2, the dependent variable is the banks' voluntary buffer ratio, in deviation from the corresponding bucket's average; the running variable used to construct the bandwidths is the standardised score. Different methodologies for the optimal choice of a bandwidth are considered: mean square error (MSE) optimal bandwidths, and coverage error rate (CER) optimal bandwidths. Point estimates and confidence intervals are computed with both the conventional and bias-corrected method (Calonico et al., 2014a). Some dispersion is observable across the different estimates provided, both in terms of magnitude and statistical significance. Yet, the broad picture emerging indicates that an increase in capital requirements, O-SII buffers, is partly offset by a contraction in the voluntary buffers. Considering that the average increase in the O-SII buffer across the different thresholds included in the sample is around 0.5 percentage points, and considering the average estimated coefficient, equal to 0.35 percentage points, the offset is about two thirds. Section 6 below presents a number of empirical validation tests and robustness checks for such regression discontinuity design. The economic intuition behind Table

[20]This statement is corroborated by preliminary regressions fitting linear relationships between the two variables on either side of the cutoff. These regressions are run without considering any additional controls and based on an arbitrary optimal bandwidth selection. Below we explore at length the sensitivity to alternative approaches for the bandwidth selection.

Figure 2: Bank voluntary buffer close to marginally higher O-SII buffer (buckets)



Notes: The y-axis displays the outcome variable, which is the voluntary buffer in ratio. The data is presented standardised for each bucket associated to the O-SII buffer amount. The data is trimmed at the 5th and 95th percentiles. The x-axis depicts the standardised score distance for each bank from the country's threshold. The non-dashed line plots fitted values of the regression of the dependent variable on the score distance from the threshold. It is estimated separately on each side of the cutoff. The dashed lines represent the 95 percent confidence interval. No controls are included. The optimal bandwidth is selected using the MSEsum method, which minimizes the sum of the mean squared errors (MSE). The reporting data used is at consolidated level.

4 is that when banks are facing marginally higher O-SII buffers, they largely use their voluntary buffer to satisfy the higher capital requirement, therefore mitigating the necessity to raise costly new equity or to deleverage, thereby foregoing profitable investment opportunities.

The above results indicate an important role for voluntary buffers, in the sample under examination, as a tool for banks to absorb a large part (two thirds) of the increase in capital requirements. There are two alternative possible ways for banks to accommodate the remaining part: either by increasing equity or by deleveraging. We test for the relative role of these two effects by running regressions similar to those presented in Table 4, except for the dependent variable considered which now is the percentage CET1 ratio, again in deviation from the corresponding bucket's average. The idea behind this exercise simply relates to the notion that if banks react by increasing equity, this should be one-to-one reflected in increases in the total capital ratio, that is the sum of the capital requirement and the voluntary buffer ratio. In the opposite polar case where the adjustment (on top of the one obtained by eroding voluntary buffer) is undertaken by deleveraging, the total capital ratio remains unaffected. In this way we can provide a complete characterisation of the balance sheet implications of higher capital requirements, including on the liability side, which is the focus of this paper. The results of this exercise, shown in Table 5, indicate that an increase in capital requirements is associated with an increase in the total capital ratio which is neither statistically nor economically significant, and is in all alternative estimates below 1 basis point. This suggests that the one third of the adjustment to the increase in capital requirements not explained by the decline in voluntary buffers is achieved by a reduction in risk-weighted assets.[21] This result is consistent with those documented in the literature about

[21]Taking for given the estimation in Table 4, this coefficient is bound to be below 15 basis points. This is the maximum it can be expected to reach when all the adjustment to the (50 basis points) increase in capital requirements and not explained by the (35 basis points) decline in voluntary buffers is achieved by increasing equity.

Table 4: Average effect of marginally higher O-SII buffer requirements on banks' voluntary buffer

	Conventional	Bias-corrected
MSEsum-optimal bandwidth	-0.306**	-0.353**
	(0.155)	(0.155)
Bandwidth	103	103
MSErd-optimal bandwidth	-0.283*	-0.325*
	(0.167)	(0.167)
Bandwidth	94	94
MSEtwo-optimal bandwidth	-0.166	-0.165
	(0.160)	(0.160)
Bandwidth	[141,273]	[141,273]
CERsum-optimal bandwidth	-0.453**	-0.481**
	(0.229)	(0.229)
Bandwidth	79	79
CERrd-optimal bandwidth	-0.629***	-0.653***
	(0.238)	(0.238)
Bandwidth	72	72
CERtwo-optimal bandwidth	-0.210	-0.212
	(0.147)	(0.147)
Bandwidth	[108,210]	[108,210]
Observations	1,432	1,432

Notes: This table presents the estimates for the sharp regression discontinuity design analysing the effect of marginally higher treatments (capital buffer requirements for O-SII). The dependent variable is the bank voluntary buffer ratio, in deviation from the corresponding bucket's average. It is expressed in percentage points. The running variable used to construct the bandwidths is the standardised score (the O-SII score in deviation from the closest threshold). Estimations are based on local linear regressions, a triangular kernel and optimal bandwidths selected via different MSE and CER criteria (sum, rd, two). Results for comb1 and comb2 bandwidth selection are presented in Model 1 in Table 8 of the Appendix. Two different procedures are displayed: (i) conventional RD estimates with conventional variance estimator, (ii) bias-corrected RD estimates with conventional variance estimator. The estimates are conditional on the following controls: return-on-assets (ROA), the logarithm of risk-weighted assets (RWA) and non-performing loans ratio (NPL), with country-quarter fixed effects. Robust standard errors (clustered by bank) are in parentheses. The data is trimmed at the 5th and 95th percentiles to reduce the influence of extreme values on the precision of the estimates. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively.

the asset-side implications of higher capital requirements. Authors find that banks subject to higher capital requirements, as the O-SII buffer, deleverage or derisk their denominator of the capital ratio (these include, among others, Admati et al., 2018; Gropp et al., 2019; Cappelletti et al., 2024, and Ponte Marques et al., 2024).

Table 5: Average effect of marginally higher O-SII buffer requirements on banks' CET1 ratio

	Conventional	Bias-corrected
MSEsum-optimal bandwidth	0.004	0.005
	(0.006)	(0.006)
Bandwidth	102	102
MSErd-optimal bandwidth	0.003	0.004
	(0.006)	(0.006)
Bandwidth	117	117
MSEtwo-optimal bandwidth	0.000	0.000
	(0.003)	(0.003)
Bandwidth	[128,527]	[128,527]
CERsum-optimal bandwidth	0.007	0.008
	(0.007)	(0.007)
Bandwidth	78	78
CERrd-optimal bandwidth	0.006	0.006
	(0.006)	(0.006)
Bandwidth	90	90
CERtwo-optimal bandwidth	0.001	0.001
	(0.003)	(0.003)
Bandwidth	[98,404]	[98,404]
Observations	1,579	1,579

Notes: This table presents the estimates for the sharp regression discontinuity design analysing the effect of marginally higher treatments (capital buffer requirements for O-SII). The dependent variable is the bank's CET1 ratio, in deviation from the corresponding bucket's average. The running variable used to construct the bandwidths is the standardised score (the O-SII score in deviation from the closest threshold). Estimations are based on local linear regressions, a triangular kernel and optimal bandwidths selected via different MSE and CER criteria (sum, rd, two). Results for comb1 and comb2 bandwidth selection are presented in Model 2 in Table 8 of the Appendix. Two different procedures are displayed: (i) conventional RD estimates with conventional variance estimator, (ii) bias-corrected RD estimates with conventional variance estimator. The estimates are conditional on the following controls: return-on-assets (ROA), the logarithm of risk-weighted assets (RWA) and non-performing loans ratio (NPL), with country-quarter fixed effects. Robust standard errors (clustered by bank) are in parentheses. The data is trimmed at the 5th and 95th percentiles to reduce the influence of extreme values on the precision of the estimates. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively.

5.2 Heterogeneous effects

This subsection assesses the presence of heterogeneous effects of capital requirements on voluntary buffers. It does so by specifically exploring the role of some bank characteristics which can be expected to be relevant in this respect.

Table 6 extends the baseline specification presented in Table 4 in a way that allows assessing such heterogeneous effects. It interacts the dummy $Treated$, which identifies all observations with a positive standardised score, with some banks' characteristics such as their current non-performing loan ratio (NPL), return-on-asset (ROA) and risk-weighted assets (RWA).[22]

[22] For comparability, the regressions are conducted by considering the same bandwidths of Table 4 and the corresponding weighting scheme. RWA is taken in logarithms, in order to address possible repercussions of its skewed distribution. Results are displayed for the mean-squared error MSE-sum optimal bandwidth, but a broadly consistent picture emerges when considering alternative bandwidths adopted in Table 4. All variables considered for the interaction terms are also included as additional controls, not interacted. The number of observations diminishes considerably, reflecting limited data availability for some of these banks.

Table 6: Heterogeneous effects of capital requirements on voluntary buffer (ratio) — Multivariate analysis

Variables	Model 1	Model 2	Model 3	Model 4
Treated	-0.540**	-0.320	-0.349	-0.601**
	(0.266)	(0.215)	(0.211)	(0.274)
Standardised score	-0.000	-0.001	-0.001	-0.000
	(0.002)	(0.002)	(0.002)	(0.002)
Treated*Standardised score	0.011*	0.007	0.007	0.010*
	(0.005)	(0.005)	(0.005)	(0.006)
Treated*NPL	0.109*			0.115**
	(0.058)			(0.056)
Treated*ROA		-0.055		0.081
		(0.316)		(0.216)
Treated*RWA			0.084	0.136
			(0.168)	(0.172)
Constant	0.050	0.024	0.046	0.089
	(0.140)	(0.138)	(0.159)	(0.164)
Observations	359	359	359	359
R-squared	0.035	0.024	0.024	0.036
Controls	Yes	Yes	Yes	Yes
MSEsum-optimal bandwidth	103	103	103	103

Notes: This table presents the estimates for the heterogeneous effects of the application of capital requirements across different banks' characteristics. The dependent variable is the banks' voluntary buffer, in ratio. The running variable, *Treated*, is a dummy indicating if the bank is above (1) or below (0) the specific threshold for O-SII capital requirements. The bank characteristics return-on-assets ratio (ROA), the logarithm of risk weighted assets (RWA) and non-performing loan ratio (NPL) are interacted with the above *Treated* variable: interaction ROA (Model 1), interaction RWA (Model 2), and interaction NPL (Model 3). Model 4 presents all covariates interacted with the running variable together in one regression. The estimates are conditional on the following controls: NPL, ROA and RWA. The Models present the results for mean squared error (MSE) sum optimal bandwidth. The estimates are obtained using bank and quarter fixed-effects and the robust standard errors are clustered by bank. The data is trimmed at the 5th and 95th percentiles for all variables to reduce the influence of extreme values on the precision of the estimates. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively.

Banks' tendency to offset increases in capital requirements by reducing their voluntary buffers can be expected to be influenced by their asset quality (NPL) because these institutions could face market pressure to preserve their management buffer, also reflecting a more difficult or costly access to financial markets when trying to issue new bonds or equity. Conversely, for opposite considerations, highly profitable banks might be less resistant in eroding their voluntary buffer, also anticipating that they might be able to replenish them more quickly in the future, if needed. Similar considerations apply to larger-size banks, who tend to have a more facilitated access to financial markets reflecting, for instance, a higher degree of diversification. Results in Table 6 show that the only significant interaction term is the one with the non-performing loans ratio. This holds both when taken in isolation and in the multivariate specifications where the three interaction terms are added all at once.[23] These coefficients imply an economically significant heterogeneity in the impact of *Treated* across O-SII banks characterised by different levels of asset quality. Specifically, for banks with a non-performing loan ratio (in deviation from the corresponding bucket average) equal to the 75th percentile of the distribution (0.2 percent), such elasticity is 0.2 percentage points larger than that for intermediaries with an NPL ratio equal to the 25th percentile (-1.3 percent). Therefore, banks with low asset quality tend

[23]The average effect on the voluntary buffer ratio implied by Model 1 of Table 6 is similar to the effect presented in Table 4, though slightly higher, the difference being explained by the different sample considered.

to accommodate almost in full the increase in capital requirements by eroding their voluntary buffer ratio. By highlighting such heterogeneity, these results offer an interesting new cross-sectional perspective on the role that macroprudential policy can play, particularly in an environment characterised by a high level of capital ratios. Macroprudential policy is effective in enhancing the resilience of the financial system, by supporting in particular the capitalisation of weaker banks.

6 Validation of the empirical strategy and robustness checks

The regression discontinuity design relies on the key assumption that banks do not intently try to "manipulate" their scores to fall below the threshold and be identified as non-OSII. This is essential for causally identifying the effect of higher capital requirements on banks' voluntary buffer. It is possible to be confident that banks do not manipulate their score to fall below or rise above the threshold for two reasons: i) the feature of the O-SII framework that does not allow for a manipulation of the scores (as explained below and also in Section 3), and ii) the validation tests provided in this Section.

Firstly, the O-SII score depends on several variables: banks' characteristics, size of the national banking system, supervisory expert judgment. Because of this, it is unlikely that each bank can predict its score and "manipulate" it to stay below the threshold (thus influencing the probability of being identified as an O-SII).[24] Secondly, an empirical test of density continuity at the cutoff is implemented, the McCrary (2008) test (in the Appendix, upper panel of Figure 5). The density of the standardised scores (score minus threshold) does not present evidence of manipulation at the threshold. The non-jumpy distribution of the scores with respect to the threshold can be interpreted as absence of manipulative sorting. Thirdly, it is important to check that O-SII banks near the cutoff have similar characteristics to non-OSII banks, since this would support the assumption that banks lack the ability to manipulate the value of the score received. This also allows us to consider the treatment, at the threshold, as random. In particular, predetermined covariates (in our study, risk-weighted assets, non-performing loans, and return-on-assets) should be similar across treated and untreated banks, just above and below the cutoff. For this purpose, the continuity of the covariates at the cutoff is tested. Table 7 and Figure 6 in the Appendix confirm the continuity of the covariates between treated and untreated groups, as the jumps are non-significant. These results provide evidence of the absence of non-random sorting by banks close to the threshold, therefore justifying a randomised experiment. Also, results presented in Tables 4 and 6 are robust and independent of the selected bandwidths. This is ensured by using different data-driven selection approaches to set an optimal bandwidth. Our results are consistent for the different combinations of bandwidths, thus attesting their robustness. The optimal bandwidth selectors applied here are the mean square error (MSE) and coverage error rate (CER).

In Section 5, the effect of receiving a marginally higher O-SII buffer requirement is studied, for banks falling just above the bucket threshold, and banks falling just below the bucket threshold and receiving a lower O-SII buffer requirement (or none). The current Subsection is rather focused on the effect of banks receiving an O-SII buffer requirement, and banks falling below the threshold therefore not receiving an O-SII buffer requirement (Appendix, Table 14). For this, a fuzzy regression discontinuity design is applied, as the probability of being identified as an O-SII bank is not dichotomous, due to the supervisory expert judgment (Figure 7, in the Appendix). The assumptions for the RDD are satisfied as can be seen in Figure 8. This specification allows us to address two different features of our analysis: 1) study the effect of the

[24] An example is to reduce assets via deleveraging.

O-SII buffer requirement on banks' voluntary buffer, without considering the different magnitudes of the buffer; 2) account for the supervisory expert judgment, when banks below (or above) the main threshold receive (or not) the buffer requirement, as discussed in Section 3. Our results for the fuzzy regression discontinuity design are negatively consistent and significant (just in few specifications), for both the effect of the introduction of an O-SII buffer on banks' voluntary buffer in ratio (Appendix, Table 14). Thus, results are consistently negative also when taking into account the main threshold of eligibility of an O-SII and the supervisory expert judgment (i.e., when banks below (or above) the main threshold receive (or not) the buffer requirement).

Our results are also tested for robustness. First, in the Appendix, Tables 12 and 13 depict a placebo cutoff which is used to check whether the regression functions are continuous at points other than the given cutoff (as suggested by Cattaneo et al., 2020a and 2020b). This method allows us to prove the robustness of the regression discontinuity design, where no significant treatment effect should occur at the artificial cutoff values. Evidence of discontinuities away from the cutoff could provide doubts on the regression discontinuity design, where discontinuities in the usability of the voluntary buffer should only be explained by our specific case studied. For this, the true cutoff value is replaced with another value for which the treatment status does not change. Also, to avoid "contamination" due to real treatment effects, and following Cattaneo et al. (2020a and 2020b), only treated observations are used for artificial cutoffs above the real cutoff, and only control observations are used for artificial cutoffs below the real cutoff. This ensures that the analysis of the placebo cutoff only uses observations with the same treatment status.

7 Conclusion

Looking at the design and effectiveness of the macroprudential framework represents one of the main policy challenges. It is essential that macroprudential policy remains appropriate; therefore, the research question of how banks comply with higher capital buffer requirements is crucial from a financial stability perspective and needs to be studied in depth. Further policy measures may become necessary if macroprudential policy leads to undesirable adjustments to ensure that existing buffers are sufficient to ensure financial stability as envisaged by the policy framework.

This paper provides the first causal evidence on how changes in capital requirements affect banks' voluntary capital buffers — the capital headroom above the regulatory requirement. By focusing on the numerator of the capital ratio, rather than the more widely studied denominator effects related to lending and risk-taking, this study offers a novel view on the transmission of capital regulation and helps reconcile conflicting findings in the literature.

Our findings provide new empirical evidence on how banks adjust their capital structure in response to changes in capital requirements, with a particular focus on banks' voluntary capital buffers. While the regulatory reforms introduced in the aftermath of the Global Financial Crisis were designed to strengthen the resilience of the banking system by increasing the loss-absorbing capacity of banks, our results indicate that the effectiveness of such measures may be partially undermined by banks' offsetting behaviour. Specifically, our evidence shows that banks tend to partly reduce their voluntary buffers when faced with higher capital requirements, rather than raising additional equity, lowering adjustment costs. This behaviour is more relevant for banks facing marginally higher requirements, indicating that treatment intensity matters. This substitution effect suggests that part of the intended regulatory objective — namely, ensuring that banks build up capital — may not be fully realised. The offsetting effect is more pronounced among banks with weaker balance sheets, particularly those with higher levels of non-performing loans. This heterogeneity shows the complexity of the transmission of capital regulation, as well as the relevance of bank-specific characteristics in shaping the response to prudential measures.

These findings complement existing evidence that higher capital requirements may generate unintended consequences for credit supply and, ultimately, the real economy (e.g., Admati et al., 2018; Cappelletti et al., 2024; Ponte Marques et al., 2024).

From a broader perspective, our results contribute to the ongoing debate on the effectiveness of capital-based macroprudential tools. Consistent with the findings of Hanson et al. (2011) and Gropp et al. (2019), our results point out the limitations of focusing mainly on regulatory capital ratios and highlight the importance of ensuring that banks maintain adequate absolute capital levels. This would mitigate the unintended effects of regulatory policy measures, such as muted increases in capitalisation, temporary adverse effects on the real economy attributable to deleveraging, and potential optimisation of risk-weighted assets.

In conclusion, the results of this study reinforce the idea that prudential regulation must strike a delicate balance between setting binding requirements and allowing sufficient flexibility for banks to manage their capital structure. Voluntary buffers play a central role in banks' strategies to safeguard against uncertainty and maintain market confidence, therefore, policymakers may consider the interplay between required and voluntary capital in designing future reforms. By doing so, regulation can better ensure that capital requirements meet their ultimate objective: strengthening the resilience of banks, limiting systemic risk, and safeguarding the real economy.[25]

[25] Macroprudential policy and the respective capital buffer framework was introduced after the Global Financial Crisis, providing a foundation for a resilient banking system that is able to support the real economy through the economic cycle (BCBS, 2011). Capital buffers are placed on top of minimum capital requirements to enhance banks' resilience against economic shocks. Buffers aim to mitigate procyclicality by enabling banks to absorb losses while maintaining their lending activity to the real economy.

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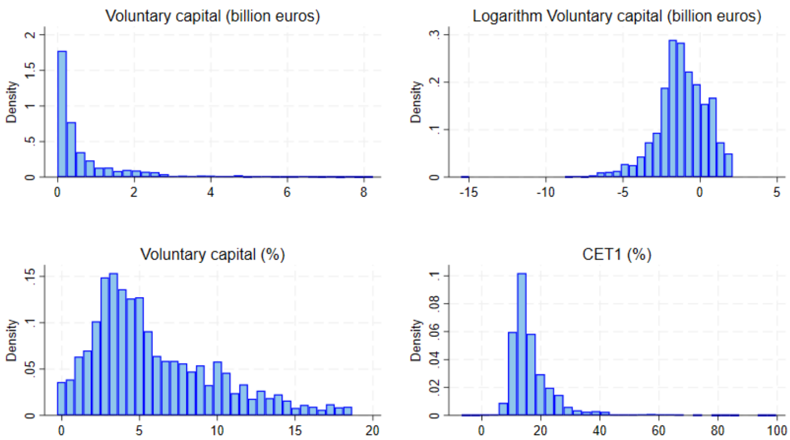
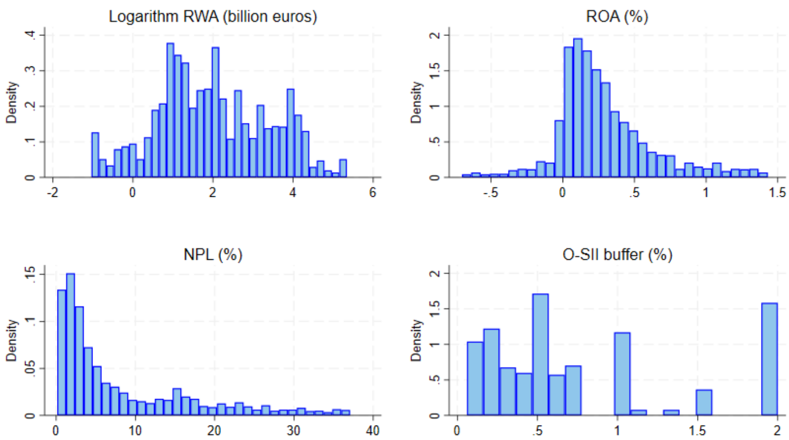
A Descriptive statistics

Figure 3: Density of the dependent variable



Notes: The figure presents the density of the main dependent variables: the voluntary buffer in amount (billions of euros), the logarithm of voluntary buffer in amount (billions of euros), the voluntary buffer ratio and the CET1 ratio. All variables are trimmed at the 5th and 95th percentiles.

Figure 4: Density of the covariates

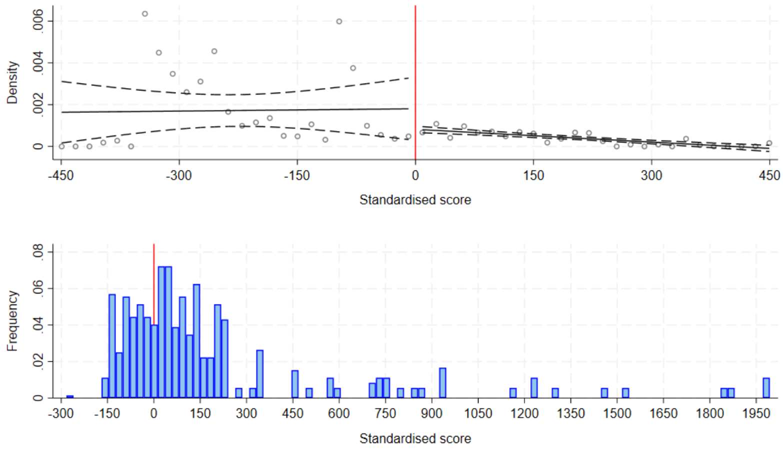


Notes: The figure presents the density of the covariates used in this study: the logarithm of risk-weighted assets in billions of euros (RWA), the return-on-assets ratio (ROA), the non-performing loans as a ratio of total loans (NPL) and the O-SII buffer (percent). All variables are trimmed at the 5th and 95th percentiles, except for the O-SII buffer that by construction, as can be seen from visual inspection, is not supposed to present outliers.

B Validity of the regression discontinuity design

B.1 Manipulation test of the running variable

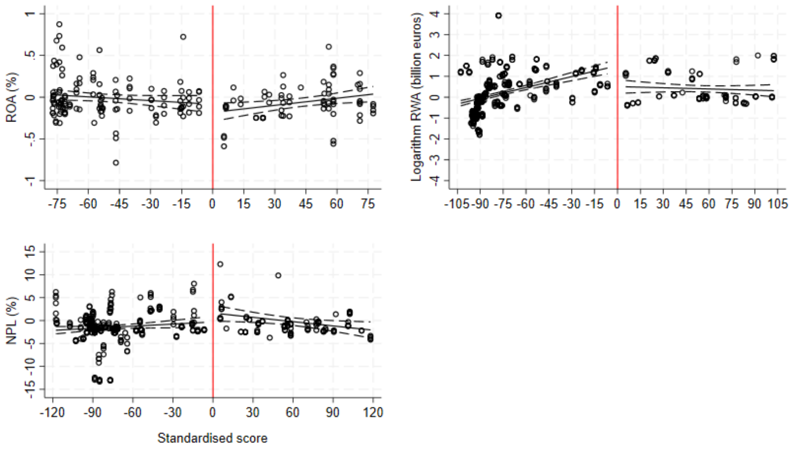
Figure 5: McCrary's manipulation test of the running variable



Notes: The figure presents the McCrary's test (McCrary, 2008) that is used to assess the continuity at the cutoff of the score density. The lower panel represents the density of the standardised scores. The vertical and horizontal axes indicate, respectively, the relative frequency of the banks' scores and the score distance from the threshold. Moreover, on the upper panel, the McCrary test for density continuity is presented. The fitted values of the correlation between the bank's score and the score's distance from the threshold are represented by the solid line between the dashed lines, and the estimation is performed separately on each side of the cutoff. The dashed lines represent the 95 percent confidence interval. The data is trimmed at the 5th and 95th percentiles. The figure allows for a visual test of the analysis based on multiple buckets related with the probability of receiving a marginally higher O-SII capital requirement. From the two figures, it is possible to conclude that there is no significant visual evidence of systematic manipulation of the running variable.

B.2 Continuity of covariates

Figure 6: Continuity of covariates



Notes: The figure presents the test of continuity for covariates by Skovron and Titiunik (2015). The vertical axes presents the outcome variables: the return-on-assets (ROA), the logarithm of risk-weighted assets (RWA) and the non-performing loans (NPL). The data is presented in deviation from the mean for each bucket associated to the O-SII buffer amount. The horizontal axis measures the standardised score of the bank. The central non-dashed line plots the fitted values of the dependent variable on a first-order polynomial in the score distance from the threshold. The fitted values are estimated separately on each side of the cutoff. The dashed lines represent the 95 percent confidence interval. The covariates just above and below the cutoff are not statistically different across treated and untreated banks. This implies the bank's inability to manipulate the value of the score received. The variables ROA, log RWA, and NPL are trimmed at the 5th and 95th percentiles.

Table 7: Continuity of covariates: Marginal average effect of changes in the O-SII bucket on ROA, RWA, and NPL

	ROA (Ratio)		RWA (Log billion euros)		NPL (Ratio)	
MSEsum-optimal bandwidth	-0.11	-0.25*	-0.03	-0.04	0.71*	1.31
	(0.10)	(0.14)	(0.02)	(0.03)	(0.37)	(0.91)
Bandwidth	158	200	142	103	141	116
CERrd-optimal bandwidth	-0.14	-0.26	-0.04*	-0.05	1.04**	1.28
	(0.12)	(0.18)	(0.02)	(0.04)	(0.43)	(0.94)
Bandwidth	120	138	108	76	102	104
MSEtwo-optimal bandwidth	-0.06	-0.22	-0.01	-0.02	0.47	1.15
	(0.07)	(0.15)	(0.02)	(0.02)	(0.37)	(0.87)
Bandwidth	[169,390]	[175,380]	[134,291]	[123,397]	[139,445]	[144,440]
Observations	1,432	1,657	1,432	1,809	1,432	1,581
Controls	Yes	No	Yes	No	Yes	No
FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table presents the test of continuity for covariates (Skovron and Titiunik, 2015). The sharp regression discontinuity design estimates are presented for the effect of banks identified as systemically important (O-SII) separately on their return-on-assets (ROA), the logarithm of risk-weighted assets (RWA), and non-performing loans ratio (NPL). The dependent variables are respectively the bank ROA in percentage, the RWA in billions of euros, and the NPL in percentage. In this regression the effect of the marginally higher treatments is analysed. Thus, the distances of the score from the different thresholds to which a bank is assigned (for incremental O-SII buffers) are considered. Local linear regressions with a triangular kernel are used, employing different optimal bandwidths (MSEsum, CERrd and MSEtwo). The estimates are conditional on the following controls: for ROA: the logarithm of risk-weighted assets (RWA), non-performing loans ratio (NPL), and the banks' voluntary buffer in ratio; for the logarithm of RWA: return-on-assets (ROA), non-performing loans ratio (NPL), and the banks' voluntary buffer in ratio; for NPL: return-on-assets (ROA), the logarithm of risk-weighted assets (RWA) and the banks' voluntary buffer in ratio. The data is trimmed at the 5th and 95th percentiles in order to reduce the influence of extreme values in the precision of the estimates. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively.

C Complementary results

Table 8: Average effect of marginally higher O-SII buffer requirements on banks' voluntary buffer and CET1 ratio (comb1 and comb2 optimal bandwidth selection)

	(1) Vol. buffer ratio		**(2) CET1 ratio**	
	Conventional	Bias-corrected	Conventional	Bias-corrected
MSEcomb1-optimal bandwidth	-0.283*	-0.325*	0.004	0.005
	(0.167)	(0.167)	(0.006)	(0.006)
Bandwidth	94	94	102	102
MSEcomb2-optimal bandwidth	-0.306**	-0.353**	0.003	0.004
	(0.155)	(0.155)	(0.006)	(0.006)
Bandwidth	103	103	117	117
CERcomb1-optimal bandwidth	-0.629***	-0.653***	0.007	0.006
	(0.238)	(0.238)	(0.007)	(0.007)
Bandwidth	72	72	78	78
CERcomb2-optimal bandwidth	-0.453**	-0.481**	0.006	0.006
	(0.229)	(0.229)	(0.006)	(0.006)
Bandwidth	79	79	90	90
Observations	1,432	1,432	1,579	1,579

Notes: This table presents the estimates for the sharp regression discontinuity design analysing the effect of marginally higher treatments (capital buffer requirements for O-SII). In Model (1), the dependent variable is the bank's voluntary buffer, measured as the deviation from the average of the corresponding bucket and expressed in percentage points. In Model (2) the dependent variable is the bank CET1 ratio, in deviation from the corresponding bucket's average. The running variable used to construct the bandwidths is the standardised score (O-SII score in deviation from the closest threshold). Estimations are based on local linear regressions, a triangular kernel and optimal bandwidths selected via different MSE and CER criteria (comb1, comb2). For each Model, two different procedures are displayed: (i) conventional RD estimates with conventional variance estimator, and (ii) bias-corrected RD estimates with conventional variance estimator. The estimates are conditional on the following controls: return-on-assets (ROA), the logarithm of risk-weighted assets (RWA) and non-performing loans ratio (NPL). All models include country-quarter fixed effects. Robust standard errors (clustered by bank) are in parentheses. The data is trimmed at the 5th and 95th percentiles to reduce the influence of extreme values on the precision of the estimates. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively.

Table 9: Average effect of marginally higher O-SII buffer requirements on banks' voluntary buffer

	Robust
MSEsum-optimal bandwidth	-0.353*
	(0.183)
Bandwidth	103
MSErd-optimal bandwidth	-0.325*
	(0.184)
Bandwidth	94
MSEtwo-optimal bandwidth	-0.165
	(0.189)
Bandwidth	[141,273]
MSEcomb1-optimal bandwidth	-0.325*
	(0.184)
Bandwidth	94
MSEcomb2-optimal bandwidth	-0.353*
	(0.183)
Bandwidth	103
CERsum-optimal bandwidth	-0.481**
	(0.224)
Bandwidth	79
CERrd-optimal bandwidth	-0.653***
	(0.231)
Bandwidth	72
CERtwo-optimal bandwidth	-0.212
	(0.181)
Bandwidth	[108,210]
CERcomb1-optimal bandwidth	-0.653***
	(0.231)
Bandwidth	72
CERcomb2-optimal bandwidth	-0.481**
	(0.224)
Bandwidth	79
Observations	1,432

Notes: This table presents the estimates for the sharp regression discontinuity design analysing the effect of marginally higher treatments (capital buffer requirements for O-SII). The dependent variable is the bank voluntary buffer, in deviation from the corresponding bucket's average. It is expressed in in percentage points. The running variable used to construct the bandwidths is the standardised score (the O-SII score in deviation from the closest threshold). Estimations are based on local linear regressions, a triangular kernel and optimal bandwidths selected via different MSE and CER criteria. The procedures displayed are bias-corrected RD estimates with robust variance estimator. The estimates are conditional on the following controls: return-on-assets (ROA), the logarithm of risk-weighted assets (RWA) and non-performing loans ratio (NPL), with country-quarter fixed effects. Robust standard errors (clustered by bank) are in parentheses. The data is trimmed at the 5th and 95th percentiles to reduce the influence of extreme values on the precision of the estimates. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively.

Table 10: Average effect of marginally higher O-SII buffer requirements on banks' voluntary buffer (billion euros)

	Conventional	Bias-corrected
MSEsum-optimal bandwidth	-0.197*	-0.223*
	(0.116)	(0.116)
Bandwidth	136	136
MSErd-optimal bandwidth	-0.195*	-0.209*
	(0.116)	(0.116)
Bandwidth	116	116
MSEtwo-optimal bandwidth	-0.183	-0.209*
	(0.115)	(0.115)
Bandwidth	[135,233]	[135,233]
MSEcomb1-optimal bandwidth	-0.195*	-0.209*
	(0.116)	(0.116)
Bandwidth	116	116
MSEcomb2-optimal bandwidth	-0.196*	-0.223*
	(0.117)	(0.117)
Bandwidth	[135,136]	[135,136]
CERsum-optimal bandwidth	-0.185*	-0.202*
	(0.110)	(0.110)
Bandwidth	104	104
CERrd-optimal bandwidth	-0.180	-0.187
	(0.114)	(0.114)
Bandwidth	89	89
CERtwo-optimal bandwidth	-0.163	-0.181*
	(0.107)	(0.107)
Bandwidth	[104,180]	[104,180]
CERcomb1-optimal bandwidth	-0.180	-0.187
	(0.114)	(0.114)
Bandwidth	89	89
CERcomb2-optimal bandwidth	-0.184*	-0.200*
	(0.110)	(0.110)
Bandwidth	104	104
Observations	1,443	1,443

Notes: This table presents the estimates for the sharp regression discontinuity design analysing the effect of marginally higher treatments (capital buffer requirements for O-SII). The dependent variable is the bank voluntary buffer, in deviation from the corresponding bucket's average. It is expressed in logarithms of billions of euros. The running variable used to construct the bandwidths is the standardised score (the O-SII score in deviation from the closest threshold). Estimations are based on local linear regressions, a triangular kernel and optimal bandwidths selected via different MSE and CER criteria. Two different procedures are displayed: (i) conventional RD estimates with conventional variance estimator, (ii) bias-corrected RD estimates with conventional variance estimator. The estimates are conditional on the following controls: return-on-assets (ROA), the logarithm of risk-weighted assets (RWA) and non-performing loans ratio (NPL), with country-quarter fixed effects. Robust standard errors (clustered by bank) are in parentheses. The data is trimmed at the 5th and 95th percentiles to reduce the influence of extreme values on the precision of the estimates. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively.

Table 11: Average effect of marginally higher O-SII buffer requirements on banks' risk weighted assets

	Conventional	Bias-corrected
MSEsum-optimal bandwidth	-0.027	-0.033
	(0.027)	(0.027)
Bandwidth	122	122
MSErd-optimal bandwidth	-0.028	-0.031
	(0.027)	(0.027)
Bandwidth	119	119
MSEtwo-optimal bandwidth	-0.020	-0.026
	(0.020)	(0.020)
Bandwidth	[130,414]	[130,414]
MSEcomb1-optimal bandwidth	-0.028	-0.031
	(0.027)	(0.027)
Bandwidth	119	119
MSEcomb2-optimal bandwidth	-0.027	-0.033
	(0.027)	(0.027)
Bandwidth	122	122
CERsum-optimal bandwidth	-0.035	-0.039
	(0.030)	(0.030)
Bandwidth	94	94
CERrd-optimal bandwidth	-0.037	-0.040
	(0.030)	(0.030)
Bandwidth	91	91
CERtwo-optimal bandwidth	-0.027	-0.032
	(0.021)	(0.021)
Bandwidth	[100,317]	[100,317]
CERcomb1-optimal bandwidth	-0.037	-0.040
	(0.030)	(0.030)
Bandwidth	91	91
CERcomb2-optimal bandwidth	-0.035	-0.039
	(0.030)	(0.030)
Bandwidth	94	94
Observations	1,581	1,581

Notes: This table presents the estimates for the sharp regression discontinuity design analysing the effect of marginally higher treatments (capital buffer requirements for O-SII). The dependent variable is the bank's risk weighted assets, in deviation from the corresponding bucket's average. It is expressed in logarithms of billions of euros. The running variable used to construct the bandwidths is the standardised score (the O-SII score in deviation from the closest threshold). Estimations are based on local linear regressions, a triangular kernel and optimal bandwidths selected via different MSE and CER criteria. Two different procedures are displayed: (i) conventional RD estimates with conventional variance estimator, (ii) bias-corrected RD estimates with conventional variance estimator. The estimates are conditional on the following controls: return-on-assets (ROA) and non-performing loans ratio (NPL), with country-quarter fixed effects. Robust standard errors (clustered by bank) are in parentheses. The data is trimmed at the 5th and 95th percentiles to reduce the influence of extreme values on the precision of the estimates. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively.

D Robustness of the regression discontinuity design

D.1 Placebo cutoff

Table 12: Effect of marginally higher O-SII buffer by bucket on banks' voluntary buffer (score-50): RDD with Placebo Cutoffs

	Conventional	Bias-corrected
MSEsum-optimal bandwidth	-0.004	-0.003
	(0.283)	(0.283)
Bandwidth	84	84
MSErd-optimal bandwidth	0.006	0.008
	(0.254)	(0.254)
Bandwidth	97	97
MSEtwo-optimal bandwidth	-0.148	-0.195
	(0.246)	(0.246)
Bandwidth	[100,383]	[100,383]
MSEcomb1-optimal bandwidth	-0.004	-0.003
	(0.283)	(0.283)
Bandwidth	84	84
MSEcomb2-optimal bandwidth	0.006	0.008
	(0.254)	(0.254)
Bandwidth	97	97
CERsum-optimal bandwidth	0.020	0.018
	(0.320)	(0.320)
Bandwidth	65	65
CERrd-optimal bandwidth	-0.008	-0.006
	(0.305)	(0.305)
Bandwidth	75	75
CERtwo-optimal bandwidth	-0.295	-0.320
	(0.305)	(0.305)
Bandwidth	[77,294]	[77,294]
CERcomb1-optimal bandwidth	0.020	0.018
	(0.320)	(0.320)
Bandwidth	65	65
CERcomb2-optimal bandwidth	-0.008	-0.006
	(0.305)	(0.305)
Bandwidth	75	75
Observations	1432	1432

Notes: Falsification test in the case of the sharp regression discontinuity design (Cattaneo et al., 2020a and 2020b). This test replaces the true cutoff value by another value at which the treatment status does not really change (score-50), and performs estimation and inference using this artificial cutoff point. The expectation is that no significant treatment effect occurs at the placebo cutoff values. In this regression the effect of the marginal treatments is analysed. The dependent variable is the banks' voluntary buffer in ratio. Local linear regressions with a triangular kernel using both MSE and CER different optimal bandwidths are used. Two different procedures are displayed: (i) conventional RD estimates with conventional variance estimator, (ii) bias-corrected RD estimates with conventional variance estimator. The estimates are conditional on the following controls: return-on-assets ratio (ROA), risk-weighted assets in logarithms of billions of euros (RWA) and non-performing loans ratio (NPL). The data is trimmed at the 5th and 95th percentiles, in order to reduce the influence of extreme values on the precision of the estimates. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively.

Table 13: Effect of marginally higher O-SII buffer by bucket on banks' voluntary buffer (score+50): RDD with Placebo Cutoffs

	Conventional	Bias-corrected
MSEsum-optimal bandwidth	0.216	0.248
	(0.203)	(0.203)
Bandwidth	117	117
MSErd-optimal bandwidth	0.242	0.265
	(0.205)	(0.205)
Bandwidth	122	122
MSEtwo-optimal bandwidth	0.244	0.273
	(0.187)	(0.187)
Bandwidth	[96,447]	[96,447]
MSEcomb1-optimal bandwidth	0.216	0.248
	(0.203)	(0.203)
Bandwidth	117	117
MSEcomb2-optimal bandwidth	0.214	0.239
	(0.202)	(0.202)
Bandwidth	[117,122]	[117,122]
CERsum-optimal bandwidth	0.169	0.187
	(0.237)	(0.237)
Bandwidth	90	90
CERrd-optimal bandwidth	0.158	0.173
	(0.228)	(0.228)
Bandwidth	93	93
CERtwo-optimal bandwidth	0.108	0.127
	(0.245)	(0.245)
Bandwidth	[74,344]	[74,344]
CERcomb1-optimal bandwidth	0.169	0.187
	(0.237)	(0.237)
Bandwidth	90	90
CERcomb2-optimal bandwidth	0.156	0.170
	(0.234)	(0.234)
Bandwidth	[90,93]	[90,93]
Observations	1432	1432

Notes: Falsification test in the case of the sharp regression discontinuity design (Cattaneo et al., 2020a and 2020b). This test replaces the true cutoff value by another value at which the treatment status does not really change (score+50), and performs estimation and inference using this artificial cutoff point. The expectation is that no significant treatment effect occurs at the placebo cutoff values. In this regression the effect of the marginal treatments is analysed. The dependent variable is the banks' voluntary buffer both in logarithms of billions of euros and ratio. Local linear regressions with a triangular kernel using both MSE and CER different optimal bandwidths are used. Two different procedures are displayed: (i) conventional RD estimates with conventional variance estimator, (ii) bias-corrected RD estimates with conventional variance estimator. The estimates are conditional on the following controls: return-on-assets ratio (ROA), risk-weighted assets in logarithms of billions of euros (RWA) and non-performing loans ratio (NPL). The data is trimmed at the 5th and 95th percentiles, in order to reduce the influence of extreme values on the precision of the estimates. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively.

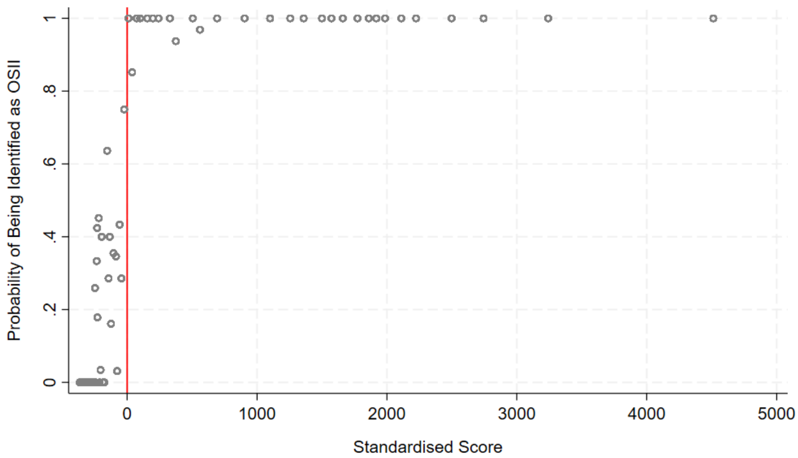
E Analysis of the effect of being identified as O-SII

This section presents the results for the pure effect of being identified as an O-SII versus not being identified as such on the retention of voluntary capital. In this research design, only the main threshold is used. The first threshold permits to discriminate between banks that receive an O-SII capital requirement or not. Both the analysis of the effects of marginally higher O-SII capital requirements and the analysis of the pure effect of being identified as systemically important banks, are possible as the EBA scoring process allows a randomised experiment in a neighborhood of the threshold. For the purposes of this section, the EBA scoring process allows us to identify the effect of receiving a capital requirement or not, comparing the change in the outcome of banks just above and below the cutoff after the introduction of the capital surcharge. As discussed in Section 3, the EBA setting relies on a two-step procedure to identify O-SII banks: i) a scoring process, which automatically qualifies a bank, with a score above a predetermined threshold, as systemically important; and ii) a supervisory expert judgment, which may qualify some banks below the threshold as systemically important.

E.1 Supervisory judgment

Several institutions below the cutoff are, nevertheless, designated as other systemically important institutions (O-SII) because of supervisory judgment.[26] To deal with this matter, when the analysis uses the main threshold and includes the supervisory judgment, it is relevant to rely on the fuzzy regression discontinuity design. As a reminder, our baseline setup of this paper, which considers the effect of marginally higher O-SII buffers, drops banks that do not receive an O-SII buffer or were subject to supervisory judgment.

Figure 7: Probability of being identified as O-SII as a function of the score



Notes: This figure represents the relationship between the bank score and respective identification as O-SII. The vertical axis presents the probability of being identified as O-SII and the horizontal axis depicts the standardised score. This figure is similar to the one presented by Ponte Marques, et al. (2024) in the Appendix, Figure 1. The small differences arise from the differences in consolidation and cleaning.

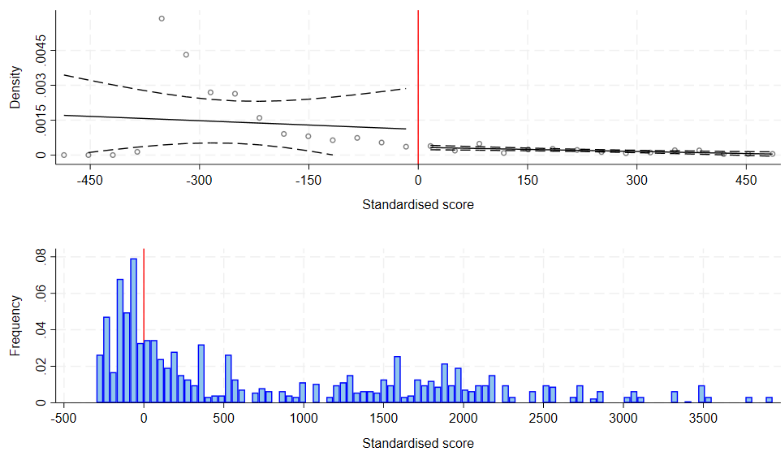
[26]Belgium, Estonia, Germany, France, Malta and the Netherlands used both the automatic calculation for the identification of O-SIIs and the supervisory judgment.

E.2 Average effect of being identified as O-SII on voluntary capital

Table 14 presents the results that assess the impact of higher buffer requirements (the O-SII buffer) on banks' voluntary buffer ratio. In our regression discontinuity design, the bank voluntary buffer is the dependent variable, and the standardised score (the difference between the score and the corresponding bucket threshold to determine the requirement of the O-SII buffer) is used to construct the bandwidths. To test the sensitivity of the results, different methodologies for the optimal choice of bandwidth are considered: mean square error (MSE) optimal bandwidths, and coverage error rate (CER) optimal bandwidths. Table 14 shows that the coefficients are consistently negative (and significant in some specifications) across the different specifications.

The economic intuition behind Table 14 is that when banks are constrained by an O-SII buffer, they use their voluntary buffer to comply with their higher capital requirement, without raising new equity. Banks have the incentive to offset an increase in capital requirements by compressing their voluntary buffer. This finding provides further evidence that banks do not raise additional equity but instead use their voluntary buffer to satisfy higher capital requirements — according to Table 4, banks with marginally higher buffer requirements hold less average voluntary buffer than banks just below the specific bucket. The validity of the design is confirmed by visual inspection of Figure 8, where McCrary's test confirms the continuity at the cutoff of the score density.

Figure 8: McCrary's manipulation test of the running variable — FRDD



Notes: The figure presents the McCrary's test (McCrary, 2008) that it is used to assess the continuity at the cutoff of the score density. The lower panel represents the density of the standardised scores. The vertical and horizontal axes are, respectively, the relative frequency of the banks' scores and the score distance from the threshold. Moreover, in the upper panel, the McCrary test of density continuity is presented. The fitted values of the correlation between the bank's score and the score's distance from the threshold are represented by the solid line between the dashed lines, and the estimation is performed separately on each side of the cutoff. The dashed lines represent the 95 percent confidence interval. From the two figures, it is possible to conclude that there is no significant visual evidence of systematic manipulation of the running variable. The figure is based on a single threshold (350 for most of the countries).

Table 14: Average effect of marginally higher O-SII buffer requirements on banks' voluntary buffer

	Conventional	Bias-corrected
MSEsum-optimal bandwidth	-0.402	-0.475*
	(0.261)	(0.261)
Bandwidth	103	103
MSErd-optimal bandwidth	-0.376	-0.443
	(0.270)	(0.270)
Bandwidth	94	94
MSEtwo-optimal bandwidth	-0.196	-0.198
	(0.195)	(0.195)
Bandwidth	[141,273]	[141,273]
MSEcomb1-optimal bandwidth	-0.376	-0.443
	(0.270)	(0.270)
Bandwidth	94	94
MSEcomb2-optimal bandwidth	-0.402	-0.475*
	(0.261)	(0.261)
Bandwidth	103	103
CERsum-optimal bandwidth	-0.628	-0.681*
	(0.413)	(0.413)
Bandwidth	79	79
CERrd-optimal bandwidth	-0.882*	-0.933*
	(0.494)	(0.494)
Bandwidth	72	72
CERtwo-optimal bandwidth	-0.256	-0.262
	(0.192)	(0.192)
Bandwidth	[108,210]	[108,210]
CERcomb1-optimal bandwidth	-0.882*	-0.933*
	(0.494)	(0.494)
Bandwidth	72	72
CERcomb2-optimal bandwidth	-0.628	-0.681*
	(0.413)	(0.413)
Bandwidth	79	79
Observations	1432	1432

Notes: This table presents the estimates for the regression discontinuity design analysing the effect of marginally higher treatments (capital buffer requirements for O-SII). The estimates for the fuzzy regression discontinuity design are presented. The dependent variable is the bank voluntary buffer, in deviation from the corresponding bucket's average. It is expressed in percentage points. The running variable used to construct the bandwidths is the standardised score (the O-SII score in deviation from the closest threshold). Estimations are based on local linear regressions, a triangular kernel and optimal bandwidths selected via different MSE and CER criteria. Two different procedures are displayed: (i) conventional RD estimates with conventional variance estimator, (ii) bias-corrected RD estimates with conventional variance estimator. The estimates are conditional on the following controls: return-on-assets (ROA), the logarithm of risk-weighted assets (RWA) and non-performing loans ratio (NPL), with country-quarter fixed effects. Robust standard errors (clustered by bank) are in parentheses. The data is trimmed at the 5th and 95th percentiles to reduce the influence of extreme values on the precision of the estimates. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively.

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Aurora Abbondanza
European Central Bank, Frankfurt am Main, Germany; email: aurora.abbondanza@ecb.europa.eu

Ugo Albertazzi
European Central Bank, Frankfurt am Main, Germany; email: ugo.albertazzi@ecb.europa.eu

Aurea Ponte Marques
European Central Bank, Frankfurt am Main, Germany; email: aurea.marques@ecb.europa.eu

Giulia Leila Travaglini
Columbia University, New York, United States; email: gt2426@columbia.edu

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

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