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Has regulatory capital made banks safer? Skin in the game vs moral hazard

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Abstract

The paper evaluates the impact of a *phased-in* introduction of capital requirements on equity, risk-taking, and probability of default for a sample of European systemically important banks. Contrary to the case of a *one-off* introduction of capital requirements, this study does not find evidence of deleveraging through asset sales. A phased-in tightening promotes adjustment to lower leverage via an increase in equity thereby improving resilience and loss absorption capacity. The higher resilience comes at the cost of a portfolio reallocation towards riskier assets. Consistently with models on agency costs and gambling for resurrection, the risk-taking is driven by large and less profitable banks. The net impact on bank probabilities of default is positive albeit statistically insignificant, suggesting that risk-taking may crowd-out solvency.

JEL Classification: E51, G21, G28, O52

Keywords: capital requirements, macroprudential policy, risk-taking, impact evaluation, difference-in-difference.

Non-technical summary

The Capital Requirements Regulation (CRR) and the Capital Requirements Directive (CRD IV) introduced a new macroprudential framework transposing the Basel III agreement in the EU. The overarching goal of the new EU macroprudential regulation is to increase the loss absorption capacity of banks through the introduction of a set of systemic capital requirements. Higher capital requirement should foster the stability of the banking system and increase the resilience of banks in time of crisis allowing them to sustain the real economy.

This study estimates the effects of macroprudential capital requirements on bank capital and risk taking by looking at the reaction of EU banks to a series of increments of macroprudential capital requirements. In general, banks can increase their regulatory capital ratio in three mutually non-exclusive ways: by increasing capital, reducing the risk-weights or reducing their assets.

The sample is composed by all G-SIB and O-SIB in the EU and Norway from 2006Q1 until 2017Q3, leading to a total number of 205 banks, divided in 14 globally-systemically important banks (G-SIBs) and 191 other-systemically important banks (O-SIBs). The bank specific systemic macroprudential capital requirements are obtained from the European Systemic Risk Board (ESRB) database on macroprudential policies based on the notifications from the national authorities.

The paper finds that the EU-wide regulatory effort to increase the resilience of the banking sector has contributed to a better capitalized European financial system: a one percentage point increase in capital requirements increases CET1 capital by an average of 13 percent. The impact is higher (17.7 percent) for banks with less than two percentage points buffer from the minimum capital requirement.

However, the significant increase in capital is accompanied with a cost: banks react to a one percentage point hike in capital requirements by increasing the average risk weights of their portfolio by 6.1 percentage points. The highest increase in risk taking is due to medium and large less profitable banks which try to achieve higher returns by substituting toward more riskier assets and compensate thus for their lower profitability. Importantly, wholesale funded banks have a lower tendency to increase their risk profile after a capital requirement increase.

In order to gauge the overall impact on banks' probabilities of default (PD) of the two opposing effects - i.e. higher resilience achieved with increased capital versus lower resilience arising from more risk-taking - the study estimates the impact of the policy change on PDs extrapolated from credit ratings. The results indicate that the positive effect of accumulating more equity capital is counterbalanced by the negative substitution effect toward more riskier assets.

The countervailing effect of risk taking on solvency raises the attention to the non-intended consequences of regulatory action. The regulatory task is not a simple one, any policy change requires a comprehensive assessment of hidden incentives behind regulatory action.

1 Introduction

Capital requirements are generally seen as an effective regulatory option to increase banks' loss absorption capacity during financial downturns and preserve the resilience of the financial system and the real economy (Admati and Hellwig, 2014; Jiménez et al., 2016). In particular, the notion that more equity capital is indispensable to stifle risk-taking is at the heart of a series of international regulatory standards, most notably the Basel Capital Accords (Thakor, 2014).

A branch the economic theory is supporting this view. Higher capital levels may curtail risk-taking behaviour since managers and shareholders would have more skin in the game and would have an incentive to act prudently (Merton, 1977; Furlong and Keeley, 1989; Acharya et al., 2016; Barth and Seckinger, 2018). In addition, bank managers may have incentives to avoid excessive risk-taking, either because they hold own career preservation motives (Benston, 1986; Saunders et al., 1990), or because more risk increases the variance of returns which can amplify the probability of significant losses on banks' equity (Hellmann et al., 2000; Repullo and Suarez, 2004; Repullo, 2004). Similar arguments have been put forward by theories of the charter value of the bank, (Marcus, 1984; Benston, 1986).

However, the principal-agent theory posits that the presence of imperfect information, which is endemic in complex organizations such as banks, can manifest itself in moral hazard due to distorted incentives between the principal and the agent.[1] For instance, Dewatripont and Tirole (1994) model the classic moral hazard problem with unobservable managers' effort to conclude that banks with low leverage have an incentive to increase risk. Admati et al. (2018) show that if a firm has superior information about its asset quality, shareholders would prefer to reduce leverage by selling safer assets and retaining the riskier ones, without issuing equity. In the context of a *one-off* tightening of leverage requirements, Gropp et al. (2018) find empirical support for assets reduction and no impact on equity; however they do not find evidence of risk-taking as measured by risk weight densities. By taking a historical perspective, Jorda et al. (2017) conclude that higher capital ratios are more likely to be correlated with financial crisis.

[1]Several strands of the literature have shown the consequences of the principal-agent asymmetric information problem on risk-taking. Academic contributions range from the fields of economics (Stiglitz and Weiss, 1981), finance (Acharya, 2009; Acharya and Naqvi, 2012), managerial (Wiseman and Gomez-Mejia, 1998), corporate finance (Ross, 1973; Bolton et al., 2015; Admati et al., 2018) to law and banking regulation (Alexander, 2006). Similarly, empirical banking literature shows a positive correlation between capital and risk-taking, (Koehn and Santomero, 1980; Kim and Santomero, 1988; Blum, 1999) or more generally with the occurrence of financial crisis Jorda et al. (2017). A more extensive literature review is provided in Appendix A-II.

This divergence of views raises the question as to how banks adjust their balance sheet in response to tighter regulation and whether banks' risk-taking behaviour is affected by regulatory capital requirements. The paper sheds light on these questions by exploiting an exogenous policy change in the macroprudential capital requirements for Global Systemically Important Banks (G-SIBs) and Other Systemically Important Banks (O-SIBs) in the European Union (EU). These requirements have been implemented within the context of the Basel III regulatory overhaul. Starting in 2014, macroprudential capital instruments have been gradually phased-in at individual bank-level and at different times across 28 EU countries. The staggered policy implementation across time and borders allows for a research design based on a quasi-natural experiment and a difference-in-difference (D-i-D) identification strategy. Throughout the paper, the risk-taking behaviour is measured by individual bank-level risk densities, as the ratio of risk-weighted assets over total assets.

The contribution is closely related to the empirical literature on the relationship between bank risk-taking and leverage (Shrieves and Dahl, 1992; Jacques and Nigro, 1997; Jokipii and Milne, 2011), the research on the adjustment mechanisms to more stringent capital requirements (Admati et al., 2018; Gropp et al., 2018), and the discussion on the optimal design and sequencing of prudential regulation, (Khatkhate, 1998; Hart and Zingales, 2011; Lall, 2012). More broadly, the paper is related to the emerging literature on the effectiveness of capital-based macrprudential policy (Repullo and Suarez, 2012; Ferrari et al., 2016; Cerutti et al., 2017; Akinci and Olmstead-Rumsey, 2018; Cizel et al., 2019).

From the point of view of the optimal design of macroprudential policy, this paper complements the conclusions of Admati et al. (2018) and Gropp et al. (2018) by presenting evidence that banks' responses to more stringent leverage rules are dependent on their pace of introduction. As shown by the authors, when a *one-off* leverage requirement is imposed, a costly equilibrium emerges where banks react by reducing assets and lending to the real economy, holding equity constant. The results presented below add to these findings. When capital requirements are *phased-in* over several years, a clear policy trade-off between risk and resilience emerges. On one hand, banks comply with the regulation by raising equity capital, improving their resilience and do not engaging in asset reduction. On the other hand, the additional equity induces moral hazard instead of promoting skin in the game, and banks reallocate their portfolio towards riskier assets. A detailed analysis of the heterogeneous responses to capital regulation with respect to size, profitability, and funding sources complements the main findings.

The results indicate that the EU regulatory reforms have contributed to a better capitalized European financial system. In the baseline specification, a one percentage point increase in capital requirements increases CET1 capital by an average of 13 percent. The impact is higher (17.7 percent) when the policy tightening is more binding. When requirements are relaxed in a downturn, the increase in highest quality CET1 capital can help the banks in supplying credit acting counter-cyclically to sustain economic growth in bad times, see Jiménez et al. (2016); Jorda et al. (2017).

The significant increase in capital is accompanied by substitution effects toward more riskier assets: banks react to a one percentage point hike in capital requirements by increasing the average risk weights of their portfolio by 6.1 percentage points. The impact is attenuated for small banks (4.3 p.p.). However, medium (7.3 p.p.) and large (9.6 p.p.) systemically important banks show a significantly higher risk-taking behavior. These findings indicate that risk-taking could be arising from an intensification of agency problems as the bank grows in size. In fact, Ang et al. (2000) shows that a diluted ownership structure, which is typical of large publicly traded firms, is proportionally associated with increasing agency costs.

In terms of the overall net impact on solvency, as measured by probabilities of default, the positive effect of accumulating more equity capital is counterbalanced by the negative substitution effect toward more riskier assets. In other words, risk-taking crowds-out the positive effect of greater equity.

The paper documents a substantial amount of heterogeneity across banks. Financial institutions adopting the internal rating based (IRB) approach show a lower propensity to risk-taking. This suggests the existence of a competitive advantage for IRB banks since lower risk weights imply a lower cost of compliance to higher capital requirements. Further, the increase in risk-taking arises in less profitable institutions, suggesting that gambling for resurrection motives may underlie the substitution toward more riskier assets. The findings indicate that wholesale-funded, relative to retail-funded banks, have a lower tendency to increase their risk profile. As shown by Bruno and Shin (2015), this behavior may be a consequence of competitive advantage arising from the capacity to exploit cross-border funding in regions where monetary policy conditions are more expansionary.

The paper is organised as follows: the empirical methodology is illustrated in Section 3. Section 4 presents the evidence for the baseline specification and Section 5 investigates heterogenous treatment effects. The robustness to common trend assumption is presented in Section 6, and a formal test of endogeneity is presented in Section 7. The overall impact on the probabilities of default is described in Section 8, and conclusions are drawn in Section 9.

2 The EU macroprudential capital based regulation

One of the criticisms of earlier Basel standards for capital requirements, is the lack of emphasis on risks stemming from correlated exposures that may accumulate over time and increase systemic risk (Hellwig, 1995; Acharya, 2009; Haldane and May, 2011). Basel I and II capital standards are focused exclusively on individual portfolios without acknowledging the importance of how much these portfolios are diversified, the pattern of co-variances among individual assets, systemic correlation of risks and interconnectedness, and/or the cost of failure of big and more complex banks.[2]

Basel III standards include additional capital requirements aimed at tackling some of these issues and add three main new buffers: the Capital Conservation Buffer (CCoB) for build-up of adequate buffers above the minimum that can be drawn down in periods of stress, the Countercyclical Capital Buffer (CCyB) aimed at limiting the procyclicality of credit growth, and additional capital buffers for Global Systemically Important Banks (G-SIB) aimed at addressing the liquidation cost of too-big-to fail banks.[3] These efforts notwithstanding, critics have questioned both the lack of ambition and the design of some of the Basel III buffers (Repullo and Saurina, 2011).

In Europe, the Capital Requirements Regulation (CRR) and the Capital Requirements Directive (CRD IV) introduced a new macroprudential framework transposing the Basel III agreement.[4] The CRDIV has been officially transposed in law on 17th July 2013 and the full

[2]On one hand Basel I introduced risk-weighted exposures in order to force banks with more risk in their portfolios to maintain a higher capital level, while Basel II main innovation was the introduction of the Internal Rating Based (IRB) and the Standardized Approach (SA) models for the computation of risk-weights. For a more detailed history of Basel capital standards and their possible deficiencies see for instance Brealey (2006) and Hellwig (2010).

[3]In addition, Basel III introduces favourable risk-weights for OTC derivatives cleared through central counterparties (CCPs), and is raising the risk-weights on exposures to financial institutions relative to the non-financial corporate sector, as financial exposures are more highly correlated than non-financial ones.

[4]Detailed information on the Capital Requirements Regulation and Directive can be found on the European

reform package entered into force on the 1st January 2014. The overarching goal of the new EU regulation is to limit systemic risk in the banking sector through the introduction of a set of Systemic macroprudential Capital Requirements (SMCR) available to national authorities to address systemic risks, see Table 1 for a summary of the macroprudential capital requirements in the EU.

The set of SMCR include three main capital based requirements applied at individual institution level: the Systemic Risk Buffer (SRB), the G-SIB buffer and the O-SIB buffer requirements.[5] The SRB aims to address systemic risks of a long-term structural and non-cyclical nature as for instance the accumulation of systemic risk and the degree of interconnectedness. The O-SIB and G-SIB buffers are predominantly concerned with increasing loss absorption capacity and reducing public costs of default of bigger and complex banks.

While the economic rationale behind the diverse types of buffers may differ in scope and objective, all of them have to be met with an additional highest quality Common Equity Tier1 (CET1) capital as a share of risk-weighted assets (RWA). All SMCRs are applied at individual bank-level and are specifically addressed to the set of both globally and nationally systemically important banks (SIBs).[6] The list of systemically important banks is updated each year by national authorities following EBA guidelines. The main criteria for determining a bank as systemically important for the domestic economy are: a) size; b) importance for the economy of the relevant Member State or the Union, capturing substitutability/financial institution infrastructure; c) complexity, including the additional complexities from cross-border activity; d) interconnectedness of the institution or (sub-)group with the financial system.[7]

In sum, and contrary to the Basel III capital standards, the EU package is more ambitious since instructs Member States to designate own systemically important banks to which then

Commission website. Norway and Iceland, despite not being formally EU Member States opted for participating in the new EU macroprudential framework for banks as established in the CRR and the CRDIV.

[5]The new macroprudential regulation in the EU implements also the Basel III capital conservation buffer (CCoB) as well as the dynamic countercyclical capital buffer (CCyB). Nevertheless, the CCoB and the CCyB are buffers set at the country-level. In the empirical framework of this paper these two requirements are absorbed by country-quarter fixed effects and as such they are not contributing to additional variation and to the identification of the effects.

[6]Under the CRD IV/CRR capital framework, EU banks are required to hold a minimum amount of total capital equal to at least 8% of RWA. The new regulation raises the minimum share of capital that has to be of the highest quality CET1 capital from 2% to 4.5%. Additional capital until the minimum threshold of 8% can be fulfilled with Tier 1 minimum capital or Tier 2 minimum capital (max. 2%). As such, the new EU-wide CRD IV/CRR minimum capital regulation places greater emphasis on the quality of capital.

[7]For more details cfr. the EBA Guidelines on the criteria to assess systemically important banks in the EU. The EBA provides and maintains also an updated G-SIBs list and O-SIBs list in Europe over time on its website.

a *wider* battery of bank-specific systemic capital buffers may be applied. Table 1 provides an overview of the newly introduced capital requirements in the EU.

2.1 Calibration and Setting of the Macroprudential Capital Requirements

The calibration of the G-SIB buffer is set internationally according to the Basel G-SIB score range for each G-SIB (BCBS, 2013). The calibration of the SRB and the O-SIB buffers depend on the systemic importance of the bank for the country in question and is not subject to centralized guidelines from EBA. In other words the EBA guidelines provide criteria for determination of systemically important banks but not have normative prescriptions in terms of the calibration of buffers. This provides leeway for national authorities to protect domestic banks. To counter the peril of inaction bias, the ECB has developed a framework to provide a minimum common floor when calibrating O-SIB buffers at the national level to foster a level playing field. Above this floor, each country calibrates the buffers using own methodologies.[8]

It is important to notice that not all G-SIBs or O-SIBs are subject to the SMCR as of 2017Q3: despite the EU introduction of the capital based macroprudential framework in 2014, some national macroprudential authorities have not yet activated any of the structural SMCRs. Under the oversight of the ESRB and the ECB, the EU regulation allows for discretion to activate and to set the level for each O-SIB and SRB buffer.

On the one hand, these country divergences and the staggered implementation across countries facilitate the empirical identification problem. On the other hand, they may lead to concerns regarding the potential endogeneity of the policy change with respect to the health of the country banking system. These concerns are, however, alleviated by four main elements enshrined in the regulation: i) four EU institutions coordinated oversight contribute to refraining from inaction bias and national favoritism,[9] ii) the ECB has the power to top-up the requirement if considers it insufficient to cope with the relevant risk, or may object the decision in case considered excessive or punitive toward foreign subsidiaries, and iii) the ESRB can issue public

[8] For instance, the Commission de Surveillance du Secteur Financier (CSSF), the macroprudential authority in Luxembourg adopts *"a statistical approach involving linear regression and a scaling framework with the goal to ensure consistency between O-SIBs buffers and the buffers applied to G-SIBs."* See CSSF notification to the ESRB. Additional notifications may be found on the ESRB website.

[9] It is important to notice that in order to ensure consistent macroprudential oversight across the Union, the ESRB develops principles tailored to the Union economy and is responsible for monitoring their application.

warning and recommendations where an identified systemic risk has materialised and has not yet been addressed and iv) the reciprocation framework allows a Member State to request a reciprocation of a macroprudential measure.[10]

The first provision establishes that four different EU institutions are overseeing the implementation of macroprudential buffers across the EU, namely the European Systemic Risk Board (ESRB), the EU Commission, the EBA and the ECB.[11] Second, the ESRB ha the mandate to identify and monitor systemic risk in the EU. To preserve financial stability, the ESRB can issue public *warnings* and *recommendations* to Member States where identified systemic risks are deemed to be significant and not addressed. Moreover, the ESRB can issue confidential warnings to the Heads of States in the EU Council and must monitor their follow-up.[12] Third, the ECB has top-up power for Euro Area banks, this guarantees that there is no inaction bias toward strategically important domestic banks since the ECB can apply higher macroprudential capital requirement than the one established at national level.[13] With a further aim of fostering consistency, the ECB has also developed a framework to provide a minimum common floor when calibrating systemic capital requirements applied at the national level.[14] Fourth, any measure requires the approval of the ECB Governing Council, and acting on a proposal by the EU Commission, the EU Council of ministries has the power to reject the proposed national macroprudential measure. This provision guarantees that foreign subsidiaries are treated fairly and equally without being affected by protectionist measures.[15]

The validity of the research method could be further questioned if large banks shift their assets across borders to branches or subsidiaries in order to conduct regulatory arbitrage. In this case, the existence of spillover effects may produce biased estimates. However, also this concern is addressed within the regulatory framework which envisages the possibility of reciprocation.

[10] See respectively, Article 131(7) of the Capital requirements Directive IV (CRDIV), Articles 5(1) and 5(2) of the Single Supervisory Mechanism Regulation, Article 3 of the ESRB regulation and the Recommendation of the ESRB/2015/2 in conjunction with Article 5 of Decision ESRB/2015/4

[11] See fot instance, Article 131(7) of the Capital requirements Directive IV (CRDIV) which states that before setting or resetting an O-SIB buffer, the competent authority shall notify the Commission, the ESRB, EBA, and the competent microprudential supervisors of the Member States concerned one month before the publication of the decision.

[12] For more information on ESRB's tasks and powers see the related ESRB regulation.

[13] For the ECB top-up power and the scrutiny of the ECB on national macroprudential measures see Articles 5(1) and 5(2) of the Single Supervisory Mechanism Regulation.

[14] See ECB floor methodology for setting the capital buffer for an identified Other Systemically Important Institution (O-SII). By providing a minimum floor, the ECB reduces national discretion in calibration of the capital instrument and provides the basis of a discussion between the ECB and national authorities on the overall assessment of the appropriateness of a macroprudential stance.

[15] This is in accordance with Article 291 of the Treaty on the Functioning of the European Union (TFEU).

This grants the power to a Member State to request a countervailing capital increase to foreign branches, or directly across borders when risks of spillover are deemed significant. Reciprocation should ultimately ensure the reduction of the incentive to search for regulatory arbitrage and the enforcement of a level playing field among parents, subsidiaries, and branches within and across the borders.[16]

3 Empirical Methodology

3.1 Data

This study uses two main data sources to construct an integrated dataset combining bank-level financial accounts data and systemic macroprudential capital requirements. The source of bank-level financial accounts data is the commercial provider SNL Financials which collects financial accounts from financial institutions around the World. More specifically, financial accounts for all G-SIB and O-SIB in the EU and Norway from 2006Q1 until 2017Q3, leading to a total number of 205 banks in the sample, with 14 G-SIBs and 191 O-SIBs. They represent 86% of total consolidated assets of EU banks in 2016 according to consolidated balance sheet statistics.[17] The list of banks sorted by total assets is presented in Appendix A-I.[18]

The bank specific SMCRs are obtained from the ESRB database on macroprudential policies based on the notifications from the national authorities.[19] Table 3 illustrates the evolution of

[16]The reciprocity framework is codified in two main documents: (i)Recommendation of the ESRB/2015/2; (ii) Article 5 of Decision ESRB/2015/4. For a detailed account of the reciprocation framework in the EU consult the dedicated ESRB web page on reciprocation, and Chapter 11 of the ESRB Handbook on operationalising macroprudential policy. In this context, the ESRB has an important coordination role in assessing measures, discussing cross-border effects, and recommending mitigating measures, including reciprocity.

[17] The sample composition of SIBs may vary from year to year due to new banks being designated as O-SIB, or old banks not satisfying any more the requirements to be designated as O-SIBs. See European Banking Authority Guidelines on O-SIB. For the list of G-SIB with cut-off date 2016Q4 consult the the Financial Stability Board.

[18]One caveat to keep in mind when constructing a bank-level database over a long time period is the churning rate of financial institutions from the sample. In particular the merger of two or more financial institutions may bias the results. To limit this possibility, When a merger happens, the study sample is adjusted in order to reflect this change: old entities are discontinued in the sample and a new entity is added with a separate identifier as a result of the merger. To grasp the idea of sample construction in case of mergers, one examples of recent merger episodes over the period is shortly summarised in this footnote. On 2nd Jan 2017 Nordea Bank Denmark merged with Nordea Bank AB, see link. As a consequence of the merger, a Danish entity Nordea Real Kredit has been identified as O-SIB by the Danish macroprudential authority. It follows also that Nordea Bank Denmark has been removed from the O-SIB list in DK, and also from the list of O-SIBs in the study sample.

[19]The ESRB macroprudential database covers all changes in macroprudential regulation notified by the 28 EU countries and Norway. Notifications are published on the ESRB website or disseminated through ESRB publications. For detailed information on the national macroprudential policies in the EU cfr.: ESRB National

capital requirements for the sample of EU G-SIBs and O-SIBs from 2010Q1 until 2017Q3. In Panel A of Table 3 we present the simple mean of the capital requirements for both treated and non-treated banks. The first row shows the phasing-in of the SMCR after 2014. From 2014 onward the SMCR CET1 capital requirements for EU G-SIBs and O-SIBs increase by an average of 0.21 percentage points yearly.[20]

The average capital requirement is higher if we compute the average conditional on effectively treated banks. This conditional mean is shown in Panel B of Table 3 and implies an average increase of the SMCR by 1.18 percentage points in 2017Q3. This is a substantial increase in capital requirement, in particular for banks that are closer to the minimum requirement. An inspection of the standard deviation of SMCR shows that there is a significant variation in capital requirements. This is a welcome feature of the data since it contributes to lower the variance of the estimated coefficient of interest and provide more precise estimation of the relationship between risk-taking and capital requirements.

As explained in Section 2, an O-SIB may not have any macroprudential capital requirement imposed if the national regulator decides not to activate the requirement for that bank. This result that in our sample 26.34% of bank-quarter observations are not treated. In other terms, for those banks the regulator opted not to activate the SMCR. While this is a discretionary decision, there are substantial institutional arrangements to guarantee that the decisions are taken objectively without favoring any national champion.

The second row of each panel of Table 3 shows the Overall Capital Requirement (OCR) for CET1 capital, i.e. the sum of the Pillar I capital requirements and the combined macroprudential capital requirement. The average supply levels of CET1 capital are shown in the third row of each panel. The difference between the OCR and the supply of capital by banks is then computed in order to derive a proxy for the stringency of the binding of the capital requirement at bank-level (row four of Table 3). Banks' response to higher capital requirement are expected to be a function of the distance to the regulatory minimum, or in other words an

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[20]Note that over the sample period, other type of *country level* macroprudential buffers were also levied on EU banks, as for instance the CCoB and the CCyB. The total combined yearly average of macroprudential buffer averaged 0.65% from 2014 until 2017Q3. However, in this paper, the focus is exclusively on bank-level macroprudential buffers since they allow for more precise estimates and allow to control for time varying country-level variation by including country-time fixed effects. In other terms, the country-time fixed effects absorb the variation generated by the country-level capital requirements. Note also that there is a small average increase (i.e. 0.01%) of the SMCR across the sample already in 2013 since in Norway the macroprudential capital requirements where the Systemic Risk Buffer (SRB) was introduced in 2013Q3.

inverse function of their excess capital above the minimum requirement. In particular, banks are expected to increase their capital supply if they are close to the regulatory minimum as found already in Jacques and Nigro (1997) and Rime (2001).

Table 4 illustrates descriptive statistics of banks' financial accounts as extracted from the SNL Financials database. Descriptive statistics are shown for all variables used in the subsequent empirical analysis, when absolute values are shown these are expressed in EUR throughout the paper. The asset side of the balance sheet is composed by three major components: loans gross of provisions for impairment (58.29%), securities (25.13%) and cash (15.29%).[21] It is worth noting the average level of RWA over total assets, i.e. the risk-ratio, which is 50.91%, as this measure will be a useful benchmark for the following analysis. Securities can be further broken down by Held for Trading (HFT), Available for Sale (AFS) and Held to Maturity (HTM). On the liabilities side the table shows the means of the main funding sources for banks: deposits (48.5% of total assets), short and long-term wholesale funding (33.3%) and debt (17.9%).[22]

Importantly, the SNL Financials database also allows to capture the extent to which systemically important financial institutions are interconnected with each other and the wider financial system. Excluding measures of bank interconnectedness and complexity would bias the results due to their direct correlation with the level of the SMCR, see Section 2 above and EBA Guidelines on the criteria to assess systemically important banks in the EU. Table 4 presents four indicators used in the paper as proxies for interconnectedness and complexity, namely: i) interbank lending as a direct measure of interconnectedness; ii) assets held for trade as measure of complexity and interconnection with financial markets' developments through mark-to-market trading book accounting which directly impacts banks' profit and loss statements; iii) over the counter (OTC) derivatives securities held on the balance sheet as a measure of both complexity and interrelation with the counterparty risk in he financial system; iv) cash held at the Central Bank for interbank payments' settlements.[23]

[21] Cash includes reserves and balances at the Central Bank, operating cash, cash and cash equivalents according to the relevant accounting standard, i.e. "short-term, highly liquid investments that are readily convertible to known amounts of cash and which are subject to an insignificant risk of changes in value".

[22] The total sum of funding sources and equity is not 100% of total assets due to few missing observations across these variables.

[23] Cash held at the central bank is also an important bank-level control variable for unconventional monetary policy operations of quantitative easing whereby bank's accounts at the ECB were credited with cash after monetary policy operations.

3.2 Empirical Methodology

The introduction of the CRD IV/CRR regulatory framework and of the new macroprudential capital requirement offers an opportunity to employ an identification strategy based on a controlled comparison by studying the effect of a policy change on differently affected banks. As noted in previous sections, the SMCRs are set at individual bank-level for systemically important banks in the EU. This implies that within a country banks are subject to different level of requirements depending on their systemic importance. This ensures cross-country and within-country variation at bank-level, which in turn is suited for using a multi-treatment group difference-in-difference identification strategy. [24] The baseline estimated equation is:

$$Y_{ict} = \alpha_i + \beta SMCR_{ict} + \ln X_{ic,t\;\;1}\gamma + \delta_{ct} + [\phi_i \cdot t] + u_{ict} \tag{1}$$

Where i, c and t are indicators for bank, country and time respectively and u_{ict} is the residual unexplained term.

The outcome variables of interest are in the vector Y_{ict} and they include the capital ratio (CET1/RWA), the logarithm of the levels of CET1 and total capital for the capital based specifications; the logarithm of the RWA, and its decomposition in RWA/Assets (i..e risk density) and the logarithm of total assets for risk based specifications. The policy variable of interest is the level of the systemic macroprudential capital requirement $SMCR_{ict}$ which is imposed at individual bank-level and is gradually phased-in over five years. Both the outcomes and the policy variables are at time t to reflect a contemporanous reaction to higher capital requirements. The main coefficient of interest in the equation is β, which can be interpreted as the average treatment effect of a one percentage point increase in capital requirement on the outcome variable of interest.

The matrix $X_{ict\;\;1}$ includes bank-specific, time varying control variables lagged by one quarter to limit simultaneity bias. The set of control variables is motivated by two main reasons. The first is to control for the EBA criteria for designating systemically important banks and the resulting implied calibration of the SMCR, see Section 2. The EBA criteria are taken into account using total assets (as proxy for size), loans (the importance of the bank in the financial

[24] In this setting each bank is a group of treatment and is compared with other treated banks in terms of intensity of treatment (i.e. different levels of capital requirement increases) and with the group of banks that had not have any increase in the SMCR over the sample period. For details on the multi-treatment group difference-in-difference estimation technique see Chapter 5.2. in Angrist and Pischke (2008).

system), interbank lending, holding of securities and OTC derivatives (the complexity and the interconnectedness of a bank with the financial system). The second is to control for structural and cyclical characteristics that may confound risk-taking or equity raising. For those the model uses total debt and deposits (as proxy for leverage and funding), return on assets and the cost to income ratio (cyclical and structural profitability), total cash (liquidity) and reserves held at the central bank (quantitative easing).[25]

In addition, the specification includes bank fixed effects, α_i, to control for time-invariant bank heterogeneity as for instance the business model (i.e. retail vs investment bank). The parameters δ_{ct} are interacted country-quarter dummy variables for capturing within country endogenous variation, for instance time varying macroeconomic effects such as: credit and economic growth, supply and demand shocks or fiscal and monetary policy changes within a country. In a cyclical downturn, when counterparties are more likely to be downgraded than upgraded, the resulting effect is a mechanincal increase in risk weights to account for major counterparty risk and viceversa. Moreover, during an economic upturn banks may underestimate risks and shift the composition of their portfolios to riskier activities (Rajan (1994); Jokipii and Milne (2008); Shim (2013)). Therefore, the δ_{ct} fixed effects control for time varying country-level factors that might simultaneously affect the level of the SMCR and any of the dependent variables in Y_{ict}. In addition, with respect to the use of simple macroeconomic controls the country-quarter fixed effects ensure a lower risk of omitted variable bias.

A version of Equation 1 is augmented with the bank specific trends $\phi_i \cdot t$, this is for a robustness test of the common trends assumption. In fact, the inclusion of trends at the level of the change of the policy variable should be a standard robustness test for diff-in-diff specifications, see Wolfers (2006) and Angrist and Pischke (2008).[26]

3.3 Threats to Identification and Solutions

Throughout the paper, the identification of a more robust casual impact is facilitated exploiting the flexibility of a cross-country bank-level panel. The advantages of a bank-level cross-country dataset are manifold. Firstly, a cross-country bank-level panel allows for a robust method

[25] All the control variables in $X_{ict\ 1}$ are scaled by total assets to limit heteroscedasticity, except of course total assets which are included using the natural logarithm.

[26] Notice that matching methods are often more intuitive but regression techniques are more straightforward to implement, this is true in particular when covariates are continuously distributed and matching on continuous covariates would requires stratification or pairing as in our case (Cochran, 1968; Angrist, 1998)

to control for time varying macroeconomic variation which is absorbed by country-time fixed effects. Second, the paper exploits the granular bank-level data to measure banks interconnectedness with the financial system through interbank lending and OTC derivatives. This is an essential for delivering unbiased estimates since by regulation the calibration of capital requirements is a function of banks' interconnectedness with the broader financial system and its operational complexity. Third, in the bank-level panel utilised in this paper it is possible to control for the quantitative-easing effects due to non-conventional monetary policy by including excess reserves held at the Central Bank. Quantitative easing may influence banks ability to raise equity since they would have a more stable source of alternative funding, omitting the quantitative easing channel may thus bias the estimates. Fourth, in contrast to *single* country bank-level studies, it can increase the external validity of the results. Finally, in comparison to macro *country*-level panels, a bank-level dataset improves on the granularity of available data fostering the study of heterogeneous effects across banks.

Notwithstanding these advantages, threats to the identification of causal effects may still arise from violations of one of one of the following assumptions of the D-i-D technique: i) banks do not anticipate the change, i.e. the common trend assumption is violated, ii) the policy change is exogenous, iii) there are no spillovers across borders.

The failure of the common trend assumption due to anticipating behavior by control group banks is a standard threat for the identification. Section 6 discusses those threats and presents two robustness tests. The first test of the common trend assumption controls for bank-level trends in the regression as in Wolfers (2006). The second test investigates the presence of announcement effects of the policy and is akin to Alpert (2016). Both tests present robust evidence on the absence of diverging pre-treatment effects across the treated and the control group.

The exogeneity of the policy change may not be warranted because capital requirements are set by national macroprudential authorities and are not centralised at EU level. This leaves discretion to national regulators and could cause the introduction of these requirements to be endogenous if the Member State acts strategically to protect (weaker) domestic banks. If this is the case then capital requirements may not be effective as planned because of Member States inaction bias. The paper investigates the potential presence of policy-maker protective behavior and inaction bias in Section 7 without finding evidence supporting endogenous behavior. This is not surprising since several arrangements enshrined in EU banking regulation are specifically aimed at eliminating national biases with respect to macroprudential risks, as described in Section 2.

Concerns on spillovers are addressed by using consolidated financial accounts of EU banks which eliminate the possibility of arbitrage. The use of consolidated data is warranted also because macroprudential capital requirements are levied at a group consolidated level. In a nutshell, the robustness tests provided in the paper, in conjunction with other provisions established in the EU banking regulation, address the concerns on the validity of the research method due to endogeneity.

3.3.1 Bank Risk Measure

In terms of measurement, one of the most important elements of the analysis presented in this paper is the measurement of risk-taking behaviour which must be able to identify individual bank specific risk-taking. One way to approach this problem is to look directly at the intrinsic risk stemming from the combination and composition of the portfolios on the assets side of banks' balance sheet. This is the approach followed by the Basel Committee on Banking Supervision (BCBS) under the Basel II rules on risk sensitive capital requirements.

But how can banks adjust their CET1 ratio after an increase in the regulatory capital requirement? A look at the CET1 ratio can help discerning the effects:

$$CET1Ratio = \frac{CET1}{RW_a Asset_a} \tag{2}$$

where CET1 is the amount of Common Equity Tier 1 capital held by the bank, RW represents the non-negative risk weight specific to asset a, and Asset is the amount of nominal exposure in asset a. As Equation 2 shows, banks can increase their regulatory capital ratio in three mutually non-exclusive ways: by increasing capital, reducing the risk-weights or reducing their assets. A bank can raise capital by either issuing new shares and/or not paying dividends to its shareholders to retain earnings. The newly issued shares and retained earnings increase the CET1 ratio, provided that the bank does not increase its risk-weighted assets. Alternatively, holding equity constant, the management of the bank can reduce risk-weighted assets, either through shifting assets composition towards exposures with lower risk-weights such as government securities, or reducing assets, that is by reducing lending, selling securities, impaired loans or other assets.[27]

From Equation 2 a logical approach for the measurement of bank specific risk-taking behaviour lies in the Basel II rules on risk-sensitiveness of assets. The ratio of RWA over total assets, for simplicity *risk density*, is a natural measure of bank risk-taking behaviour if we keep fixed the risk weights measurement approach. The risk density provides the average risk the bank's portfolio according to the risk-weight associated with each asset. It has the advantage of being a simple and very intuitive measure of bank risk-taking, (Berger, 1995), even if the appropriateness of risk-weights has been questioned in the literature, (Hellwig, 2010). A further benefit of using the risk density is that it takes into account the deterioration of the *quality* of a credit portfolio, as already noted by Shrieves and Dahl (1992) and Jacques and Nigro (1997). In fact, regulatory provisions foresee higher risk-weights for non performing exposures and impaired assets.[28]

In addition, the risk density indicator is a *decision* variable within the reaction function of banks' risk-management and its decision making process to changes in capital requirements determined by the regulator. The response of the risk management is exclusively determined by strategic decision and thus more apt to measure risk-taking behaviour than market based risk measures such as CDS spreads which are usually measures of solvency. In addition, the latter are of minor interest since they are external to the decision making of the banks management, and are a mere reflection on how the financial markets judge the probability of the bank being solvent when payments are due.[29]

A further advantage of the use of internal risk-weights is that they provide for a timely and not delayed response when an increase in capital requirements occurs. Banks find issuing new capital generally more expensive than issuing debt or retain earnings, and they do not find profitable reducing their assets in order not to hamper their returns. As such, either increasing

[27]Note that this paper does not look at alternative supervisory measures aimed at increasing the risk-weighted capital ratio, as for instance the CRR Art. 458 measure on the floor of risk-weights to be applied to specific exposures such as real estate. Despite having a similar effect on the overall risk-weighted capital requirements this provision is fundamentally different since constraints banks' reaction to a specific channel of adjustment.

[28]Some authors suggest to use directly non-performing loans (NPLs) as proxies for risk-taking since granting high-return, but high-risk, loans underlines a risk-taking propensity. However, NPLs would not be entirely apt to our task due to lags in their accounting rules, they are recognized as non-performing starting on the 90th day past due (depending on the type of asset and the accounting classification) implying a difficult identification problem for the econometrician regarding the timing of the impact.

[29]It is also important to notice that the scope of application of CDS pricing is very limited in our sample since CDS prices are generally available only for some of the large systemic banks. In our sample, this translates to only 49 banks with available CDS prices.

CET1 or shrinking the balance sheet earlier than necessary is not an efficient allocation of resources. Similarly, the costs of regulatory sanctions for non-compliance ensure there is no lag in the reaction. The absence of lags or delays in the reaction of bank managers in setting their preferred risk level entails that risk-taking can be readily discernible in regular financial statements.

Some notes of caution in using the risk density are due. Banks using internal rating based approach (IRB) to set risk-weights on their portfolio have a competitive advantage with respect to banks using standardized approach (SA), (Praet, 2004; Tschemernjak, 2004; Haselmann and Wahrenburg, 2016). The competitive advantage arises because IRB banks use their own empirical models to estimate more appropriately market and credit risk, while SA banks use the one-size-fit-all risk weights defined in the regulation which are generally more stringent. This study controls for this heterogeneity using bank-level fixed effects in all specifications (the risk weights measurement approach is generally sticky in time), in addition it explores the extent of the competitive advantage of IRB banks by interacting the macroprudential capital requirement with an IRB dummy in Section 4.

A final note of caution is warranted since, by construction, the risk density identifies risk stemming predominantly from on-balance sheet exposures, while the risk associated with off-balance sheet exposures transactions are not entirely captured in this metric. In the transposition of Basel standards in the EU, the CRR asserts that off-balance sheet items are treated like on-balance sheet exposures and shall be risk-weighted, however the calculation method implies a lower risk weight for off-balance sheet exposures.[30] Since off-balance sheet items are unobserved in the dataset, we can only try to form an educated guess on the bias arising from omitted variable. Table 2 shows the direction of omitted variable bias given the correlation patterns between the omitted variable, the treatment variable and the dependent variable. Due to the preferential regulatory treatment for off-balance sheet assets, it is likely that banks arbitrage and react to higher capital requirement by shifting some of their risky assets to unobserved off-balance sheet positions implying a *positive correlation* between a hike in regulatory

[30] Not all activities of the banks can be moved off-balance sheet, off-balance sheet items are typically exclusively those not owned by or not a direct obligation of the bank, for instance securitised activities and operating leases are the most common off-balance items, others are credit conversion factors which calculate the amount of a free credit line or guarantees. The key difference between off-balance and on-balance sheet exposures relates to the calculation method of the *exposure value* that should be risk-weighted. The definition and calculation of the exposure value of off-balance sheet items is detailed in CRR Article 166 for the IRB approach and CRR Article 111 for the SA.

capital and off-balance sheet activity. In addition, due to lower risk weights of off-balance sheet exposures, the β_2 coefficient in Table 2 should be lower than zero. It follows that the estimates on the impact of capital requirements on risk-taking behaviour may result downward biased. This downward bias may underestimate the real risk-taking behaviour in our estimates, probably even more for more complex institutions which have a higher capacity to transfer assets off-balance sheet.

4 Results

By presenting the first set of results, the paper acknowledges that banks tend to maintain a capital buffer on top of the regulatory minima as a signal of financial health to the markets, to attract funding and to minimize supervisory interference (Shrieves and Dahl, 1992; Jacques and Nigro, 1997). Moreover, microprudential supervisors encourage banks to maintain an additional voluntary buffer on top of the requirements, this indicates the adequate level of capital to be maintained in order to withstand stressed situations.[31] This study sorts banks by how binding is the new capital requirement. To this end, an indicator of the distance from the OCR is interacted with the change in the systemic macroprudential capital requirement.[32]

4.1 Capital: Baseline and binding distance interaction

Before investigating the relative importance of the moral hazard versus the skin in the game channels, it is instructive to understand how effective the capital requirement is at increasing the banks' capital. This section provides evidence on whether banks increase the numerator of the capital ratio and, as a consequence, whether their solvency is strengthened. Table 5 illustrates the results of the impact of an increase in the Systemic macroprudential Capital Requirements (SMCR) on three measures of capital: the risk-weighted CET1 ratio, the volume of available CET1 capital and the volume of supplied total capital. All regressions follow the specification in Equation 1, and include quarterly varying country-time fixed effects. The first

[31] In the Banking Union framework, this is regulated via an additional Pillar 2 Guidance which is calibrated on the basis of the adverse scenario in the supervisory stress tests. see ECB description of the Pillar 2 Guidance

[32] In turn, levels of desired capital may depend on external factors such as the macroeconomic environment, the market interest rate, the degree of tax differentials between debt and equity financing Schepens (2016), as well as the degree of regulatory pressure. In a bank-level empirical setting, the country-level features can be controlled for in specification 1 via country-time fixed-effects, these help to absorb the bias in the estimates arising from country-level specific influences.

columns (1)-(3) present the baseline estimates, while Columns (4)-(6) differentiate the impact by the cushion banks maintain from the OCR.

Column (1) shows how the resulting average impact on the risk-weighted capital ratio is not statistically significant. For the average bank, and without categorizing banks by distance from the minimum requirement, the impact of the SMCR is not strictly binding. This result is however not distinguishing by the buffer banks maintain on top of regulatory minima.[33] Column (4) indicates that once we include in the regressions dummies for distance, and their interaction with the SMCR, a one percentage point increase in the capital requirement induces an increase of the CET1 ratio by 0.83 percentage points, providing evidence that significant European banks are effectively constrained by the regulatory change. The interaction effect is not statistically different for the group of banks with a more than two percentage points excess capital with respect to the minimum requirement. The absence of negative sign for non capital constrained banks, provides evidence that the reaction to the hike in capital requirement is widespread. This finding is in line with the notion that banks have a preference to maintain a desired, or target level of capital, above the minimum to assuage market pressure and reduce supervisory interference, (Shrieves and Dahl, 1992; Jacques and Nigro, 1997).

But how this increase in the ratio occurs? In Column (2), the focus shifts to the amount of CET1 capital, i.e. the numerator of the CET1 ratio. On average, a one percentage point higher SMCR yields CET1 to increase by 8.9 percent. In Column (5), we differentiate the impact by distance to OCR: the result highlights again that banks with a relative shortage of capital have almost a double effect (17.7 percent) with respect to the average impact in Column (2). The coefficient for the reference group of banks with less than 2 p.p. of CET1 buffer above the minimum, translates in a 17.7 percent increase of CET1 ratio for a 1 p.p. rise in capital requirements. This positive impact provides evidence of the direct benefits of capital based macroprudential regulation in the EU. The reforms promoted widespread increase in capital levels across the sample of systemically important banks, and in particular for banks with lower loss absorption capacity, increasing capital for banks with lower buffers and therefore improving the overall resilience of the system. Significant banks with capital in excess of the minimum regulatory threshold have somewhat weaker, but still strong effects, in terms of the magnitude

[33] In the following note that the estimation sample is composed by 137 significant banks, the distribution of the OCR distance variable in the estimation sample has mean 8.7 percentage points and median at 7.8 percentage points. Similar results are obtained with different break-down of the distance from OCR, the results are available from the author.

of CET1 capital increase.

Column (3) and Column (6) corroborate the results on CET1 capital when including additional Tier1 capital and Tier2 instruments in the numerator. The net impact is attenuated since the bulk of the increase is borne by CET1 capital, a natural consequence of the SMCR requirement. The induced higher levels of capital ratios mean a greater loss absorption capacity for European banks when the next financial crisis hits, Jiménez et al. (2016).

4.2 Risk: Baseline and binding distance interaction

This section presents the first results on the skin in the game versus moral hazard channels. As summarized in Appendix A-II, a branch of the banking literature shows how more regulated banks can have risk-taking incentives due to the negative effect of higher capital requirements on bank profits.[34] On the other hand, the skin in the game argument postulates that for banks with higher capital ratios there is an incentive by bank managers to avoid excessive risk-taking since more risk increases the variance of returns with higher probability of significant losses on banks' equity.[35] This section shed lights on the capital requirements and risk-incentive relationship using the risk density as a measure for riskier assets, and interacting the SMCR with the distance from the OCR in order to study the interaction of risk-taking with the supply of regulatory capital.

Table 6 presents the estimates. Columns (1)-(3) investigate the effect without distinguishing banks by their distance from the overall capital requirement. Column (1) shows the estimates on the impact on the combined risk weighted assets, columns (2) and (3) presents the impact on the decomposition of RWA in risk density and total assets. The results suggest that, on average, banks have a significant tendency to increase their RWA after a tightening of the capital requirements. In particular, in Column (2), the impact stems from higher risk-taking, as the composition of the asset side of banks' balance sheets tilts toward more riskier assets. The risk-taking behaviour manifests in considerably higher risk densities (RWA/Assets), with a one percentage point hike in capital requirements being associated with 6.9 percentage points increase of the risk density. The estimates are significant at 1 percent confidence level and are indicative of the existence of a risk-taking channel of capital adequacy requirements, raising concerns on the non-intended consequences and perverse effects of capital based regulation.

[34] See for instance Koehn and Santomero (1980); Kim and Santomero (1988); Blum (1999).

[35] See for instance Hellmann et al. (2000); Repullo and Suarez (2004); Repullo (2004)

To understand better the magnitude of this impact, recall that the average risk density level in the sample is 50.9 percent (see Table 4). In other words, a one percentage point increase in the SMCR could shift the average risk density to 57.8 percent. This is an economically significant amount and, as noted in Appendix A-II, the qualitative impact is consistent with previous theoretical and empirical work. Moreover, we can try to extrapolate this impact to the average EU systemically important bank, we can compare how much this risk-taking relates to the effective increase in capital requirement occurred during the observation period. Table 3 shows that over the four years between 2014 and 2017, the SMCR increase on average in the sample of systemically important EU banks by 0.87 percentage points. A simple linear approximation would thus entail an average increase of risk weights by 6 percentage points, i.e. 0.87 multiplied by 6.9 the coefficient of Column (2).

The second part of Table 6 tests the hypothesis of a non-linear relationship between capital requirement and risk-taking, (Hellmann et al., 2000; Repullo and Suarez, 2004; Repullo, 2004). In particular, Jokipii and Milne (2011) find that banks with a lower management buffer above the minimum capital requirement reduce their risk while banks with a higher buffer increase risk. Contrary to the predictions of this strand of the literature, the evidence in Columns (4)-(6) does not show signs of a decreasing risk-taking behaviour by more capitalized banks. The interaction terms in the specification are not significant at standard confidence levels, i.e. irrespective of their level of capital supply, banks have similar propensities to take on more risk after a hike in capital demand.

The results of this section present a clear banks' tendency to react to more capital by shifting the portfolio toward riskier assets. The predisposition to take on more risk can be interpreted as evidence that the moral hazard channel is stronger than the skin in the game channel of capital regulation. Potential losses to equity holders arising from greater risk-taking are not the main driver of risk management decisions in the adjustment process. The positive aspect of the new regulation is that banks react by increasing the amount for capital even if this does not restrain them from taking on more risk.

5 Heterogeneity

5.1 Heterogeneity by Size and IRB

This section investigates how size and internal rating based approach affect the relationship between capital requirements and risk-taking behaviour. Bank size is measured using total assets, with small banks classified as those having less than EUR 20 billions in total assets, medium banks defined as banks with assets between EUR 20 to EUR 100 billions and large banks have more than EUR 100 billions in total assets.[36]

Further, banks are distinguished by their risk weights measurement approach in order to gauge whether more sophisticated financial institutions can successfully circumvent the risk-weighting system and present lower risk-weights on their books. The indicator variable for the IRB approach is constructed from SNL Financials where the risk weights measurement framework is provided and the dummy takes value one if the bank is using either the advanced or the foundation IRB.[37] A priori, we expect a positive correlation between size and IRB, due to resource constraints smaller banks may not have the required human capital to design and deploy the IRB approach which is more demanding in terms of modelling skills. In our sample, size and IRB have a positive pairwise Paerson correlation coefficient of 0.31, this correlation is significant at one percent significance level. Table 7 presents the evidence on the impact of a hike in capital requirements for capital indicators, while Table 8 shows the estimates for measures of risk. All regressions include bank-level controls, bank fixed effects and country-quarter fixed effects, the latter control for time varying macroeconomic heterogeneity.

[36]The classification of banks follows a division of the sample in three approximately equal parts in order not to lose observations and hence statistical power when performing heterogeneity effects, see Table A-I. For the smaller banks, this subdivision is also in line with the EU Banking Union criteria to distinguish Least Significant Institutions (i.e. total assets $<$ EUR 30 billions) and Significant Institutions (total assets $>$ EUR 30 billions). Other thresholds for size have been tested and results do not alter the conclusions presented in this section. Regressions by other categorizations are available from the author.

[37]There are two versions of the IRB approaches. The Advanced (A-IRB) is the most sophisticated of two credit risk modelling approaches agreed by regulators in 2004. It allows banks to calculate the probability of default (PD) for a loan, as well as the exposure at the point of default and the resulting losses. Its simpler cousin, the foundation IRB, only allows PD to be modelled. In the following we consider a dummy one for banks using either the A-IRB or the foundation IRB approaches, or a mixture of the two. The dummy is set to zero for purely standardized approaches (SA).

5.1.1 Impact on Capital by Size and IRB

Following the results in Section 4.1, Table 7 adopts the specification with a dummy variable for distance which is 1 if the distance from the OCR is greater than two percentage points, for the sake of space and according to the results of Table 5 the dummy for distance takes on only two values.[38] The estimates on the impact of capital do not present strong evidence of hetereogeneous impact by size or risk weights measurement framework. The interaction with the distance from the overall capital requirement is likewise not significant. The evidence on capital raising from Table 7 leads to conclude that there is no significant heterogeneous behaviour between small and big banks or between banks adopting the IRB or the SA.

5.1.2 Impact on Risk by Size and IRB

The results related to the risk-taking behaviour are more informative. Table 8 illustrates the outcome of the regression without differentiating by distance from the OCR since risk-taking behaviour does not appear to be related to the buffer of capital the bank maintains on top of the minimum requirement, this was shown in Table 6. Columns (1)-(3) present the results by bank size while Columns (4)-(6) illustrate the estimates for banks with IRB and for the interaction of size and IRB.

Column (1) of Table 8 indicates that RWA are increasing by approximately seven percent for a one percentage point increase of capital requirements. The impact on RWA does not appear significantly different between smaller and bigger banks. In Column (2), RWA are divided by total assets to obtain the risk density. The evidence indicates a clear increase of the impact on the risk density as the size of the banks increases. Banks with total assets above EUR 20 billions tend to take on more risk compared to small banks, approximately a two percentage point more for every percentage point increase in capital requirements. Column (3) confirms further that banks do not decrease their assets size significantly following an increase in capital requirements.[39]

In Column (4)-(6) we augment the specification with the risk weight measurement framework

[38] Same categories for the breakdown of distance from OCR as in the previous section, as well as other categories of size of the bank have been experimented, the results are similar in terms of both magnitude and statistical significance, they are available from the author.

[39] In a separate set of regressions the interaction with size is tested by interacting a dummy for G-SIBs with the SMCR, these results do not have a significant interaction term, this is likely due to the fact that variation of treatment status is not sufficient enough among the G-SIBs, see Appendix A-I

represented by the indicator variable for IRB, which takes the value one if the bank is using the internal rating based approach. Column (4) reveals that the increase in RWA is driven exclusively by banks with assets greater than EUR 100 billions. The coefficient for large banks increased to eighteen percent following a one percentage point hike in capital requirements. The impact for smaller banks is no longer significant. More telling is the impact for banks with more than EUR 100 billions in assets using the IRB approach, they have lower risk-taking by fifteen percent with respect to large banks relying on the SA. The marginal impact of one percentage point increase of the SMCR on large IRB banks is a two percent increase in RWA.

Column (5) of Table 8 takes a closer look by netting out the confounding effect of the RWA ratio denominator. The first and the forth row of Column (5) confirm that even smaller banks take more risks following a rise in capital requirements while the IRB approach for small banks does not bring significant benefit in curtailing their risk density. For smaller banks, a one percentage point increase in capital requirements induces an increase of the risk density by 4.3 percentage points. More interestingly, the second and the third row of Column (5) suggests that there is a positive relation between risk-taking behaviour and bank size. As the size of the bank increases, and with it its systemic importance, the risk-taking behaviour is more accentuated. A one percentage point increase in capital requirements is associated with a 7.3 percentage points increase of the risk density for medium banks, and with a 9.6 percentage points increase for large banks, both at 5% significance level. These results are consistent with the presence and intensification of agency costs as the financial institutions becomes larger with a more fragmented shareholders base. In fact, as pointed out by Ang et al. (2000), agency problems are directly proportional with the dilution of the ownership structure, and it can be inferred that in large publicly traded banks these are substantial.

Can IRB banks reduce the *observed* risk-taking behaviour by using the more advanced approach to measure risk weights? The last row of Table 8 presents the results. For medium banks, the interaction coefficient between size and IRB is negative but is not statistically significant. Large IRB banks with total assets above EUR 100 billions have a significantly lower propensity to augment their risk density when capital requirements are incremented, the point estimate is 3.6 percentage points lower relative to SA banks of same size. This implies that large IRB banks present a reduced risk exposure from a supervisory perspective, suggesting overall lower levels of risk-taking than large SA banks. To what extent this risk reduction is real and effective, or is just the result of manipulating the risk weights in their own favor, it is impossible to discern with the data used in this paper.[40] Nevertheless, the evidence establishes the presence of a competitive advantage for IRB banks since lower risk weights imply a lower cost of compliance to a hike of regulatory capital requirements.[41]

5.2 Heterogeneity on Risk by Profitability, Funding and Leverage

This section explores further the heterogenous impacts of a change in capital requirements on bank risk-taking behaviour by looking at three measures of bank performance: net interest income as a proxy for profitability, wholesale funding as a proxy for inherent liquidity risk, and the leverage ratio as a measure of bank capitalization.

5.2.1 Profitability and risk-taking

The low interest rate environment which characterised the past decade shrinks the interest income margin of banks and increases pressure on their profitability. The literature has shown convincingly this link in both theoretical and empirical contributions, (Samuelson, 1945; Hancock, 1985; Borio et al., 2017). Therefore, less profitable banks may take more risk in order to compensate for the reduced profitability. This argument is strictly intertwined with the proponents of the charter value theory of the bank, as summarized in Appendix A-II, which support the skin in the game argument whereby banks have more incentives to operate conservatively when the amount of equity is at risk, (Marcus, 1984; Benston, 1986).

If the above arguments are true, more profitable banks should have a less risk-taking behaviour when faced with a capital increase. To test this proposition, the specification is augmented including an interaction of the SMCR and an indicator dummy of net interest income (NII) as a proxy for profitability. NII is defined as interest income less interest expense before provisions for loan losses, and hence is a direct measure of return stemming from interest rate. Table 9 presents the results for profitability in Columns (1)-(2). The dummy for profitability is

[40] The marginal effect for large IRB banks is however still greater than the small banks with assets lower than EUR 20 billions.

[41] These result raise the question whether very big and sophisticated banks, the G-SIBs and their subsidiaries across Europe, are driving this behaviour. Unfortunately, all 14 G-SIB in our sample are sophisticated enough to adopt the IRB approach for risk weights measurement, this lack of variation does not permit to test this hypothesis. A solution is to use a higher threshold for the size of the very large banks and as a proxy rule we defined the threshold of EUR 300 billions for the very big banks in the EU, but even in this case the required variation in the IRB variable was not sufficient to obtain the estimates, see Table A-I. Only three banks with assets greater than EUR 300 billions adopt the SA and 29 use the IRB.

switched on if net interest income is above median (NII = 1), reporting the estimates for more profitable banks.

The evidence suggest that there is a greater tendency to take on more risk by the cluster of less profitable banks, i.e. when the dummy for profitable banks is turned on (NII = 1). The interaction coefficient of small banks with a net interest income above the median has a positive albeit insignificant magnitude. More interestingly, profitable medium and large banks have a significantly lower propensity to increase risk with respect to similarly sized less profitable banks. Medium banks with above median net interest income decrease their risk density by 1.6 percentage points (s.d. 0.741) less than same sized banks with below median NII. The same compensatory pattern in risk-taking is observed for large profitable banks, they decrease the risk density by 2.07 percentage points (s.d. 0.925) with respect large banks with below median NII. For both median and large banks, a test of the sum of the coefficients for above and below median NII banks, fails to reject the null.[42]

These results confirm the fact that more profitable banks have a less aggressive risk-taking behaviour when faced with a capital increase, and indicate that most of the increase in risk-taking associated with size is related to less profitable institutions. This leads to the conclusion that the increase in risk-taking associated with bank size is due to less profitable banks and the tendency to gamble for resurrection.

5.2.2 Wholesale funding and risk-taking

This section introduces a link between liquidity risk and the risk-taking behaviour. In general, banks with a greater reliance on market funding are more prone to liquidity runs in times of crisis, (Rajan, 2006; Brunnermeier, 2009).[43] wholesale-funded banks have to frequently rollover large amounts of funds which makes them particularly vulnerable when market or interbank liquidity dries up. In addition, Huang and Ratnovski (2011) show how on the supply side of wholesale funding the financiers do not have incentives to conduct costly monitoring of banks since they may withdraw on short notice based on negative news signals, exacerbating further the risk of a potential bunk run. This inherent liquidity risk residing in wholesale-funded banks poses a threat to their stability.

[42]For median banks the null hypothesis of the linear combination 2.158-1.634=0 has a p-value=0.63 and fails to reject the null. For large banks the tested linear combination is 2.842-2.067=0 with a resulting p-value=0.48

[43]For instance, Shin (2009) notes that in the Northern Rock bank run case, wholesale funding plummeted by more than 50%, from 26.7 billion pounds in June to 11.5 billion pounds in December 2007.

Based on the evidence provided in previous sections the question arises as to whether wholesale-funded banks recognize the inherent liquidity risk of their funding model when reacting to a hike in regulatory capital or not. If not, the consequences of an increase in capital requirement from a systemic standpoint may be even more worrisome since higher risk-taking is more likely to lead to negative news signals and subsequent bunk runs.

The evidence on the interaction between wholesale funding model and risk-taking behaviour following an increment of the SMCR is provided in Column (3)-(4) of Table 9. wholesale-funded banks are coded with a dummy being one when the ratio of wholesale funding, short and long term, over total assets is greater than the median. The first three rows corroborate the results observed in previous specifications. Medium and large banks have more than two percentage points higher reaction than smaller banks, corroborating that agency costs may be a driver of this difference. The results change significantly when the SMCR increase is interacted with size and a dummy representing wholesale-funded banks (WHS=1). Smaller wholesale-funded banks show a further increase in the risk density by 1.34 percentage points with respect to similar size non wholesale-funded banks. On the contrary, medium and large wholesale-funded banks decrease their risk density by the same amount of their risk increase after the hike in capital requirements.

This reduction compensates the propensity to rise the risk density associated with medium and large banks and indicates that the increase of the risk density is largely driven by medium and large retail-funded banks. The results suggest that wholesale-funded banks have a lower incentive to increase the riskiness of their portfolio when faced with a capital requirement hike.

This may be due to several factors, in particular can be interpreted as a strategic need to reduce the publicly observed risk density in view of the already riskier funding model. A further interpretation may be related to profitability and the results in Column (3)-(4) on wholesale funding can be reconciled with the evidence provided in the previous section on profitability and risk-taking in Columns (1)-(2). Recent literature has shown that wholesale-funded banks have a competitive advantage in a low interest rate environment since they can shift their funding globally towards regions where monetary policy conditions are looser and exploit thus cross-border funding to limit the negative pressure on profitability due to low interest rates, (Bruno and Shin, 2015). It follows that wholesale banks are on average more profitable than banks relying on standard deposit funding, this is described in Figure 1 for our sample of G-SIBs and

O-SIBs in the EU, and therefore have lower incentives to increase their riskiness to compensate for lower interest income.

5.2.3 Leverage and risk-taking

This section investigates the link between the leverage ratio and risk-taking. The relationship is expected to be positive according to the previous contributions by Furlong and Keeley (1989), Dewatripont and Tirole (1994) and Jokipii and Milne (2011). Leverage is measured following the Bank of International Settlements definition by dividing Tier 1 capital by the bank's average total consolidated assets (i.e. the sum of the exposures of all assets and non-balance sheet items).[44] In addition, a dummy variable is defined for above (LR=1) or below (LR=0) the median leverage ratio in the sample. The evidence for the interlinkages between leverage and risk-taking subject to a regulatory capital increase is presented in Columns (5)-(6) of Table 9.

While the first three rows confirm again the incremental impact of regulatory capital on the risk-taking behaviour by bank size, the heterogeneous impact by above median leverage ratio is not statistically significant. The sign of the interaction coefficients for medium and large banks hints at a negative relationships, however the estimates are rather noisy suggesting an absence of relationship between risk-taking and leverage ratio following an increase in regulatory capital requirement. This result is consistent with the evidence presented for the baseline regression for risk-taking presented in Table 6 where the impact was broken down by the distance from the minimum overall capital requirement. Despite the distance from OCR being a risk-sensitive measure of capital due to the use of risk-weighted assets at the denominator, it is positively correlated (correlation coeff. = 0.35) with the non-risk-based leverage ratio measure and has a similar economic interpretation.

6 Robustness: Common Trends

The failure of the common trend assumption due to diverging behavior between treated and control banks is a standard threat for the identification of Difference-in-Difference (DiD) empirical strategies, (Angrist and Pischke, 2008). In the current setting the common trend assumption implies that the risk-taking behaviour of banks would be same in the absence of treatment. This

[44] For more detailed information on the Basel III leverage ratio consult the documentation provided on the BIS website

section presents the evidence of two alternative tests of the common trend assumption for DiD regressions. The first test controls for bank specific trends in the specification and estimates them on a longer time dimension in the panel; the second interacts a treatment dummy with a dummy for the announcement period to investigates for diverging behavior between treated and control groups prior to the phasing-in of the SMCR.[45]

6.1 Bank specific trends and a longer T

The first test studies the influence of confounding pre-existing trends at the level of the policy variable by including a bank specific trend in the model as in Wolfers (2006). If banks' trends are not controlled for, and treated and control banks have diverging trend, then the estimates of the impact of capital requirements may suffer of bias due to the confounding effect on them induced by the diverging trends across the two groups.[46]

It is important to note another reason why including bank specific trends in the regression is necessary for unbiased identification. When pre-existing bank trends are correlated with both the change in capital requirements (i.e. main regressor of interest) and the risk-taking behaviour of banks (i.e. the dependent variable), the inclusion of bank specific trends in the model ensures that the estimated coefficient on the variable of interest is not affected by omitted trend bias, (Wolfers, 2006).

Formally, to test for the robustness of the inclusion of bank trends the baseline model is augmented with bank specific trends represented by the product $\phi_i \cdot t$ where i is the indicator for banks and t stands for the time dimension (i.e. quarters):

$$Y_{ict} = \alpha_i + \beta SMCR_{ict} + \ln X_{ic,t\ \ 1}\gamma + \phi_i \cdot t + \delta_{ct} + u_{ict} \tag{3}$$

If the impact of the increment in capital requirements on the risk density is not statistically

[45]It is useful to note the difference between the standard two-way DiD setting and the multi-group setting. In the two groups setting, uniformly treated and non-treated groups are compared and the uniform treatment variables is a dummy (1/0). In the multi-group DiD setting the intensity of treatment varies across the treated group: in this paper these are represented by heterogeneous capital requirements across banks, i.e. the treatment variable is not a simple dummy but varies across banks. In addition, in this study the time dimension is not constituted by only two periods (after/before) as in the standard two-way DiD approach, instead, each quarter can have progressively stricter treatment intensity per bank introducing thus a more dynamic multi-period treatment.

[46]Note that trends in risk-taking behaviour may diverge because of several reasons: for instance structural changes in bank business models or because of the formation of expectations on future regulation as for example the introduction of new rules within Basel IV that may affect strategic portfolio allocation of banks.

significant after including bank-level trends then the evidence presented should be interpreted with caution. In that case, it is very likely that divergent trends would affect the findings, i.e. the increment in capital requirements would have happened predominantly in banks where already a rising risk density was being implemented by bank management.

The first evidence for the first test on common trends is illustrated in Table 10. The Table is split in two parts, Columns (1)-(3) present the results for capital to be compared with baseline regression without bank specific trend as in Table 5; Columns (4)-(6) presents the results for risk-taking behaviour to be compared with baseline Table 6. After including bank specific trends the statistical significance of the coefficients remains unchanged for both capital and risk-taking. The magnitude of the coefficients for the *level* of CET1 and total capital are slightly smaller than in the baseline regressions. Similarly, the coefficient on the risk density decreases after including bank trends, the impact of higher capital requirement on risk-taking results halved to 3.1 percentage point increase for a one percentage point increase of the SMCR. While this is a considerable reduction of risk-taking, it is a symptom that bank specific trends play a significant role in the estimates driving down the overall results.[47]

For the second part of the evidence on the bank specific trends, it is important to notice that the estimated trends may depend on the length of the time series. As shown in Wolfers (2006), controlling for bank specific trends only works well when there is a sufficient sample period available before the treatment period commences. As such, the estimated trends in Equation 3 may require more observations to be properly fitted to the data.[48] The test is therefore repeated extending the estimation sample to begin in 2006 rather than in 2010. This allows to estimate bank specific trends on a full financial cycle starting in 2006 before the financial crisis and ending with the introduction in 2014 of macroprudential capital buffers.

The second part of the evidence is presented in Figure 3. From left to right in each plot, the dots represent different βs estimated when increasing progressively the starting period of the sample by one year and shrinking thus the available observations for the estimation of the trend. The first column of Figure 3 presents the evidence for capital variables with one plot each for CET1 ratio, CET1 capital and total capital. The second column illustrates the

[47]Note that the coefficient of determination R-squared is considerably higher since data now explain a greater portion of the variation of dependent variables. As common when trends at the policy variable are included standard errors are bigger implying a higher p-value.

[48]The problem is exacerbated when there is a structural break in the pre-existing trend of the outcome variable as it is likely to have happened after the 2007-8 financial crisis as illustrated for capital levels in Figure 2.

evidence for risk with one plot for RWA, the risk density and total assets. Vertical bars show confidence intervals for every estimated β.

By looking at the results, it is confirmed that the assumption of common trends is robust also to different lengths and starting years of the sample which allow for a better fit of pre-existing trends to the data. Consistently with the previous results, the risk density and the RWA show similar estimated coefficients as in Table 10. The level of CET1 is however not always significant when the trend is allowed to be computed prior to 2010, even if the failure to accept is due to few decimals of a percentage points, indicating that the results for the level of CET1 may suffer marginally from the non holding of the common trend assumption.

6.2 Announcement effects

A further method to test for the presence of diverging trends prior to the implementation of the policy is to look at announcement effects. The announcement of a change in the capital requirements policy may itself lead to strategic reactions by banks invalidating the common trend assumption. The European Commission anticipated publicly the intention to strengthen its capital framework for systemically important banks in September 2009, when it introduced the possibility to increase macroprudential capital buffers in good times to be released in a downturn.[49] This change of paradigm may have induced banks to anticipate their reaction to the capital increase before the implementation in 2014 and may confound the previous findings. In order to test formally for the impact during the announcement period this section relies on an event analysis framework akin to Alpert (2016). In the following set-up, the announcement period dummy $D(Announcement)$ is defined as one for the period from 2009Q4, the first period since the announcement, until 2013Q4, the last quarter before the phasing-in of the policy.

During the announcement period, large European banks may already expect to be charged with higher capital requirement and may have an incentive to send positive signals to the market by increase their capital supply. However, being effectively levied a capital requirement and hence assigned a treatment status happens only after 2014 and is a discretionary choice of the regulator. The treatment status is exogenous to banks' expectations which are predetermined

[49]The proposed changes were introduced under the Commission Directive 2009/111/EC of the European Parliament and of the Council of 16 September 2009 amending Directives 2006/48/EC, 2006/49/EC and 2007/64/EC as regards banks affiliated to central institutions, certain own funds items, large exposures, supervisory arrangements and crisis management. A copy of this directive may be found at this link.

to the regulators' decision. In other terms, during the announcement period banks are not aware of what would be the regulators revealed preferences in 2014. This set-up ensures that banks cannot self-select in the treatment group since the decision to levy a capital requirement on a specific bank is exogenous to their expectations. As such, in the following, the treatment status $D(Treated)$ is defined equal to one if the bank has been subject to a positive SMCR in any quarter after the phasing-in of the policy from 2014q1 until 2017Q3.

Formally, variants of the following DiD equation are estimated:

$$\begin{aligned} lnY_{ict} = \alpha_i + \beta SMCR_{ict} + \omega D(Announcement) * D(Treated) + \ln X_{ict\ \ 1}\gamma + \\ + \eta D(Announcement) + \theta D(Treated) + \delta_{ct} + u_{ict} \end{aligned} \tag{4}$$

This basic strategy compares deviations from trends of capital and risk-taking between a treatment and a control group of banks during the announcement period, the coefficient of interest is the ω of the interaction term $D(Announcement) * D(Treated)$. If the coefficient is statistically significant then the trend deviations across the treated and control groups are diverging and the common trend assumption across the two groups would not hold.

The results are presented in Figure 4 for the level of CET1 capital and in Figure 5 when the dependent variable is the risk density. The left panels of each figure depict the ω coefficient of the interaction term $D(Announcement) * D(Treated)$ for different starting periods of the estimation sample similar to the reasoning of Table 3. The right panels of each figure plot the β coefficient for the level of the $SMCR_{ict}$ as specified in Equation 4.

For either capital or risk indicators, the evidence indicates that there is generally no statistically significant difference in the reaction of treatment banks during the announcement period and in comparison to the non-treated group. For the risk density, and only when the sample begins in 2006, the impact is significant at the ten percent confidence level. The impact of the SMCR in the implementation period, i.e. after 2014, remains in line with the coefficient found in the baseline Tables 5 and 6. In other words, the impact of the SMCRs is not absorbed or curtailed by the introduction of a dummy that captures the announcement period and we can conclude that the estimated positive relationship between higher capital requirements and higher capital and risk-taking is robust to the inclusion of announcement periods.[50]

[50] Alternative later periods may be considered as the beginning of the new macroprudential framework in the EU as for instance since the EU Commission public consultation on the new CRD-IV in 2010Q2. Nevertheless, similar results to those presented in Figures 4 and 5 are obtained when the announcement period is set in

7 Robustness: Endogeneity

The exogeneity of the policy change may not be warranted even if the change in the SMCR is external to the bank decision making process. A variable of interest that is external, but not exogeneous, will not yield consistent estimates of the parameter of interest, see Deaton (2010).

Macroprudential capital requirements are set for each bank individually at national level by its own macroprudential authority. This leaves discretion to national regulators and could cause the introduction of macroprudential capital requirements to be endogenous if the Member State behaves strategically and wants to protect (weaker) domestic banks. If it does, then undercapitalised banks may have a favorable treatment and the level of capital will be determining the SMCR introducing reverse causality. As described earlier, significant regulatory provisions are aimed at ensuring that this does not happen, nevertheless a test for this possibility is warranted.

This section presents a simple procedure to test for the possibility of endogeneity by looking if the outcome variables of interest are correlated with the SMCR exploiting the within variation of the fixed effect estimator. The following equation is estimated:

$$\begin{aligned} SMCR_{ict} = \alpha_i + \psi Y_{ict} * D_{2010Q1\quad 2013Q4} + \ln X_{ict\quad 1}\gamma + [\phi_i \cdot t] \\ + \chi D_{2010Q1\quad 2013Q4} + \zeta Y_{ict} + \delta_{ct} + u_{ict} \end{aligned} \tag{5}$$

In Equation 5, the systemic macroprudential capital requirement is regressed separately on the series of outcomes of interest Y_{ict} representing in turn the capital and risk variables used as dependent variables throughout the paper. The dummy variable $D_{2010Q1\quad 2013Q4}$ is turned on in the period prior to the commencement of the phasing-in of the SMCR in the EU, that is prior to 2014. The specification controls for bank-level characteristics $\ln X_{ict\quad 1}$ and a bank trend $\phi_i \cdot t$ is included to control for diverging trends across treated and control groups, as before, α_i are bank fixed effects and δ_{ct} are country-time fixed effects.

The main coefficient of interest in the equation is the coefficient of the interaction term $Y_{ict} * D_{2010Q1\quad 2013Q4}$ estimating the relationship between pre-determined outcome variables prior to the treatment period and the realised capital requirement after 2014. If the coefficient ψ is significant then bank capital situation prior to the phasing-in may have influenced the setting of the SMCR questioning the exogeneity assumption. If this is not the case, then results

2010Q2. Results are available from the author. The document of the consultation is available at this link.

will substantiate the assumption on the absence of strategic targeting by policy makers. For simultaneity bias then it is useful to observe the ζ coefficient of Y_{ict}.

Results are presented in Table 11 for capital and in Table 12 for risk. In both tables any sign of correlation between outcome variables and the SMCR vanishes as bank specific trends are included in the regression. For capital, in Table 11 Columns (1)-(2) the CET1 ratio is not related with the SMCR even without bank trends. The level of CET1 in Columns (3), however, presents negative relation prior to 2014, as a potential sign of favouritism towards weaker banks. In the robustness check, this disappears once bank trends are controlled for in Column (4). For risk, in Table 12 Columns (1), (3) and (5) may suggest endogeneity, this however is not robust to inclusion of bank specific trends in Columns (2), (4) and (6). Importantly, for the risk density which is the main variable of interest, the simultaneous bias does not appear to be a problem even when bank trend are not controlled for in Column (3). Overall, the results indicate once more the importance of bank specific trend in the estimation and the relevance of the tests presented and discussed in Section 6.1.

A similar result is presented in Table 13. The table presents a simple regression of the average of the SMCR by bank after 2014 on the average prior to 2014 of the bank-level outcome variables. The aim is to investigate whether the average of the outcome variables before 2014 correlates with the regulation after 2014. If there is positive correlation then is likely that the SMCR is endogenous since bank capital and risk-taking prior to the implementation of the macroprudential capital requirements would have affected the discretionary decision of national competent authorities in setting the capital requirement. Note that by taking bank-level averages prior and post the start of the implementation phase the bank-level trend is controlled for by construction.

Results in Table 13 confirm that there is no statistical relationship between the capital and risk position of the bank prior to 2014 and the subsequently levied capital requirements. Column (1) indicates that there is some positive relation between the average CET1 ratio before 2014 and the later SMCR, however this relation is positive suggesting that stronger (and not weaker) capitalised banks may have been subject to harsher capital requirements. Nevertheless this relationship is not robust to the inclusion of country dummies. Similarly, from Column (3) to (8) there is no systematically strong evidence of capital and risk prior to 2014 influencing the setting of the SMCR post policy implementation. The absence of significant correlation is an encouraging sign since it shows that SMCR were not systematically levied on less capitalised banks or banks with higher risk densities.

8 Solvency: Probability of Default

This section explores the impact of a hike in capital requirements on the solvency of financial institutions. As presented in Section 4, the tightening of the capital requirements has two opposing effects: i) results of Section 4.1 would suggest that higher capital requirements would make banks more solvent and, consequently, reduce their probability of default; ii) at the same time, the findings in Section 4.2 indicate that higher capital requirements may lead to moral hazard and increased risk-taking, thus weakening banks solvency. Hence, the net impact of the two opposing effects on banks' probability of default is ambiguous.

In order to shed light on which of the two opposing effects on solvency is stronger, this section uses credit ratings as a gauge of banks' probabilities of default. The advantage of using credit ratings is that regulatory action is not directly taken into account but only financial performance and solvency is assessed, a stringent regulation is encompassed in the evaluation only to the extent that banks react to higher capital requirement. Nevertheless, a caveat is that they are provide only probabilities of default through the financial cycle and may have lags in their setting. The default probabilities are extrapolated from bank issuer ratings provided by three major rating agencies.[51] The probabilities of default are obtained by mapping and converting of alphanumeric ratings using publicly available conversion tables on rating agencies websites. The constructed distance to default variable informs about the solvency of a bank by estimating the default probability over the next, two, three, four and five years. It provides timely information reflecting current market perception, and summarises market-wide information on the drivers of default probability.

Similarly to Section 3.2, the phasing-in of SMCR in the EU is used as a tool for a controlled comparison whereby different institutions across Europe are subject to heterogeneous intensity of capital requirements. However, this section departs fundamentally from the previous estimates since the dependent variable is now part of the reaction function of *market agents* to higher capital requirements and not a reaction of the bank itself. Results are presented in Table 14. The table presents in each column the evidence for a different probability of default horizon.

[51] The rating agencies are Fitch, Moody's and S&Ps

Estimates are broken down by the size of the bank. Notice that the sample size decreased due to the limited availability of ratings for some banks with respect to previous specifications, the consequence is that results should be interpreted with caution for external consistency.[52]

The evidence suggests that the market reaction to higher capital requirements is bringing some benefits to medium and large banks in terms of reduced probability of default but only *relative* to smaller banks. The relative impact is slightly greater for banks with total assets above EUR 100 millions, and increasing in the probability of default horizon for both medium and large banks. Depending on the maturity horizon of the probability of default, medium and large banks have a lower probability of default with respect to small banks, i.e. 1.3-2.0 percentage points lower for a one percentage point increase in capital requirements. This result suggests that, *relative* to small banks, for medium and large banks the effect of the increase in CET1 capital is stronger than the risk-taking channel.

Nevertheless, the *marginal* effects for medium and large banks, while having a negative sign, is not statistically significant as shown in the second panel of Table 14. For instance for the one year horizon, the marginal effect of a one percentage point increase in capital requirements for large banks is -0.938 (st.dev. 0.900). While this indicates that the rating agencies may tend to assess the capital increase channel to be stronger, this assessment cannot be statistically corroborated. Similar results are obtained for the marginal effects at different time horizons and for medium sized banks.[53]

The evidence on leads to conclude that the increase of capital requirements does not improve banks' probability of default in absolute terms. In other words, the positive effect of accumulating more equity capital is counterbalanced by the negative substitution effect toward more riskier assets, the overall net effect on solvency is zero. This raises a concern for the policy maker since the improved resilience achieved by demanding higher capital requirements can be crowded-out by an increase in risk-taking.

[52] An alternative market based measure of banks' solvency are CDS prices. Nevertheless, contrary to the ratings, the scope of application of CDS pricing is very limited in our sample since CDS prices are generally available only for some of the large systemic banks. In our sample, this translates to 49 banks with available CDS prices which is much less than the number of clusters in previous regressions. The use of CDS prices would thus create a sample composition bias relative to previous estimates.

[53] This is further confirmed by a baseline regression of the probability of default without the dummy for size, and those broken down by the distance from the OCR, the net interest income and wholesale funding dummies. All of them do not have statistically significant results at standard confidence levels, these specifications are available from the author.

9 Conclusions

The paper presents empirical evidence on the reaction of systemically important EU banks to a phased-in capital requirement regulation. Contrary to one-off leverege requirement exercises, the evidence indicates that the impact contributed to a substantial increase of equity capital in the EU banking sector. As such, the resilience of European systemically important banks increased. At the same time, some unintended consequences appear. In a phased-in set up, the increased resilience comes at the cost of a higher incentive to exploit moral hazard by banks, which shift the asset composition towards more risky assets.

The findings add to more recent evidence on EU capital exercises Gropp et al. (2018) which is based on a one-off capital increase. Their contribution does not find evidence of a increase in bank equity but a substantial deleveraging effect through lending reduction. As a complement, this paper concludes that the pace of introduction of capital requirements is fundamental if we want to fully understand the banks' responses. On one side, a one-off fast shock to capital requirements may have negative consequences on the real economy; on the other side, a more gradual approach leaves time for banks to plan their funding needs promoting an increase in equity, but also risk-taking.

The paper documents that risks-taking is particularly relevant for less profitable and large banks, suggesting that gambling for resurrection and agency costs may be promote moral hazard. At the same time, banks adopting the IRB approach mitigate substantially the increase in risk-taking, and wholesale-funded banks have lower risk-taking which may be explained by a strategic need to reduce the observable risk in view of their already fragile funding model.

The paper then investigates the net effect of improved resilience at the cost of higher risk-taking on the probability of default of banks as measured by external ratings. It documents that the positive effect of accumulating more equity capital is counterbalanced by the negative substitution effect toward more riskier assets. In other words, the increased risk-taking is perceived to compensate the positive results of higher capital, such that the overall marginal effect on banks' probabilities of default results insignificant.

This raises the question as to how regulation should aim at constraining bank's risk-taking behaviour. While this is not in the scope of this paper, the main message is that the pace of introduction of capital requirement has an important role when assessing how banks react to leverage restrictions. If the objective is to increase high quality bank capital such as equity, then a phased-in approach can be optimal. The caveat is that the improved absorption capacity may induce banks to exploit moral hazard and increase risk-taking.

To limit the risk-taking behavior, the regulator can contemplate, for instance, to introduce a cap on the risk weight densities as a tool to limit the incentives for moral hazard. The cap on risk-weight densities would be automatically complemented by the leverage ratio if banks would try to increase their assets with low risk-weight investments such as sovereign or corporate bonds. Future research is planned to assess this interplay with a rigorous model.

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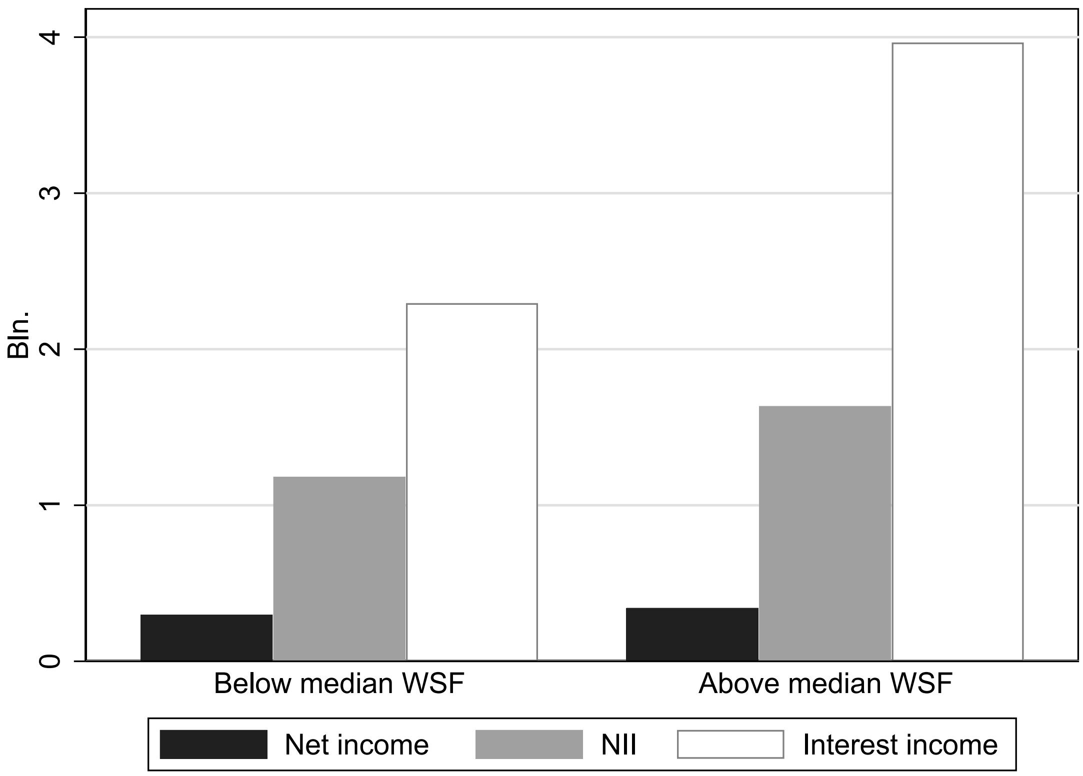
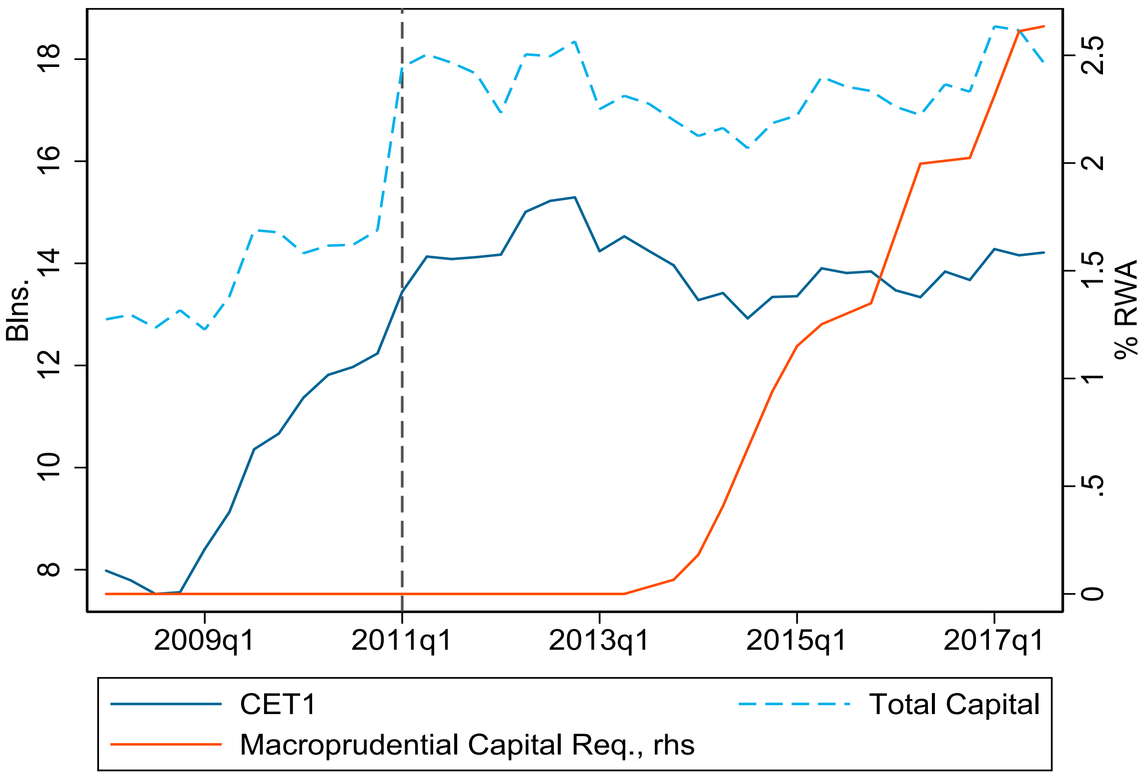
Figure 1: Profitability and Wholesale Funding



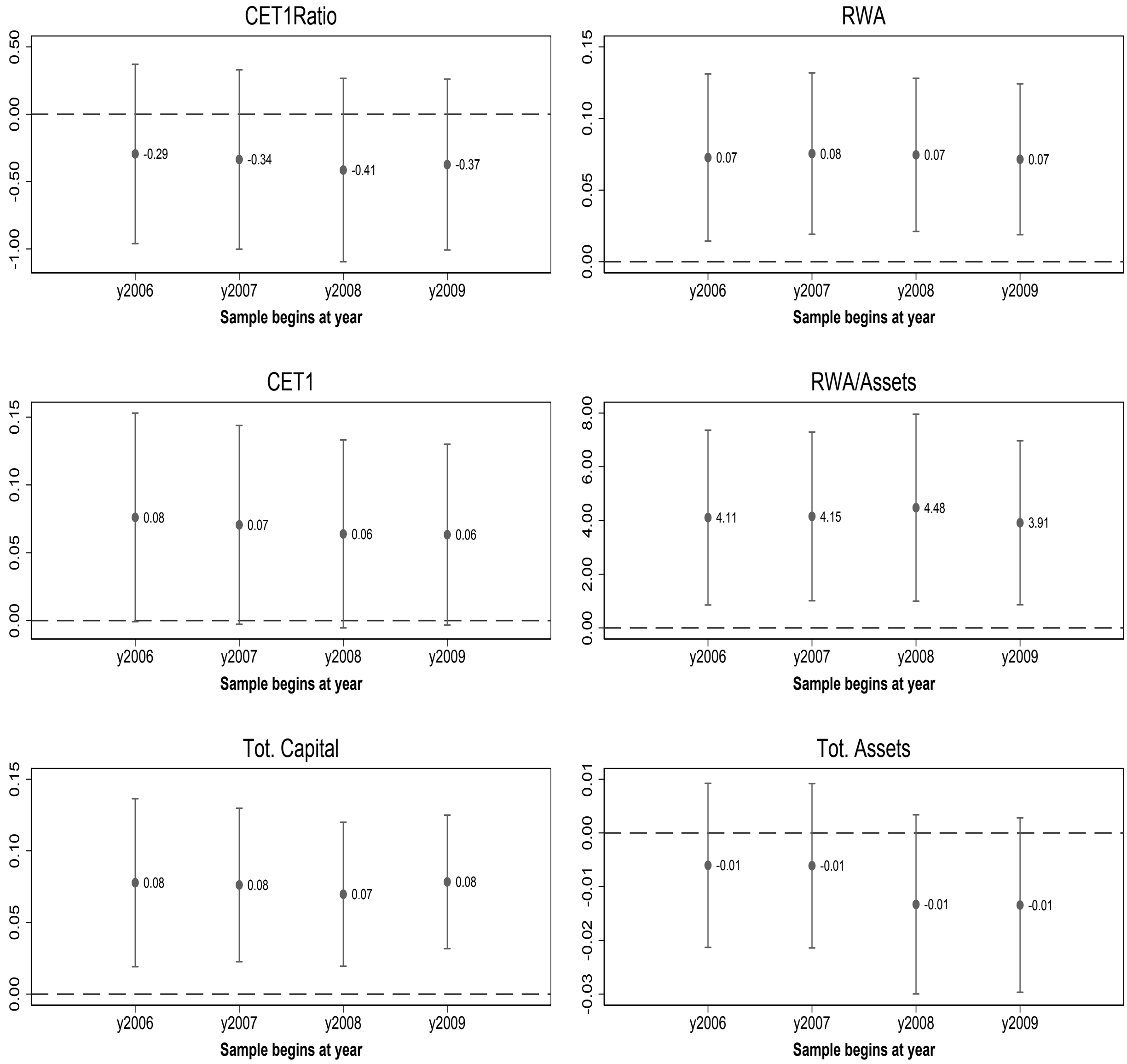
Note: the bar chart show some profitability measures broken down by above and below median wholesale funding reliance. For profitability it is used net overall income, net interest income (NII) and total interest income. A standard test of mean difference is run separately for the three income variables in a pooled panel. They are regressed on a dummy for wholesale funding above median. For net interest income and interest income the estimated β coefficients are both significant and respectively 0.45 (s.d. 0.091) and 1.67 (s.d. 0.182) where standard errors are robust to heteroschedasticity and serial correlation. The coefficient on mean difference for net income is 0.04 (s.e. 0.035) and thus not statistically significant.

Figure 2: The longer term trend of Capital



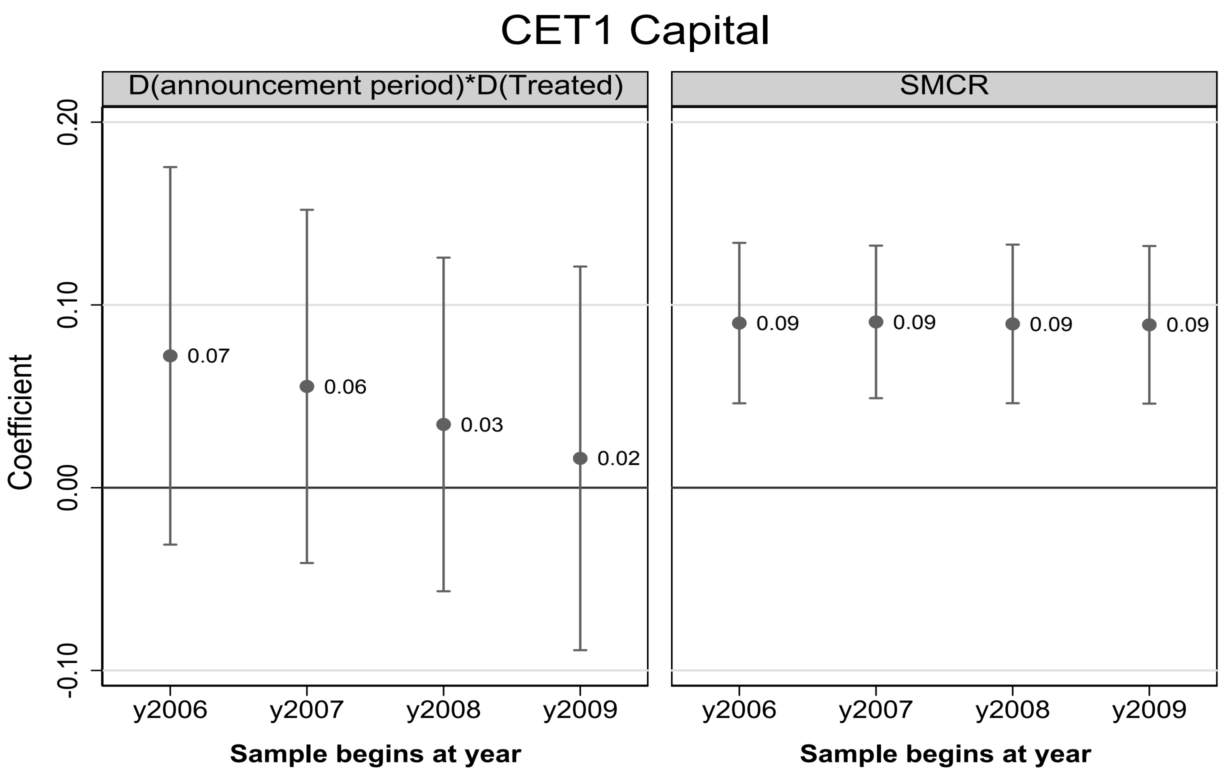
Note: The plot illustrates the evolution of the average CET1 and Total capital levels across the systemically important banks in the EU. The red line illustrates the average level of the SMCR across the EU G-SIBs and O-SIBs.

Figure 3: Robustness: Bank Trends and Longer T



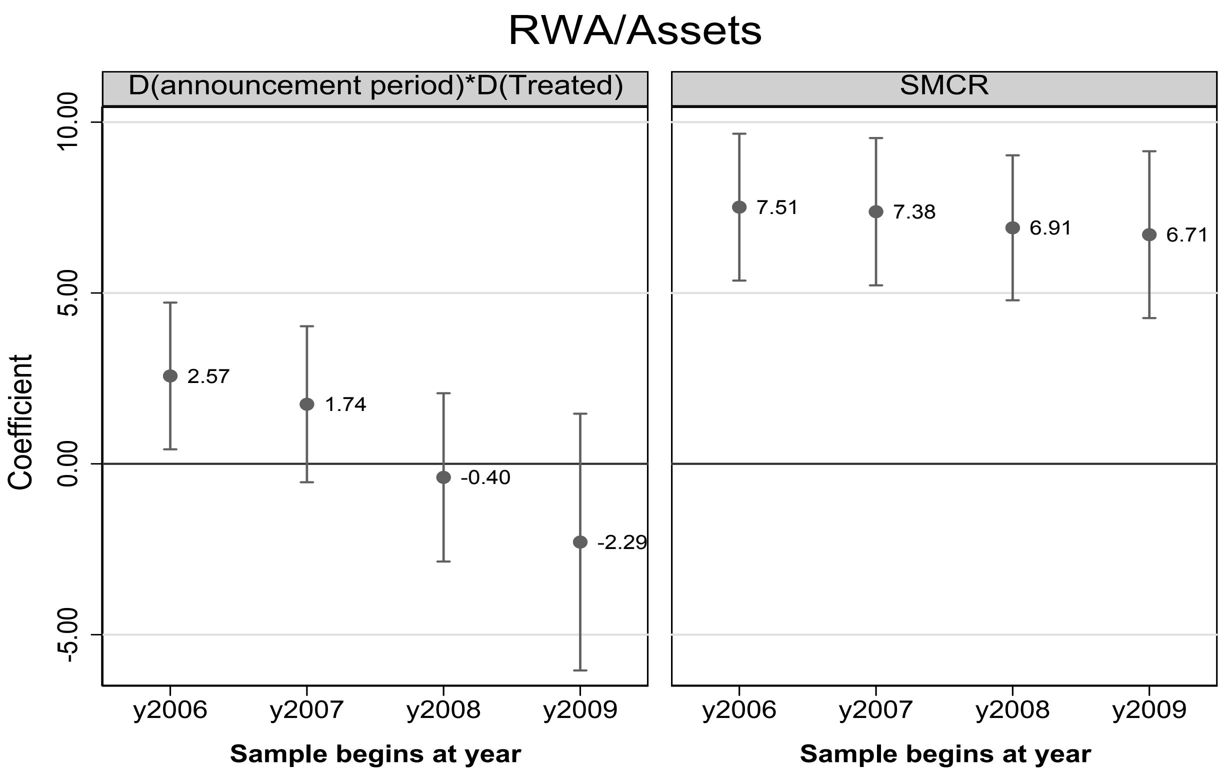
Note: The figure shows the evolution of the β coefficient for the level of the SMCR in equation 3 when the estimation sample is progressively reduced by one year. All models have bank trends included in the specification. On the horizontal axis every point represents the staring year of the respective estimation sample, for each sample the last quarter is 2017Q3. Moving to the right of each plot the sample period shrinks by one year each time and hence there are less observations available to compute bank-level trends. On the y-axis, the coefficients represent the impact of a hike in the macroprudential capital requirement. Vertical bars represent confidence interval at 10% significance level. Standard errors are clustered at bank-level and robust for serial correlation and heteroschedasticity.

Figure 4: Robustness: Announcement effect of EU macroprudential policy on CET1 Capital



Note: The graph shows the evolution of ω and β coefficients of equation 4 when the dependent variable is the level of CET1 Capital. The estimation sample is progressively reduced by one year, notice that for each sample the last quarter used in all regressions is 2017Q3. The announcement period is represented by a dummy for the period between 2009Q4-2013Q4, that is since the publication of the EU Commission Directive 2009/111/EC of the European Parliament and of the Council of 16 September pre-announcing a change in macroprudential regulation in the EU. Vertical bars represent confidence interval at 10% significance level. Standard errors are clustered at bank-level and robust for serial correlation and heteroschedasticity. Similar results are obtained when the regressions control for bank specific trends, these results are available from the author.

Figure 5: Robustness: Announcement effect of EU macroprudential policy on the risk density



Note: The graph shows the evolution of ω and β coefficients of equation 4 when the dependent variable is the risk density (i.e. RWA/Assets). The estimation sample is progressively reduced by one year, notice that for each sample the last quarter used in all regressions is 2017Q3. The announcement period is represented by a dummy for the period between 2009Q4-2013Q4, that is since the publication of the EU Commission Directive 2009/111/EC of the European Parliament and of the Council of 16 September pre-announcing a change in macroprudential regulation in the EU. Vertical bars represent confidence interval at 10% significance level. Standard errors are clustered at bank-level and robust for serial correlation and heteroschedasticity. Similar results are obtained when the regressions control for bank specific trends, these results are available from the author.

Table 1: Macroprudential Capital Requirements in Europe

Buffer	CRD Article	Level	Scope
Capital conservation buffer (CCoB)	Art. 129	The objective is to conserve the bank's capital. Mandatory capital buffer equal to 2.5% of RWAs, this implies a minimum CET1 ratio requirement is 7%	Country-level (i.e. same for all banks within MS)
Counter-cyclical Capital buffer (CCyB)	Art. 130, 135-140	The purpose of this buffer is to counteract the effects of the economic cycle. Buffer rate calibrated on MS credit-to-GDP gap.	
G-SIB and O-SIB Systemically Important Banks buffer (SIB)	Art. 131	For banks that are identified by the relevant authority as systemically important: $1 \leq x \leq 3.5\%$ of RWAs for G-SII $0 \leq x \leq 2.0\%$ of RWAs for O-SII	Bank-level (i.e. set at bank level within MS)
Systemic risk buffer (SRB)	Art. 133 and 134	To prevent and mitigate long term non-cyclical systemic or macro-prudential risks: $0 \leq x \leq 5.0\%$ of RWA Above 5% the MS must be authorized by Commission	

Note: The table summarises the four macroprudential capital requirements introduced in EU in 2014. The CCoB and the CCyB are country-level capital requirements levied on all banks within a country. The capital requirement for systemically important banks and the SRB buffer are applied at bank-level. MS stands for EU Member States, Norway, despite not being an EU Member State implemented the EU capital based macroprudential regulation.

Table 2: Direction of Omitted Variable Bias

The table illustrates the sign of the bias due to omitted variable in a simple bivariate model where x_1 is the treatment variable and x_2 is the omitted variable:

$$y = \beta_1 x_1 + \beta_2 x_2 + u$$

	$Corr(x_1, x_2 > 0)$	$Corr(x_1, x_2 < 0)$
$\beta_2 > 0$	Bias > 0	Bias < 0
$\beta_2 < 0$	Bias < 0	Bias > 0

Table 3: Descriptive statistics by year: Capital, Requirements and Distance

The table summarize the evolution over time of simple means (Panel A), means conditional on treatment (Panel B) and means for non-treated banks (Panel C) o: the level of the SMCR, the level of the OCR, the level of the CET1 ratio, the distance from the OCR and the level of the total capital ratio. Note that the OCR for the control group increases after 2014 due to phasing in of the CCoB and CCyB buffers which change at country level and are absorbed in the equation 1 by the country-time fixed effects. Standard deviations in parenthesis.

	2010	2011	2012	2013	2014	2015	2016	2017
Panel A: Simple Means:								
SMCR (%)	0	0	0	0.014	0.149	0.442	0.656	0.870
	(0)	(0)	(0)	(0.170)	(0.618)	(1.032)	(1.070)	(1.100)
Overall CET1 Req. (OCR) (%)	4.500	4.500	4.500	4.533	5.174	5.800	6.510	7.124
	(0)	(0)	(0)	(0.384)	(1.414)	(2.014)	(1.824)	(1.705)
CET1 Ratio (%)	10.70	11.51	12.58	13.90	14.90	16.16	17.09	17.58
	(2.872)	(3.314)	(3.848)	(4.752)	(5.372)	(6.895)	(6.998)	(7.415)
Distance from OCR (%)	7.190	8.043	8.523	9.806	9.993	10.33	10.50	10.47
	(6.295)	(6.536)	(6.432)	(6.935)	(6.192)	(6.622)	(6.620)	(7.270)
Tot. Capital Ratio (%)	15.26	15.92	16.12	17.44	17.83	19.08	20.17	20.83
	(7.175)	(8.050)	(7.288)	(8.015)	(6.800)	(7.584)	(8.692)	(10.59)
Observations	820	820	820	820	820	820	820	615
Panel B: Means Conditional on Treatment								
SMCR (%)	0	0	0	0.020	0.203	0.600	0.892	1.184
	(0)	(0)	(0)	(0.199)	(0.712)	(1.163)	(1.160)	(1.130)
Overall CET1 Cap. Req. (OCR) (%)	4.500	4.500	4.500	4.545	5.349	6.067	6.849	7.509
	(0)	(0)	(0)	(0.447)	(1.564)	(2.203)	(1.967)	(1.809)
CET1 Ratio (%)	11.36	11.93	12.81	14.16	15.07	16.39	17.15	17.63
	(2.858)	(2.921)	(3.278)	(4.179)	(5.327)	(7.264)	(7.301)	(7.029)
Distance from OCR (%)	7.416	8.052	8.676	9.803	9.938	10.27	10.24	10.24
	(4.408)	(4.612)	(4.352)	(4.726)	(5.556)	(6.904)	(6.766)	(6.847)
Tot. Capital Ratio (%)	15.50	15.96	16.21	17.26	17.80	19.15	20.08	20.76
	(5.077)	(5.508)	(4.972)	(5.149)	(5.761)	(7.609)	(8.090)	(7.988)
Observations	604	604	604	604	604	604	604	453
Panel C: Means Non-treated Banks								
SMCR (%)	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Overall CET1 Cap. Req. (OCR) (%)	4.500	4.500	4.500	4.500	4.685	5.056	5.565	6.046
	(0)	(0)	(0)	(0)	(0.656)	(1.042)	(0.778)	(0.563)
CET1 Ratio (%)	8.668	10.26	11.88	13.20	14.46	15.54	16.96	17.47
	(1.752)	(4.026)	(5.175)	(5.996)	(5.482)	(5.795)	(6.205)	(8.244)
Distance from OCR (%)	6.505	8.020	8.084	9.812	10.14	10.48	11.17	11.02
	(10.05)	(10.20)	(10.29)	(10.85)	(7.657)	(5.828)	(6.192)	(8.196)
Tot. Capital Ratio (%)	14.52	15.82	15.85	17.95	17.94	18.90	20.42	21.01
	(11.44)	(12.93)	(11.61)	(13.03)	(9.143)	(7.529)	(10.13)	(15.51)
Observations	216	216	216	216	216	216	216	162

Table 4: Descriptive statistics: EU G-SIB and O-SIB Financial Accounts

The table summarizes descriptive statistics of the balance sheet variables used in the paper. The sample is the sample of designated Systemically Important Banks (SIB) in the EU as described in section 3.1. For each variable the simple mean, standard deviation, the median, the 25th and 75th quintiles and the maximum are shown. Time period: 2006Q1-2017Q3. The data source is SNL Financials.

	Mean	Std.dev.	p25	p50	p75	Max.
Capital Position:						
CET1 Ratio(%)	13.64	6.06	10.20	12.60	15.70	74.93
Distance from OCR (%)	8.34	6.56	4.84	7.29	10.14	82.36
Tot. Capital Ratio(%)	16.58	7.87	12.28	15.00	18.30	111.64
Leverage Ratio (%)	7.60	4.07	4.66	6.86	9.80	32.98
Risk:						
RWA (bln.)	70.37	139.15	5.54	19.26	60.89	1129.63
RWA/Assets(%)	50.06	21.41	33.14	50.29	64.91	261.02
Assets:						
Tot. Assets (bln.)	196.15	379.97	8.58	39.19	198.37	2506.28
Gross Loans/Assets(%)	58.29	19.62	48.08	62.57	71.59	121.83
Net Loans/Assets (%)	54.71	19.06	44.77	59.03	67.53	105.21
Securities Holdings/Assets (%)	25.13	16.92	13.86	22.15	32.22	99.56
Total Cash/Assets(%)	15.29	11.86	6.94	12.23	20.58	93.64
Securities Holdings:						
Securities Held for trading/Assets (%)	7.55	9.50	1.17	4.15	10.08	65.40
Securities Available for Sale/Assets (%)	9.34	8.29	2.59	8.13	13.88	57.99
Securities Held to Maturity/Assets (%)	2.68	5.63	0.00	0.24	2.51	89.18
Funding Structure:						
Deposits/Assets (%)	48.45	22.96	31.46	51.25	66.51	98.31
Total Wholesale Funding/Assets(%)	33.23	21.95	16.69	29.29	45.48	95.82
Debt/Assets (%)	17.92	18.13	4.62	13.08	24.69	95.82
Interconnectedness:						
Loans to Banks/Assets (%)	10.01	11.23	3.07	6.21	12.95	92.65
Tot. HFT Assets/Assets (%)	8.34	10.63	1.23	4.22	11.40	67.32
Securities OTC derivatives/Assets (%)	5.56	10.01	0.37	1.84	6.12	74.30
Total cash balance at C.B./Assets (%)	5.34	6.08	1.13	3.09	7.19	43.88
Profitability:						
ROA (%)	0.32	1.14	0.10	0.31	0.71	6.56
Cost/Income(%)	58.64	21.87	47.83	56.14	65.60	390.50

Table 5: The Impact on Capital

The table summarises the baseline reduced form specification of the change in systemic macroprudential capital requirements (SMCR) on bank capital in Columns (1)-(3). Columns (4)-(6) present the heterogenous impact by bank distance from the overall CET1 capital requirements (OCR). All dependent variables that are measured in levels, i.e. CET1 capital in columns (2) and (5) and total capital in columns (3) and (6), are transformed using natural logarithms. Bank-level control variables are as specified in equation 1. Time period: 2010Q1-2017Q3. Standard errors are shown in parenthesis clustered at bank-level, robust to heteroscedasticity and serial correlation. FE stands for fixed-effects. Stars indicate statistical significance levels: *** p<0.01, ** p<0.05, * p<0.10.

	Non-Binding			Binding		
	(1) CET1 Ratio (p.p.)	(2) CET1 (ln)	(3) Tot. Capital (ln)	(4) CET1 Ratio (p.p.)	(5) CET1 (ln)	(6) Tot. Capital (ln)
SMCR	-0.054	0.089	0.081	0.834	0.177	0.116
	(0.359)	(0.027)***	(0.027)***	(0.402)**	(0.036)***	(0.042)***
SMCR × 2pp< OCR distance <5pp				-0.143	-0.042	-0.003
				(0.215)	(0.022)*	(0.026)
SMCR × 5pp< OCR distance <10pp				0.003	-0.047	-0.012
				(0.214)	(0.024)*	(0.031)
SMCR × OCR distance >10pp				0.087	-0.053	-0.013
				(0.232)	(0.024)**	(0.031)
Bank Controls	yes	yes	yes	yes	yes	yes
Bank FE	yes	yes	yes	yes	yes	yes
Country-quarter FE	yes	yes	yes	yes	yes	yes
Obs.	3174	3174	3174	3173	3173	3173
N. clusters	137	137	137	137	137	137
R2	0.688	0.672	0.663	0.800	0.763	0.695

Table 6: The Impact on Risk

The table illustrates the baseline reduced form specification of the change in systemic macroprudential capital requirements (SMCR) on banks' risk-taking and assets in Columns (1)-(3). Columns (4)-(6) show the heterogenous impact by bank distance from the overall CET1 capital requirements (OCR). All dependent variables that are measured in levels, i.e. CET1 capital in column (2) and Risk-weighted Assets in column (3), are transformed using natural logarithms. Bank-level control variables are as specified in equation 1. Time period: 2010Q1-2017Q3. Standard errors are shown in parenthesis clustered at bank-level, robust to heteroscedasticity and serial correlation. FE stands for fixed-effects. Stars indicate statistical significance levels: *** p<0.01, ** p<0.05, * p<0.10.

	Non-Binding			Binding		
	(1) RWA (ln)	(2) RWA/Assets (p.p.)	(3) Tot. Assets (ln)	(4) RWA (ln)	(5) RWA/Assets (p.p.)	(6) Tot. Assets (ln)
SMCR	0.101	6.873	-0.007	0.065	6.073	-0.016
	(0.023)***	(1.388)***	(0.008)	(0.026)**	(1.455)***	(0.012)
SMCR× 2pp< OCR distance <5pp				0.002	-0.139	-0.002
				(0.009)	(0.419)	(0.006)
SMCR× 5pp< OCR distance <10pp				0.011	-0.219	0.005
				(0.011)	(0.533)	(0.005)
SMCR× OCR distance >10pp				0.013	0.242	0.004
				(0.011)	(0.523)	(0.005)
Bank Controls	yes	yes	yes	yes	yes	yes
Bank FE	yes	yes	yes	yes	yes	yes
Country-quarter FE	yes	yes	yes	yes	yes	yes
Obs.	3277	3277	3277	3195	3195	3195
N. clusters	137	137	137	137	137	137
R2	0.749	0.646	0.875	0.768	0.677	0.875

Table 7: The Impact on Capital: the role of bank size and internal rating approach (IRB)

The table summarises the reduced form specification of the change in systemic macroprudential capital requirements (SMCR) on bank capital. Columns (1)-(3) present the heterogenous impact by bank size and distance from the overall CET1 capital requirements (OCR). Columns (4)-(6) show the heterogeneous impact by IRB and distance from the OCR. Bank-level control variables are as specified in equation 1. Time period: 2010Q1-2017Q3. Standard errors are shown in parenthesis clustered at bank-level, robust to heteroscedasticity and serial correlation. FE stands for fixed-effects. Stars indicate statistical significance levels: *** p<0.01, ** p<0.05, * p<0.10.

	Size			IRB		
	(1) CET1 Ratio (p.p.)	(2) CET1 (ln)	(3) Tot. Capital (ln)	(4) CET1 Ratio (p.p.)	(5) CET1 (ln)	(6) Tot. Capital (ln)
SMCR	0.214	0.133	0.057	-0.006	0.149	0.099
	(0.680)	(0.049)***	(0.056)	(0.543)	(0.046)***	(0.049)**
SMCR× OCR distance >2pp	0.131	-0.027	-0.006	0.164	-0.049	-0.025
	(0.463)	(0.024)	(0.031)	(0.503)	(0.035)	(0.038)
SMCR× 20bln.< Tot.Ass <100bln	0.701	0.458	0.013			
	(3.232)	(0.503)	(0.420)			
SMCR× Tot.Ass>100bln.	-0.506	-0.043	-0.055			
	(0.655)	(0.062)	(0.070)			
SMCR× OCR distance >2pp × 20bln.< Tot.Ass <100bln	-0.683	-0.455	0.006			
	(3.213)	(0.504)	(0.421)			
SMCR× OCR distance >2pp × Tot.Ass>100bln.	-0.300	0.011	0.065			
	(0.622)	(0.056)	(0.068)			
SMCR× IRB				-0.229	-0.075	-0.100
				(0.495)	(0.056)	(0.069)
SMCR× OCR distance >2pp × IRB				0.051	0.065	0.097
				(0.555)	(0.056)	(0.070)
Bank Controls	yes	yes	yes	yes	yes	yes
Bank FE	yes	yes	yes	yes	yes	yes
Country-quarter FE	yes	yes	yes	yes	yes	yes
Obs.	3312	3312	3312	3298	3298	3298
N. clusters	144	144	144	143	143	143
R2	0.692	0.711	0.662	0.696	0.706	0.656

Table 8: The Impact on Risk: the role of bank size and internal rating approach (IRB)

The table illustrates the estimates of a reduced form specification for the impact of the change in systemic macroprudential capital requirements (SMCR) on banks' risk-taking and assets. Columns (1)-(3) show the heterogenous impact by bank size. Columns (4)-(6) show the heterogenous impact by bank size and IRB. Variables measured in levels, i.e. risk-weighted Assets and total assets, are transformed using natural logarithms. Bank-level control variables are as specified in equation 1. Time period: 2010Q1-2017Q3. Standard errors are shown in parenthesis clustered at bank-level, robust to heteroscedasticity and serial correlation. FE stands for fixed-effects. Stars indicate statistical significance levels: *** p<0.01, ** p<0.05, * p<0.10.

	Size			Size and IRB Banks		
	(1) RWA (ln)	(2) RWA/Assets (p.p.)	(3) Tot.Assets (ln)	(4) RWA (ln)	(5) RWA/Assets (p.p)	(6) Tot.Assets (ln)
SMCR	0.071	3.944	-0.004	0.066	4.345	-0.020
	(0.036)*	(1.731)**	(0.018)	(0.043)	(1.904)**	(0.019)
SMCR× 20bln.< Tot.Ass <100bln.	0.020	1.864	-0.002	0.030	2.963	-0.006
	(0.019)	(1.073)*	(0.010)	(0.024)	(1.224)**	(0.010)
SMCR× Tot.Ass>100bln.	0.022	2.079	-0.001	0.181	5.324	0.004
	(0.024)	(1.149)*	(0.011)	(0.049)***	(2.149)**	(0.018)
SMCR× IRB				0.001	-0.034	0.008
				(0.014)	(0.901)	(0.004)*
SMCR× IRB × 20bln.< Tot.Ass <100bln.				-0.009	-1.498	0.008
				(0.031)	(1.469)	(0.010)
SMCR× IRB × Tot.Ass >100bln.				-0.157	-3.595	-0.002
				(0.042)***	(1.802)**	(0.016)
Bank Controls	yes	yes	yes	yes	yes	yes
Bank FE	yes	yes	yes	yes	yes	yes
Country-quarter FE	yes	yes	yes	yes	yes	yes
Obs.	3277	3277	3277	3277	3277	3277
N. clusters	137	137	137	137	137	137
R2	0.750	0.648	0.878	0.756	0.655	0.878

Table 9: Profitability, Funding and Leverage

The table illustrates the reduced form specification for the impact of the change in systemic macroprudential capital requirements (SMCR) on banks' risk-taking. Columns (1)-(2) show the heterogenous impact by bank profitability as measured with a dummy equal to one if the bank has above the sample median net interest income (NII). Columns (3)-(4) show the heterogenous impact by wholesale funding (WSF) as captured by a dummy equal to one for above median WSF. Columns (5)-(6) illustrate the impact by bank leverage as measured by a dummy above median for the ratio of Tier1 capital on total assets (LR). Bank-level control variables are as specified in equation 1. Time period: 2010Q1-2017Q3. Standard errors are shown in parenthesis clustered at bank-level, robust to heteroscedasticity and serial correlation. FE stands for fixed-effects. Stars indicate statistical significance levels: *** p<0.01, ** p<0.05, * p<0.10.

	NII		Wholesale Funding		Leverage Ratio	
	(1) RWA (ln)	(2) RWA/Assets (p.p.)	(3) RWA (ln)	(4) RWA/Assets (p.p.)	(5) RWA (ln)	(6) RWA/Assets (p.p.)
SMCR	0.070	4.296	0.066	3.699	0.052	3.943
	(0.029)**	(1.262)***	(0.032)**	(1.341)***	(0.032)	(1.389)***
SMCR×	0.026	2.158	0.022	2.101	0.030	2.199
>20bln.< Tot.Ass <100bln.	(0.017)	(0.815)***	(0.018)	(0.897)**	(0.024)	(1.226)*
SMCR×	0.055	2.842	0.027	2.310	0.033	2.605
Tot.Ass>100bln.	(0.025)**	(0.993)***	(0.027)	(1.104)**	(0.026)	(1.141)**
SMCR× NII	0.018	1.142				
	(0.013)	(0.741)				
SMCR× NII ×	-0.029	-1.634				
>20bln.< Tot.Ass <100bln.	(0.013)**	(0.761)**				
SMCR× NII ×	-0.055	-2.067				
Tot.Ass >100bln.	(0.020)***	(0.925)**				
SMCR× WSF			0.011	1.339		
			(0.011)	(0.633)**		
SMCR× WSF ×			-0.059	-2.124		
>20bln.< Tot.Ass <100bln.			(0.025)**	(1.132)*		
SMCR× WSF ×			-0.060	-2.110		
Tot.Ass >100bln.			(0.025)**	(0.994)**		
SMCR× LR					0.026	0.456
					(0.027)	(1.328)
SMCR× LR ×					-0.014	-0.451
>20bln.< Tot.Ass <100bln.					(0.027)	(1.355)
SMCR× LR ×					-0.021	-1.010
Tot.Ass >100bln.					(0.027)	(1.396)
Bank Controls	yes	yes	yes	yes	yes	yes
Bank FE	yes	yes	yes	yes	yes	yes
Country-quarter FE	yes	yes	yes	yes	yes	yes
Obs.	2794	2794	2713	2713	2794	2794
N. clusters	142	142	142	142	142	142
R2	0.747	0.644	0.747	0.649	0.748	0.644

Table 10: Bank Trends

The table presents the reduced form specification augmented with bank specific trends to control for the presence of diverging trend across banks. SMCR stands for the level in the systemic macroprudential capital requirement. Columns (1)-(3) present the estimates for the impact on capital differentiated by the distance from the OCR. Columns (4)-(5) show the evidence for risk and assets without differentiating by distance from OCR since risk and capital are not sensitive to distance from OCR, see 6. Bank-level control variables are as specified in equation 1. Time period: 2010Q1-2017Q3. Standard errors are shown in parenthesis clustered at bank-level, robust to heteroscedasticity and serial correlation. FE stands for fixed-effects. Stars indicate statistical significance levels: *** p<0.01, ** p<0.05, * p<0.10.

	Capital			Risk		
	(1) CET1 Ratio (p.p.)	(2) CET1 (ln)	(3) Tot. Capital (ln)	(4) RWA (ln)	(5) RWA/Assets (p.p.)	(6) Tot. Assets (ln)
SMCR	-0.265	0.064	0.074	0.061	3.115	-0.008
	(0.371)	(0.037)*	(0.028)***	(0.029)**	(1.555)**	(0.012)
Bank Controls	yes	yes	yes	yes	yes	yes
Bank FE	yes	yes	yes	yes	yes	yes
Country-quarter FE	yes	yes	yes	yes	yes	yes
Bank Trends	yes	yes	yes	yes	yes	yes
Obs.	3312	3312	3312	3312	3312	3312
N. clusters	144	144	144	144	144	144
R2	0.804	0.778	0.791	0.845	0.824	0.898

Table 11: Endogeneity: Capital

The table shows the relation between the level of the Systemic Macroprudential Capital Requirement (SMCR) and the main the main outcome variables used in the *capital* equation. A dummy representing the period prior to the phasing-in of the SMCR (2010Q1-2013Q4) is interacted with the main outcomes of interest for capital. Columns (2), (4) and (6) presents the estimates with bank specific trends. Bank-level control variables are as specified in equation 1. Overall time period: 2010Q1-2017Q3. Standard errors are shown in parenthesis clustered at bank-level, robust to heteroscedasticity and serial correlation. FE stands for fixed-effects. Stars indicate statistical significance levels: *** p<0.01, ** p<0.05, * p<0.10.

	SMCR					
	(1)	(2)	(3)	(4)	(5)	(6)
$D_{2010Q1\ \ 2013Q4}$	-1.420	-2.612	-0.484	-2.859	-0.576	-2.302
	(0.161)***	(1.561)*	(0.480)	(1.621)*	(0.488)	(1.749)
CET1 Ratio	0.002	-0.000				
	(0.004)	(0.002)				
$D_{2010Q1\ \ 2013Q4}$ × CET1 Ratio	-0.005	-0.002				
	(0.006)	(0.002)				
ln(CET1)			0.145	0.028		
			(0.075)*	(0.039)		
$D_{2010Q1\ \ 2013Q4}$ × ln(CET1)			-0.059	0.014		
			(0.027)**	(0.016)		
ln(Tot. Capital)					0.126	0.045
					(0.076)	(0.036)
$D_{2010Q1\ \ 2013Q4}$ × ln(Tot. Capital)					-0.056	0.014
					(0.027)**	(0.015)
Bank FE	yes	yes	yes	yes	yes	yes
Country-quarter FE	yes	yes	yes	yes	yes	yes
Bank Trends		yes		yes		yes
Obs.	3334	3334	3330	3330	3405	3405
N. clusters	144	144	144	144	144	144
R2	0.991	0.996	0.991	0.996	0.991	0.996

Table 12: Endogeneity: Risk

The table shows the relation between the level of the Systemic Macroprudential Capital Requirement (SMCR) and the main outcome variables used in *risk* equation. A dummy representing the period prior to the phasing-in of the SMCR (2010Q1-2013Q4) is interacted with the main outcomes of interest for risk-taking. Columns (2), (4) and (6) presents the estimates with bank specific trends. Bank-level control variables are as specified in equation 1. Overall time period: 2010Q1-2017Q3. Standard errors are shown in parenthesis clustered at bank-level, robust to heteroscedasticity and serial correlation. FE stands for fixed-effects. Stars indicate statistical significance levels: *** p<0.01, ** p<0.05, * p<0.10.

	SMCR					
	(1)	(2)	(3)	(4)	(5)	(6)
D_{2010Q1_2013Q4}	-0.560	-2.940	-1.640	-2.606	0.074	-3.019
	(0.441)	(1.646)*	(0.163)***	(1.598)	(0.608)	(1.624)*
ln(RWA)	0.214	0.065				
	(0.118)*	(0.057)				
D_{2010Q1_2013Q4} × ln(RWA)	-0.051	0.018				
	(0.023)**	(0.015)				
RWA/Assets			0.005	0.003		
			(0.003)	(0.002)		
D_{2010Q1_2013Q4} × RWA/Assets			0.003	-0.000		
			(0.002)**	(0.001)		
ln(Tot.Assets)					-0.006	-0.050
					(0.041)	(0.036)
D_{2010Q1_2013Q4} × ln(Tot.Assets)					-0.079	0.021
					(0.030)***	(0.018)
Bank FE	yes	yes	yes	yes	yes	yes
Country-quarter FE	yes	yes	yes	yes	yes	yes
Bank Trends		yes		yes		yes
Obs.	3423	3423	3423	3423	3573	3573
N. clusters	144	144	144	144	144	144
R2	0.991	0.996	0.991	0.996	0.990	0.996

Table 13: Endogeneity: Averaging pre and post treatment periods

The table presents a simple OLS regression of the change in the bank-level SMCR averaged for the period 2014-2017Q3 on the bank-level averages of outcome variables for the period *prior* to the implementation of the macroprudential policy 2010Q1-2013Q4. The aim is to investigate whether the average of the outcome variables before 2014 correlates with the regulation after 2014. If yes, this may suggest that weaker bank prior to the phasing-in were protected by national authorities. Bank-level control variables are also averaged prior to 2014 and are the ones as specified in equation 1. Columns (2), (4), (6) and (8) presents the estimates with bank specific trends. Standard errors are shown in parenthesis robust to heteroscedasticity and serial correlation. FE stands for fixed-effects. Stars indicate statistical significance levels: *** p<0.01, ** p<0.05, * p<0.10.

	Average bank-level SMCR post 2014							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\overline{CET1Ratio}_{i,2010Q1\ \ 2013Q4}$	0.049	0.011						
	(0.021)**	(0.007)						
$\overline{ln(CET1)}_{i,2010Q1\ \ 2013Q4}$			0.274	-0.024				
			(0.231)	(0.057)				
$\overline{ln(RWA)}_{i,2010Q1\ \ 2013Q4}$					-0.278	-0.169		
					(0.229)	(0.106)		
$\overline{RWA/Ass.}_{i,2010Q1\ \ 2013Q4}$							-0.007	-0.005
							(0.006)	(0.003)*
Bank-level controls	yes	yes	yes	yes	yes	yes	yes	yes
Country FE		yes		yes		yes		yes
Obs.	138	138	138	138	138	138	138	138
R2	0.292	0.968	0.264	0.967	0.263	0.968	0.265	0.969

Table 14: Impact on the Probability of Default

The table presents the baseline reduced form specification for the impact of the change in the SMCR on the probability of default as inferred from banks' ratings. Bank-level control variables are as specified in equation 1. Time period: 2010Q1-2017Q3. Standard errors are shown in parenthesis and are clustered at bank-level, robust to heteroscedasticity and serial correlation. FE stands for fixed-effects. Stars indicate statistical significance levels: *** p<0.01, ** p<0.05, * p<0.10.

	Probability of Default Horizon				
	5yrs (p.p.)	4yrs (p.p.)	3yrs (p.p.)	2yrs (p.p.)	1yr (p.p.)
SMCR	1.346	1.293	1.161	0.930	0.533
	(1.044)	(1.042)	(1.028)	(0.981)	(0.776)
SMCR× >20bln.< Tot.Ass <100bln.	-1.843	-1.840	-1.811	-1.717	-1.345
	(0.833)**	(0.835)**	(0.831)**	(0.803)**	(0.654)**
SMCR× Tot.Ass>100bln.	-2.011	-1.999	-1.960	-1.868	-1.471
	(0.893)**	(0.895)**	(0.888)**	(0.858)**	(0.699)**
Bank Controls	yes	yes	yes	yes	yes
Bank FE	yes	yes	yes	yes	yes
Country-quarter FE	yes	yes	yes	yes	yes
Obs.	1969	1969	1969	1969	1969
N. clusters	87	87	87	87	87
R2	0.451	0.451	0.446	0.433	0.396
	Marginal Effects				
SMCR× >20bln.< Tot.Ass <100bln.	-0.497	-0.548	-0.650	-0.787	-0.811
	(1.100)	(1.101)	(1.094)	(1.052)	(0.840)
SMCR× Tot.Ass>100bln.	-0.665	-0.706	-0.799	-0.938	-0.938
	(1.183)	(1.182)	(1.172)	(1.126)	(0.900)

A-I Online Appendix: List of Banks

Table A-I: List of GSIBs and O-SIBs with more than EUR 300 billions in total assets as of 2016Q4

Number	Country	GSI-OSI	Bank Name	Euro Area	Total Assets	IRB
1	UK	GSI	HSBC Holdings Plc	No	2251961725	1
2	FR	GSI	BNP Paribas SA	Yes	2076959000	1
3	DE	GSI	Deutsche Bank AG	Yes	1590546000	1
4	FR	GSI	Credit Agricole SA	Yes	1524232000	1
5	UK	GSI	Barclays Bank Plc	No	1421778818	1
6	FR	GSI	Societe Generale SA	Yes	1382241000	1
7	ES	GSI	Banco Santander, SA	Yes	1339124751	1
8	UK	OSI	Lloyds Banking Group Plc	No	957795606	1
9	UK	GSI	Royal Bank of Scotland Group Plc	No	935382435	1
10	UK	OSI	Goldman Sachs International	No	885924120	1
11	IT	GSI	UniCredit SpA	Yes	859532774	1
12	NL	GSI	ING Groep N.V.	Yes	845081000	1
13	FR	OSI	Credit Mutuel Group	Yes	793522000	1
14	FR	GSI	BPCE SA	Yes	765069000	1
15	ES	GSI	Banco Bilbao Vizcaya Argentaria, SA	Yes	731855527	1
16	IT	OSI	Intesa Sanpaolo SpA	Yes	725100000	1
17	SE	GSI	Nordea Bank AB (publ)	No	615659000	1
18	UK	GSI	Standard Chartered Plc	No	613193354	1
19	UK	OSI	J.P. Morgan Capital Holdings Ltd.	No	555986552	0
20	UK	OSI	Nomura Europe Holdings plc	No	548007616	1
21	DE	OSI	DZ BANK AG Deutsche Zentral-Genossenschaftsbank	Yes	509447000	1
22	NL	OSI	Rabobank	Yes	498468992	1
23	DE	OSI	Commerzbank AG	Yes	480450000	n/a
24	DK	OSI	Danske Bank A/S	No	468501389	0
25	UK	OSI	Morgan Stanley & Co. International Plc	No	401416677	1
26	UK	OSI	Merrill Lynch International	No	395201226	1
27	NL	OSI	ABN AMRO Group NV	Yes	394482000	1
28	UK	OSI	Santander UK Plc	No	355038592	0
29	ES	OSI	CaixaBank, SA	Yes	347927262	1
30	UK	OSI	Citigroup Global Markets Ltd.	No	327705506	1
31	UK	OSI	Credit Suisse International	No	315163664	1
32	DE	OSI	UniCredit Bank AG	Yes	302090000	1

Table A-II: Banks with total assets between EUR 100 and EUR 300 billions in total assets as of 2016Q4

Number	Country	GSI-OSI	Bank Name	Euro Area	Total Assets	IRB
33	BE	OSI	BNP Paribas Fortis SA	Yes	297790000	1
34	BE	OSI	KBC Group NV	Yes	275200000	1
35	SE	OSI	Svenska Handelsbanken AB (publ)	No	274321632	1
36	SE	OSI	Skandinaviska Enskilda Banken AB (publ.)	No	273597716	1
37	UK	OSI	Nationwide Building Society	No	263401902	1
38	NO	OSI	DNB Bank ASA	No	258682038	1
39	DE	OSI	Landesbank Baden-Wurttemberg	Yes	243620000	0
40	FI	OSI	Nordea Pankki Suomi Oyj	Yes	238775000	1
41	FR	OSI	La Banque Postale, SA	Yes	229577420	1
42	SE	OSI	Swedbank AB (publ)	No	224900662	1
43	ES	OSI	Banco de Sabadell, SA	Yes	212507719	1
44	DE	OSI	Bayerische Landesbank	Yes	212150000	1
45	AT	OSI	Erste Group Bank AG	Yes	208227070	1
46	ES	OSI	Bankia, SA	Yes	190167459	1
47	DK	OSI	Nykredit Realkredit A/S	No	188360510	1
48	BE	OSI	Belfius Banque SA	Yes	176720926	1
49	DE	OSI	NORD/LB Norddeutsche Landesbank Girozentrale	Yes	174797000	1
50	DE	OSI	Landesbank Hessen-Thuringen Girozentrale	Yes	165164000	0
51	DE	OSI	ING-DiBa AG	Yes	157553000	1
52	NL	OSI	NV Bank Nederlandse Gemeenten	Yes	154000000	1
53	IT	OSI	Banca Monte dei Paschi di Siena SpA	Yes	153178466	1
54	BE	OSI	ING Belgie NV	Yes	150418720	0
55	ES	OSI	Banco Popular Espanol, SA	Yes	147925728	1
56	DE	OSI	NRW.BANK	Yes	142065678	1
57	AT	OSI	Raiffeisen Zentralbank osterreich AG	Yes	134846575	0
58	FI	OSI	OP Financial Group	Yes	133747000	1
59	DE	OSI	Volkswagen Financial Services AG	Yes	130148000	1
60	NL	OSI	SNS REAAL NV	Yes	124806000	1
61	IE	OSI	Governor and Company of the Bank of Ireland	Yes	123129000	1
62	UK	OSI	Credit Suisse Securities (Europe) Ltd.	No	112791235	1
63	AT	OSI	Raiffeisen Bank International AG	Yes	111863845	0
64	DK	OSI	Nordea Bank Danmark A/S	No	108970440	1
65	AT	OSI	UniCredit Bank Austria AG	Yes	105785411	1
66	DE	OSI	Landesbank Berlin Holding AG	Yes	102437000	1

Table A-III: Banks with total assets between EUR 20 and EUR 100 billions in total assets as of 2016Q4

Number	Country	GSI-OSI	Bank Name	Euro Area	Total Assets	IRB
67	IE	OSI	Allied Irish Banks, Plc	Yes	95622000	0
68	DE	OSI	Landwirtschaftliche Rentenbank	Yes	95045800	1
69	PT	OSI	Caixa Geral de Depositos, SA	Yes	93547313	1
70	DE	OSI	Westdeutsche Genossenschafts-Zentralbank AG	Yes	89794496	1
71	DE	OSI	DekaBank Deutsche Girozentrale	Yes	85954700	1
72	DE	OSI	HSH Nordbank AG	Yes	84365000	1
73	GR	OSI	Piraeus Bank SA	Yes	81500534	1
74	DK	OSI	Jyske Bank A/S	No	78902758	1
75	GR	OSI	National Bank of Greece SA	Yes	78531000	1
76	NO	OSI	Nordea Bank Norge ASA	No	73744593	1
77	PT	OSI	Banco Comercial Portugus, SA	Yes	71264811	0
78	GR	OSI	Eurobank Ergasias SA	Yes	66393000	n/a
79	GR	OSI	Alpha Bank AE	Yes	64872266	n/a
80	PL	OSI	Powszechna Kasa Oszczednosci Bank Polski SA	No	64851280	1
81	PT	OSI	Novo Banco, SA	Yes	52332672	1
82	LU	OSI	Deutsche Bank Luxembourg SA	Yes	51787398	1
83	UK	OSI	UBS Ltd.	No	47624329	1
84	IE	OSI	Citibank Europe Plc	Yes	46729176	1
85	NO	OSI	Kommunalbanken AS	No	46082260	1
86	LU	OSI	CACEIS Bank Luxembourg SA	Yes	46081972	0
87	PT	OSI	Santander Totta, SGPS SA	Yes	44991681	1
88	LU	OSI	BGL BNP Paribas SA	Yes	44980200	0
89	LU	OSI	Banque et Caisse d'Epargne de l'Etat, Luxembourg	Yes	43468625	0
90	LU	OSI	Societe Generale Bank & Trust SA	Yes	42187856	0
91	CZ	OSI	ceskoslovenska obchodn banka, a.s.	No	40177083	0
92	AT	OSI	Bank fur Arbeit und Wirtschaft und Osterreichische Postsparkasse AG	Yes	39743000	1
93	PL	OSI	Bank Polska Kasa Opieki SA	No	39562822	1
94	CZ	OSI	ceska spoitelna, a.s.	No	39473826	0
95	AT	OSI	Raiffeisenlandesbank Oberosterreich AG	Yes	39385129	0
96	PT	OSI	Banco BPI, SA	Yes	38284652	1
97	BE	OSI	Bank of New York Mellon SA/NV	Yes	36427299	1
98	HU	OSI	OTP Bank Nyrt.	No	36291787	1
99	BE	OSI	Argenta Spaarbank NV	Yes	36156329	1
100	CZ	OSI	Komercn banka, a.s.	No	34151966	0
101	PL	OSI	Bank Zachodni WBK SA	No	34086447	1
102	FI	OSI	Kuntarahoitus Oyj	Yes	34052186	0
103	IE	OSI	Ulster Bank Ireland DAC	Yes	30694000	1
104	PL	OSI	mBank SA	No	30372081	1
105	FI	OSI	Danske Bank Oyj	Yes	28962100	1
106	BE	OSI	AXA Bank Belgium SA	Yes	27994508	0
107	IE	OSI	DEPFA BANK Plc	Yes	27596000	0
108	PL	OSI	ING Bank slaski SA	No	26678248	1
109	AT	OSI	Raiffeisenlandesbank Niederosterreich-Wien AG	Yes	25404784	1
110	IE	OSI	Permanent TSB Group Holdings Plc	Yes	23601000	1
111	CZ	OSI	UniCredit Bank Czech Republic and Slovakia, a.s.	No	23503916	0
112	LU	OSI	Banque Internationale a Luxembourg SA	Yes	23148659	0
113	CY	OSI	Bank of Cyprus Public Company Ltd.	Yes	22171935	1
114	PT	OSI	Caixa Economica Montepio Geral, caixa economica bancaria, SA	Yes	21345909	0
115	DK	OSI	DLR Kredit A/S	No	20944292	0

Table A-IV: Banks with total assets lower than EUR 20 billions in total assets as of 2016Q4

Number	Country	GSI-OSI	Bank Name	Euro Area	Total Assets	IRB
116	IE	OSI	UniCredit Bank Ireland Plc	Yes	19987653	1
117	DK	OSI	Sydbank A/S	No	19727068	1
118	HR	OSI	Zagrebacka banka d.d.	No	16980269	0
119	PL	OSI	Bank BG BNP Paribas SA	No	16419888	1
120	PL	OSI	Bank Millennium SA	No	15622293	0
121	AT	OSI	HYPO NOE Landesbank fur Niederosterreich und Wien AG	Yes	15392051	0
122	PL	OSI	Getin Noble Bank SA	No	15105513	0
123	BE	OSI	Euroclear Bank SA/NV	Yes	14885444	1
124	RO	OSI	Banca Comerciala Romana SA	No	14873912	0
125	SK	OSI	Slovenska Sporitelna, a.s.	Yes	14825374	0
126	CY	OSI	Cyprus Cooperative Bank Ltd.	Yes	14100791	1
127	SK	OSI	Vseobecna uverova banka, a.s.	Yes	14037154	0
128	AT	OSI	Sberbank Europe AG	Yes	12709542	0
129	PL	OSI	Raiffeisen Bank Polska SA	No	12094460	1
130	SI	OSI	Nova Ljubljanska banka d.d., Ljubljana	Yes	12039011	0
131	CZ	OSI	Raiffeisenbank a.s.	No	11984202	1
132	RO	OSI	Banca Transilvania SA	No	11443660	1
133	RO	OSI	BRD-Groupe Societe Generale SA	No	11429840	1
134	SK	OSI	Tatra banka, a.s.	Yes	11373028	0
135	MT	OSI	Bank of Valletta Plc	Yes	11014330	0
136	HR	OSI	Privredna Banka Zagreb d.d.	No	10867118	1
137	BG	OSI	UniCredit Bulbank AD	No	10424208	1
138	PL	OSI	Bank Handlowy w Warszawie SA	No	10266811	1
139	EE	OSI	Swedbank AS	Yes	10233000	1
140	HU	OSI	K&H Bank Zrt.	No	9148828	1
141	HU	OSI	UniCredit Bank Hungary Zrt.	No	8861671	1
142	AT	OSI	Oberosterreichische Landesbank AG	Yes	8756780	1
143	CY	OSI	RCB Bank Ltd.	Yes	8699021	0
144	HR	OSI	Erste&Steiermarkische Bank d.d.	No	8680694	0
145	SK	OSI	Ceskoslovenska obchodna banka, a.s.	Yes	8543773	0
146	RO	OSI	UniCredit Bank SA	No	8284788	0
147	AT	OSI	Hypo Tirol Bank AG	Yes	7632172	1
148	LT	OSI	AB SEB bankas	Yes	7517939	1
149	RO	OSI	Raiffeisen Bank SA	No	7371604	0
150	LT	OSI	Swedbank, AB	Yes	7324953	0
151	MT	OSI	HSBC Bank Malta Plc	Yes	7305964	1
152	CY	OSI	Hellenic Bank Public Company Ltd.	Yes	7037604	0
153	HU	OSI	MKB Bank Zrt.	No	6804454	1
154	HU	OSI	Magyar Takarekszovetkezeti Bank Zrt.	No	6776778	0
155	HU	OSI	Erste Bank Hungary Zrt.	No	6627237	1
156	HU	OSI	Raiffeisen Bank Zrt.	No	6457088	n/a
157	RO	OSI	CEC Bank SA	No	6204473	0
158	BG	OSI	DSK Bank EAD	No	6050100	0
159	EE	OSI	AS SEB Pank	Yes	5775400	0

Table A-IV: Ctd. Banks with total assets lower than EUR 20 billions in total assets as of 2016Q4

Number	Country	GSI-OSI	Bank Name	Euro Area	Total Assets	IRB
160	HU	OSI	CIB Bank Zrt.	No	5277329	0
161	LV	OSI	Swedbank AS	Yes	5242209	0
162	CZ	OSI	PPF banka a.s.	No	5063556	0
163	CZ	OSI	J&T Banka, a.s.	No	4926761	0
164	CY	OSI	Eurobank Cyprus Ltd.	Yes	4879262	n/a
165	SI	OSI	Nova Kreditna banka Maribor d.d.	Yes	4823450	0
166	HR	OSI	Raiffeisenbank Austria d.d.	No	4679339	0
167	BG	OSI	First Investment Bank AD	No	4647865	1
168	PL	OSI	Bank Polskiej Spoldzielczosci SA	No	4578087	0
169	SK	OSI	Postova banka, a.s.	Yes	4261460	0
170	LT	OSI	Luminor Bank AB	Yes	3988565	n/a
171	LV	OSI	ABLV Bank, AS	Yes	3973323	0
172	PL	OSI	SGB-Bank SA	No	3947797	1
173	SI	OSI	Abanka d.d.	Yes	3614833	0
174	HR	OSI	Splitska banka d.d.	No	3577384	0
175	LV	OSI	AS SEB banka	Yes	3523911	0
176	BG	OSI	United Bulgarian Bank AD	No	3495997	0
177	BG	OSI	Eurobank Bulgaria AD	No	3486344	0
178	LV	OSI	JSC "Rietumu Banka"	Yes	3473590	1
179	LV	OSI	AS Citadele banka	Yes	3349515	0
180	BG	OSI	Raiffeisenbank (Bulgaria) EAD	No	3329009	0
181	BG	OSI	Societe Generale Expressbank AD	No	3246381	0
182	RO	OSI	Alpha Bank Romania SA	No	3245660	1
183	SI	OSI	SKB banka d.d., Ljubljana	Yes	2955262	0
184	HR	OSI	Addiko Bank d.d.	No	2777215	0
185	BG	OSI	Central Cooperative Bank AD	No	2651696	0
186	SI	OSI	UniCredit Banka Slovenija d.d.	Yes	2642950	0
187	HR	OSI	Hrvatska postanska banka, d.d.	No	2611695	1
188	CY	OSI	Alpha Bank Cyprus Ltd.	Yes	2596415	0
189	SI	OSI	SID - Slovenska izvozna in razvojna banka, d.d., Ljubljana	Yes	2596076	0
190	RO	OSI	SC Bancpost SA	No	2564081	n/a
191	MT	OSI	MeDirect Group Ltd.	Yes	2489506	0
192	SI	OSI	Banka Intesa Sanpaolo d.d.	Yes	2325663	0
193	LV	OSI	Luminor Bank AS	Yes	2259247	0
194	RO	OSI	Garanti Bank SA	No	1973878	0
195	HU	OSI	FHB Jelzalogbank Nyrt.	No	1921279	0
196	LT	OSI	siauliu bankas AB	Yes	1861278	0
197	SI	OSI	Sberbank banka d. d.	Yes	1846119	n/a
198	RO	OSI	OTP Bank Romania SA	No	1808437	1
199	CY	OSI	Alfa Capital Holdings (Cyprus) Ltd.	Yes	1803745	1
200	HR	OSI	OTP banka Hrvatska d.d.	No	1694090	n/a
201	BG	OSI	CIBANK EAD	No	1584441	1
202	BG	OSI	Piraeus Bank Bulgaria AD	No	1508035	1
203	RO	OSI	Piraeus Bank Romania SA	No	1446053	1
204	RO	OSI	Banca Romaneasca SA	No	1418917	n/a
205	HR	OSI	Sberbank d.d.	No	1225733	n/a

A-II Online Appendix: Literature Review

Related Theoretical Literature

The theoretical literature approached the question of the relationship between higher capital and risk-taking from different angles. Since the pioneering contribution of Modigliani and Miller (1958), the literature expanded and relied on a variety of modelling techniques. Despite the richness of existing contributions a consensus has not been reached. According to theoretical literature, the effect of capital requirements on risk-taking behavior is ambiguous and hence the relationship is still an open empirical question.[54]

In the basic version of their model, Modigliani and Miller (1958) assume that financial markets are efficient and perfect, while taxes, agency and bankruptcy costs are absent. As a result, the Modigliani and Miller (1958) two famous propositions state: i) the capital structure does not affect the value of the firm and, ii) more levered firms have higher expected returns on equity than non-levered firms. The literature has shown that failure of the M&M assumptions may lead to departures from the theorems' propositions. For instance, in their later correction paper, Modigliani and Miller (1963) show how tax advantages for debt instruments lead to non-proportional after tax returns across firms. Keeping constant the balance sheet size, stricter capital requirements imply that banks are less able to exploit favourable tax treatment of debt. For banks, Miller (1995) argues that the deposit insurance can be regarded as a net tax subsidy, enabling banks to obtain funds at less than an appropriately risk-adjusted cost, promoting in the limit the minimization of the desired equity ratio.

One of the implications of the second M&M proposition is that a higher capital requirement would reduce the expected return of the bank's earning assets and thus curb the incentive for risk-taking ensuring that banks always choose socially optimal risk levels. At the same time, higher capital requirement add another layer of protection for the taxpayer, and Miller (1995) points out that capital requirements are no panacea in this regard because the banks cannot be trusted from offsetting the added taxpayer protection resulting from higher capital requirements by increasing the risk of their assets further. Furthermore, the presence of significant agency

[54] Theoretical contributions range from portfolio models maximizing a mean-variance utility function (Kahane, 1977; Koehn and Santomero, 1980; Kim and Santomero, 1988; Rochet, 1992), models using option pricing methods to value the deposit insurance subsidy (Merton, 1977; Galai and Masulis, 1976; Furlong and Keeley, 1989), dynamic models of charter value and competition (Keeley, 1990; Blum, 1999; Hellmann et al., 2000), or the principal-agent framework, (Saunders et al., 1990; Dewatripont and Tirole, 1994)

costs, which are generally higher in large firms due to the diluted ownership structure, see Ang et al. (2000), can also lead to the failure of the M&M propositions. Bankruptcy costs also play a role, as pointed out by the Basel Committee in their study on the costs and benefits of stronger capital regulation, the main benefits of a stronger financial system reflect a lower probability of banking crises and their associated bankruptcy costs, BCBS (2010). As such the predictions of the M&M theorem on the risk-taking behavior of banks after a hike in capital requirements remain uncertain.

Limited liability and deposit insurance models claim that depositors do not have any incentive to monitor banks' behaviour, it follows that managers would have more opportunity to increase asset riskiness and exploit moral hazard arising from the *deposit insurance subsidy*, Green (1984). In these models, the moral hazard problem may be further exacerbated by the presence of informational advantage for bank managers, Jensen and Meckling (1976). Similarly, Kareken and Wallace (1978) find that in a monopoly model of banking with complete contingent claims and under an FDIC-type deposit insurance scheme, the banking industry maintains a risky portfolio and capital requirements do not forestall bankruptcy.[55]

Portfolio choice models find results consistent with both arguments, on one side Kahane (1977), Koehn and Santomero (1980), Flannery (1989) conclude that capital requirements are inefficient in constraining the risk shifting in the bank portfolio insulating them from market discipline; on the other side, Furlong and Keeley (1989) show that for a value-maximizing bank and the presence of option-value of deposit insurance, the incentives to increase asset risk decline as bank capital increases. More recently, Kim and Santomero (1988) show that the the use of simple capital ratios is ineffective to bound the insolvency risk of banks, and propose theoretically corrected risk-weights as a solution to the risk-taking behaviour. Similarly, Rochet (1992) argues that utility, as opposed to value, maximizing banks can reduce risk-taking if capital ratios take into account their asset risk. Blum (1999) models a dynamic decision problem of a bank to conclude that capital adequacy rules may increase bank riskiness.

Merton (1977) fostered the use of option-pricing models which consider deposit insurance as an option-value, to reach the conclusion that more skin in the game, i.e. higher capital requirements, can reduce incentives for increasing portfolio riskiness. Galai and Masulis (1976)

[55] Notice that, as convincingly showed by Diamond and Dybvig (1983) deposit insurance is at the same time a fundamental policy tool to avoid bank runs, hence notwithstanding the moral hazard incentive, deposit insurance is widely used to limit bank panics and bank runs in time of distress.

use a capital asset pricing model and an option pricing model to show how unanticipated changes in firm capital can induce investments in portfolios with higher variance. Similarly, Gennotte and Pyle (1991) show how deposit guarantees in combination with higher capital requirements lead banks to increase asset risk.

A further strand of models uses the charter value of the bank, i.e. the difference between going concern and liquidation value, to support the skin in the game argument, Marcus (1984). By the same token, Benston (1986) argues that bank shareholders have more incentives to operate conservatively when the amount of their own funds is at risk. The prospect of loosing charter value on managers' career can remind managers of the consequences of excessive risk-taking. Saunders et al. (1990) show how managers may have incentives to reduce the default risk below the shareholders desired level in order to protect their own human capital. The question is if the bank-managers have the same incentives of the shareholders. Dewatripont and Tirole (1994) model the classic moral hazard problem with unobservable managers' effort to conclude that banks with low leverage may have an incentive to increase risk since interference from principal is lower, and viceversa. We test for this hypothesis in section 5.2. More recently, the theoretical literature using the charter value argument was augmented by including competition in the banking industry to conclude how the presence of more competitors may reduce the charter value and increase default risk through asset risk, Keeley (1990), Hellmann et al. (2000).

Related Empirical Literature

Previous empirical research on the impact of higher capital requirements on bank risk-taking is scant. Pioneering empirical contributions focused on the introduction of risk-weighted regulatory standards in the late 1980s and was rather fervent in the 1990s. It used descriptive regression analysis and simultaneous equation models relying thus on endogenous components of capital increase by bank managers, Shrieves and Dahl (1992); Jacques and Nigro (1997).

One of the earliest empirical contributions is provided by Shrieves and Dahl (1992). The authors adopt a two-stage simultaneous equation estimation to analyze the relationship between risk and capital. They estimate discretionary changes in asset portfolio risk induced by a variation of capital taken endogenously by the bank. The authors find a positive relationship between increased capital levels and risk-taking as measured by average risk-weights. The positive relation holds also for banks with capital in excess of the minimum requirements, leading the authors to conclude that risk-taking behaviour is influenced by bank owners' and/or managers' private incentives.

Haubrich and Wachtel (1993) apply an analysis of variance (ANOVA) to study whether the 1998 risk-based capital accord (Basel I) led to the risk shifting of commercial banks' portfolio toward government securities and hence a lower average risk-weight. The authors conclude that the implementation of Basel I fostered risk reduction, with poorly-capitalized banks shifting their portfolios away from high-risk assets and towards low-risk assets.

Using a three-stage least squares simultaneous equation model, Jacques and Nigro (1997) examine the impact of the risk-based capital standards on bank capital and portfolio risk in the first year the Basel risk-based standards were in effect. As in Shrieves and Dahl (1992), they use discretionary bank management adjustments to capital, and measure risk as the ratio of risk-weighted assets to total assets. The paper concludes that risk-based capital standards were effective in increasing capital ratios and reducing portfolio risk for banks which already met the new risk-based standards. Interestingly, Jacques and Nigro (1997) define also a *supervisory pressure* variable assuming that banks may respond differently depending on whether they are in excess or in shortage of required capital. For capital-constrained banks the responses showed little connection to the degree to which they fell short of the standards. Applying a similar simultaneous equation framework to a sample of Swiss banks, Rime (2001) finds that supervisory pressure induces banks to increase their capital, but does not affect the level of risk.

More recently, Gropp et al. (2018) exploit the 2011 European Banking Authority (EBA) capital exercise[56] and a difference-indifference matching estimator to find that treated banks increase capital ratios by reducing their credit supply. On the margin of their study, the authors show that the EBA capital exercise did not have significant effects on risk reduction as measured by the risk-weighted asset to total asset ratio. Similarly, Calomiris and Jaremski (2019) exploit a staggered implementation of deposit insurance laws in the U.S. and the fact that those laws were applied only to some depository institutions within the states to corroborate the theoretical literature on the moral-hazard consequences of deposit insurance.

[56] The EBA capital exercise required 61 banks to build-up additional capital buffers to reach a level of 9% core tier 1 ratio in 8 months, from 26 October 2011 until June 2012

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