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Survey Article

The Effects of Bank Regulation on the Relationship Between Capital and Risk

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Capital regulation acts as an external force in the determination of bank capital and risk levels. Changes in the regulatory framework can influence banks' decisions. Starting from the debate of the prudential regulation after the financial crisis, this paper reviews the main empirical contributions on the role of capital regulation in the determination of banks' capital ratios and risk exposure to evaluate bank behavior. Capital and risk decisions seem to be effectively influenced by regulation, although results may vary according to factors such as time period, country, and the type of capital analyzed.
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INTRODUCTION

The latest financial crisis has highlighted how bank capital regulation is necessary for the stability of the financial system. But also, it appears that it is not sufficient to ensure that banks' decisions, in terms of risk and capital, are consistent with the aims of regulation.

Regulation acts as an external force in the capital optimization process as banks set simultaneously the level of capital and the amount of risky assets to hold in order to comply with the minimum capital ratio. However, given the moral hazard and asymmetries of information characterizing the banking activity, banks might have perverse incentives that induce them to raise risk

when called to respond to stricter capital requirements, in order to keep their desired leverage.

Understanding the relationship between capital and risk decisions is therefore fundamental in banking, and the underlying mechanisms should be investigated to adjust regulation and correct any hazardous behavior. Additionally, as regulation evolves, incentives might change and banks might modify their decisions. For these reasons, it is also important to understand how bank behavior has evolved since the introduction of the Basel framework that set the capital ratio at an international level, and how banks reacted to changes in prudential regulation.

The aim of this paper is to provide a review of the main empirical research on the impact of regulation on capital and risk. The paper will also discuss how the recent evidence provided by these academic studies relates to the underlying theories highlighted within the literature to explain banks' incentives, in relation to the aims of regulation. The paper contributes to the discussion on bank capital by surveying the most recent literature on the topic, providing an updated assessment on how our knowledge and understanding of the effects of capital regulation on banks' behavior has evolved over the last decades, together with economic and market conditions.

The main conclusion that emerges from the studies is that regulation has an important role in capital and risk decisions. But the effectiveness of bank regulation depends on other factors, such as the economic cycle, country, and the type of capital considered. The contrasting evidence provided by the empirical investigations also suggests the need for further advancements, both empirical and theoretical.

The paper is organized as follows: the next section discusses how regulation enters the bank capital and risk decisions, surveying the main contributions on the evolution of regulation and its effects; the subsequent section discusses the empirical results on the role of capital regulation in the decisions of banks on capital and risk; the final section concludes.

THE EFFECTIVENESS OF THE BASEL REGULATORY FRAMEWORK ON BANK CAPITAL

Bank activity is characterized by asymmetric information. Depositors cannot monitor the quality of banks' assets and doubts on the solvency of banks might lead to panic and 'bank runs' (Llewellyn, 1999). If this should occur, depositors will be induced to withdraw their savings, causing a liquidity crisis for the bank that can potentially lead to the failure of the intermediary. Moreover, doubts regarding the solvency of one bank can create worries about

the solvency of other banks, leading to a generalized panic. Bank runs are considered as extreme events that are potentially highly disruptive. This was demonstrated during the latest financial crisis, when banks faced the threat of a bank run, not only by depositors, but also by institutional investors. In fact, following the 2007–2008 crisis, the interbank market almost dried up, suggesting that bank runs may move from the retail to the wholesale market. To prevent bank runs and their effects, governments usually create implicit or explicit guarantees to protect depositors (for a concise review see Allen *et al.*, 2009). Deposit insurance schemes however might produce unwanted effects and increase moral hazard because they can induce banks to take higher risks.[1]

Prudential authorities enforce capital regulation[2] in order to limit bank riskiness in relation to the stability of the system, to ensure the soundness of banks in normal and in turbulent times and to minimize their probability of default[3]; regulation enters the bank capital optimization problem, setting a minimum level of capital that banks must hold[4] (Kahane, 1977). Although capital regulation might induce banks to behave as desired by the authorities, the objectives of the two groups may not be completely aligned (Estrella, 2004) and therefore capital regulation might generate distortions in banks' behavior (Kim and Santomero, 1988; Blum, 1999; Calem and Rob, 1999).

[1] Various papers investigate the effects of deposit insurance on bank risk taking, but the specific topic lies outside the scope of this survey. The reader might refer to Allen *et al.* (2009) for a review.

[2] Given the aim of the survey, the paper focuses on the latest studies, while it only briefly recalls the theoretical and empirical contributions published before the introduction of Basel I. The reader can refer to Berger *et al.* (1995) for a discussion of bank capital and to Santos (2001) for a comprehensive review on previous contributions.

[3] With reference to capital ratios, Estrella *et al.* (2000) confirm that the risk-weighted capital ratio is a good measure of the probability of failure, but it does not significantly outperform other simpler ratios, for example, the leverage and the gross revenue ratio.

[4] When analyzing decisions on capital and risk it is important to differentiate between minimum capital and optimum capital. The first responds to prudential regulatory goals, it is an objective and verifiable measure of capital, it can be compared across institutions and it is usually publicly known, together with the general procedure used to compute it. The second measure expresses the level of capital desired by the firm and considered optimal to achieve its objectives (Estrella, 1995). For more recent contributions on target capital ratios, see Flannery and Rangan (2006). The authors argue that non-financial firms have a target capital ratio and each year tend to adjust their actual capitalization to approach the desired level, according to the partial adjustment framework theory. With reference to banks, Flannery and Rangan (2008) explain the capital increase experienced by US banks during the 1990s with the market perception of risk. The findings support the existence of an optimal capital which is beyond the minimum capital imposed by the authorities. In fact, as the authors underline, market participants might value the bank on the basis of a market capital ratio, that is, based on market conditions, which might differ from minimum regulatory capital, based on book items.

If banks have a desired level of leverage, they will adjust capital and risk accordingly; when there is an increase in capital requirements, banks might have the incentive to increase risk as well, in order to comply with the new regulation and, at the same time, keep their optimal leverage (Kohen and Santomero, 1980). This behavior can be corrected if regulators impose measures to limit bank riskiness and increase their supervision and monitoring (Kahane, 1977; Kohen and Santomero, 1980; Gennotte and Pyle, 1991).

Since the publication of the Basel Accord in 1988 (Basel I) by the Basel Committee on Banking Supervision (BCBS), the minimum regulatory capital has been formulated as a capital ratio, computed as regulatory capital to risk-weighted assets (RWA). The first Accord considered explicitly only credit risk, but it was later modified to also include market risks. The Basel Accord provided the first homogeneous framework on capital regulation at an international level and was a response to the growing internationalization in the industry and to the different level of capitalization of international banks (for a comprehensive discussion of capital requirements as in Basel I, see Dewatripont and Tirole, 1994 and for a review of the evolution of the Basel framework, see Rochet, 2010). Empirical evidence shows that the risk-weighted capital ratios increased after the release of the Accord (Wall and Peterson, 1996), although it is not clear whether banks met the new capital regulation by increasing capital (both Tier 1 and Tier 2) and/or decreasing risk and therefore by shrinking their assets (Jackson, 1999).

Basel I had some weaknesses, which became clear after its implementation. For instance, the regulatory framework enabled banks to implement regulatory arbitrage when choosing which asset class to hold. In fact, the risk weights were defined according to the type of borrower or issuer of a security (government, corporate, etc) and did not reflect the actual riskiness of the counterpart, nor the risk measures used by investors on the markets. The static approach on the risk weights induced banks to switch from private loans to government lending as this was classified as less risky by the regulators and therefore required a lower amount of regulatory capital.[5] According to Haubrich and Wachtel (1993), risk-based capital regulation in Basel I was one of the main determinants of this shift, which was especially strong for weakly capitalized small banks that had few opportunities to increase capital and therefore had to decrease risk, by modifying the composition of their portfolio. Diamond and Rajan (2000) document how Basel capital ratios might have contributed to the creation of a credit crunch

[5] The coefficients applied for the computation of the risk-weighted assets to securities issued by OECD governments was equal to zero, while the weighting for any corporate bond was 100%.

Table 1: Evolution of minimum capital requirements from Basel I to Basel III

	Basel I	Basel II	Basel III						
			2013	2014	2015	2016	2017	2018	2019
Minimum common equity ratio			3.5%	4%	4.5%	4.5%	4.5%	4.5%	4.5%
Capital conservation buffer						0.625%	1.25%	1.875%	2.5%
Minimum common equity plus capital conservation buffer			3.5%	4%	4.5%	5.125%	5.75%	6.375%	7%
Phase-in of deductions from CET1				20%	40%	60%	80%	100%	100%
Minimum Tier 1 Capital	4%	4%	4.5%	5.5%	6%	6%	6%	6%	6%
Minimum Total Capital	8%	8%	8%	8%	8%	8%	8%	8%	8%
Minimum Total Capital plus conservation buffer	8%	8%	8%	8%	8%	8.625%	9.25%	9.875%	10.5%
Capital instruments that no longer qualify as non-core Tier 1 capital or Tier 2 capital			Phased out over 10-year horizon beginning 2013						

The minimum capital requirement will be incremented from the actual 8% to a potential 10.5%. At the end of the phase-in period, in 2019, the highest quality components of capital shall represent at least 6% of risk-weighted assets (RWA); more in detail, at least 4.5% of RWA should be held as common equity. This change represents an acknowledgement of the importance of the quality of capital and not only of the quantity of capital. A capital conservation buffer is being gradually introduced starting 2016. Should the bank not hold this buffer, some restrictions would be placed on its activity (eg dividends distribution). Other provisions relate to the deductions from Core Equity Tier 1 (CET1) that were introduced in 2013 and will be gradually increased until 2018. Non-core Tier 1 or Tier 2 capital have to be eliminated from the regulatory capital base as they are being cancelled beginning 2013 over a 10-year period.
Source: Basel Committee on Banking Supervision, http://www.bis.org/bcbs/basel3.htm

in the United States in a period when the demand for loans was already decreasing due to the economic cycle.

Given the limits and weaknesses of capital regulation as designed in Basel I, together with the evolution of the financial system and the increased complexity of banking activities, a second version of the Accord was published in 2004, after a long consultation period.

Basel II did not modify the definition of capital introduced in the previous Accord and did not increase the minimum capital ratio (still at 8%, as shown in Table 1). However, it did present a more complex structure, partly caused by the criticisms expressed by the industry on the first Accord. In the design of the new framework, regulators allowed an excessive involvement of banks in the design of the Second Accord that arguably resulted in 'capture' of the regulator by the banking system (Rochet, 2010). Another issue related to the implementation of rules in the various countries. As underlined by Barth *et al.* (2008), the implementation was not homogeneous and this limited the effectiveness of Basel II. The key innovation in Basel II related to the computation of

risk-weighted assets, which now included credit, market, and operational risk. Also, Basel II allowed banks to choose the approach to estimating their risk exposure: a standardized approach, where all the parameters are set by the authorities, and an Internal Rating Based (IRB) approach, where the parameters used in risk exposure computation are developed by the bank, in part (IRB foundation) or fully (IRB advanced). The banks using the IRB approach generally experienced a decrease in the amount of capital they had to hold, in comparison to those banks that adopted the standard approach (Tarullo, 2008). This represented an enormous incentive to apply the IRB approach, especially for large banks (Hakenes and Schnabel, 2011). However, small banks were more likely to apply the standard approach due to the high costs of developing an internal model. Also the underlying methodology (value at risk) has been criticized because of the strong assumptions involved in the modeling and evaluation of risks. Kretzschmar *et al.* (2010) argue that the methodology used to integrate risks presented several weaknesses and the models were not able to integrate efficiently, in one measure, the overall exposure to the different types of risks. This caused banks to hold a level of capital which was not sufficient to guarantee their soundness.

Procyclicality of capital requirements represented another shortcoming of Basel II. If the models used to compute capital requirements become more risk-sensitive, the level of capital needed to satisfy these requirements grows as the economic cycle deteriorates (Bongaerts and Charlier, 2009; Jokipii and Milne, 2008). For this reason, banks facing an increase in capital requirements, due to an increase in the riskiness of their portfolio, might decide to reduce their exposure, instead of increasing their capital base, as the latter might be more difficult to achieve. Raising new capital in unstable conditions could be challenging on the financial markets due to increased uncertainty and the ensuing high cost of recapitalization. The consequent need to reduce risk exposure might lead to a credit crunch in the real sector, with consumers and firms facing more difficulties in obtaining loans. The cyclicality of capital requirements and the reduction of lending made to preserve the capital ratio can be even more severe when banks use internal methods (Behn *et al.*, 2013). To compensate for the cyclicality of capital ratios and soften the impact of economic conditions on banks' behavior, Spain introduced a countercyclical capital buffer in 2000 (later modified in 2005 and 2008) that succeeded in reducing the effects of economic boom and economic distress on capital ratios and lending decisions (Jiménez *et al.*, 2013).

The latest financial crisis prompted a further revision of the framework on capital regulation,[6] as well as the rethinking of the supervisory activity

[6] The causes of the crisis and the subsequent events have been deeply analyzed by the literature, but lie outside the scope of this survey. For a comprehensive review see Dewatripont *et al.* (2010).

exercised by the authorities.[7] After a consultation period, Basel III was published by the Basel Committee in 2011 (BCBS, 2011) with the objective of strengthening the banking and financial sector, tackling some of the weaknesses of Basel II. It introduced a stricter definition of capital and a revision of the methodologies used to compute capital ratios. Also, the new regulation introduces a series of measures to deal with liquidity risk, control banks' growth, impose higher requirements on systemically important financial institutions (SIFI), and the creation of capital buffers to face periods of economic stress.

With reference to capital prudential regulation, the new version of the Accord stresses the importance not only of the quantity, but also of the quality of capital. The Basel Committee itself recognized that the definition of capital was not harmonized and that transparency was very poor; '*raising the quality, consistency and transparency of the capital base*' (BCBS, 2009, p. 8) became an explicit goal of the Basel Committee in the reform of the regulatory framework. Basel III strengthens the quality and level of capital, by admitting only the highest quality instruments in the core Tier 1, revising the components of Tier 1 and Tier 2 and eliminating Tier 3 from the regulatory capital within 10 years. As shown in Table 1, the capital ratio is now expressed not only by a single percentage to hold, but the components constituting the total capital ratio have to meet certain criteria. By 2019, the highest quality components of capital should represent at least 6% of RWA, of which at least 4.5% of RWA should be held as common equity.

Although the minimum capital ratio remains at 8%, a capital conservation buffer of 2.5% has been introduced to encourage banks to build-up capital buffers during normal times. Banks not holding the full conservation buffer will suffer limitations in the distribution of dividends or in payments to managers.

A leverage ratio has also been added, with the objective to limit the growth and exposure of banks to risks, while the procyclicality of RWA has been tackled with a specific capital buffer (from 0% to 2.5%). Notwithstanding the importance of this amendment, as also underlined by Behn *et al.* (2013), the effectiveness of this measure relies on the capability of the authorities to correctly anticipate economic conditions and evaluate the likelihood of future distress.

[7] At European level, the prudential institutional framework has been modified: the prudential regime constituted by the three commissions, (CEBS, CESR, and CEIOPS) has been modified to substitute these commissions with three authorities (ESA – European Supervisory Authorities), with more power and influence, respectively European Banking Authority (EBA) for the banking system, European Securities and Market Authority (ESMA) and European (EIOPS). Besides, an authority for the macroprudential regulation has been created. This new framework has been in force since the beginning of 2011.

The implementation of Basel III is expected to bring benefits to the banking system, such as a reduction in the rate of banks default, a better decision-making process at management level, as well as improvements in performance.[8] Berger and Bouwman (2013) find that a high level of *ex-ante* capital tends to increase survivorship rates of medium and large banks during crises, with small banks showing a lower rate of default also during normal periods.

Cohen and Scatigna (2014) argue that the banks that have started the adjustment towards the new capital ratios have not pursued a massive reduction in lending, but rather have reinforced the capital base using mainly retained earnings and, to a lesser extent, by moving to less risky assets.

Nevertheless, a key disadvantage of Basel III is that the risk-weighting methodology will remain essentially unchanged and banks will still have the possibility to implement different methodologies to compute the capital ratio (Vallascas and Hagendorff, 2013).

The new regulatory framework has tried to consider other aspects of banking activities which can contribute to a more stable and safer financial system. Among these, liquidity risk has received much attention, since it is a key risk characterizing banking activity and can be of considerable concern during crises.[9] A Liquidity Coverage Ratio (LCR) and a Net Stable Funding Ratio (NSFR) have been introduced and will be implemented from 2015 and 2018, respectively (BCBS, 2013). The LCR measures a bank's ability to face any liquidity stress in a 30-day time period by holding a stock of high-quality liquid assets, while the NSFR aims at ensuring that banks have a sustainable maturity structure of assets and liabilities over a longer time horizon.

Furthermore, the new regulation considers the role of large and interconnected financial institutions, setting the basis for regulation of SIFIs, imposing stricter capital requirements for the global and domestic SIFIs, and taking a macroprudential perspective in relation to too-big-to-fail and too-interconnected-to-fail banks. The size of banks has in fact been growing in the last decades and this has created concerns for the authorities, facing larger banks with low capital ratios and less stable funding sources (Laeven *et al.*, 2014).

[8] An interesting point of view is provided by Admati *et al.* (2010) that analyze the arguments against stringent capital requirements (defined as equity capital requirements) and show how these criticisms can be overcome. Moreover, according to the authors, some of the cons of high capital requirements derive from the fallacies in the literature and in the industry that have produced a distortion in the way capital requirements are interpreted and enforced. A stronger capital regulation is desirable as it is necessary (but not sufficient) to have a healthy banking and financial system: social benefits deriving from high capital requirements offset any costs.

[9] It is in fact difficult to differentiate an illiquid bank from an insolvent bank in times of financial distress and crisis. This creates moral hazard problems, because insolvent banks might have access to funds initially granted by the government or Central Bank to illiquid banks, increasing the costs of public intervention (Laeven and Valencia, 2008).

During the most recent crisis, several episodes of bail out, re-capitalization and nationalization had to be implemented by governments in order to preserve market stability, especially in the case of cross-border institutions. While most of the measures were taken at a national level, authorities in Belgium, the Netherlands, and Luxembourg cooperated to nationalize both Fortis and Dexia (Gualandri *et al.*, 2009; Petrovic and Tutsch, 2009).

The crisis also highlighted the issue of 'shadow banking', that is the net of informal relationships that exists among banks and other financial institutions, that is not captured by the supervisory authorities. Measures to cope with this issue have been debated at an international level (for a more detailed discussion see Brunnermeier *et al.*, 2009).

THE IMPACT OF REGULATION: EMPIRICAL EVIDENCE

Capital and risk decisions in banking are influenced by regulation, private incentives, and market pressures. The focus of the survey is explicitly to provide an updated insight into the empirical evidence on the impact of prudential regulation on capital and risk, to present an assessment of the evolution of the mechanisms driving banks' decisions. The survey is limited to empirical investigations; to have an updated discussion of the theoretical framework of the relationship between capital and risk, see the contribution by VanHoose (2007).

The impact of bank prudential regulation on capital and risk decisions has been extensively studied by empirical contributions, which commonly state that the degree of regulatory scrutiny depends on the level of the capital ratio, that is, on the extent of the regulatory pressure. Accordingly, banks with a large buffer above the minimum capital ratio should be less subject to regulatory pressure, given that their behavior would be influenced to a lesser extent by changes in regulation (assuming an increase in capital ratios is required). On the contrary, banks with low capital ratios will be exposed to more regulatory pressure because an increase in the required minimum capital ratio will necessarily imply a change in the level of capital or risks.

Table 2 presents a concise view of the most recent empirical studies on the topic and describes the sample used by each investigation, the main research question, the empirical methodology, the definition of capital, risk and regulation, as well as a summary of the results.[10] It helps in understanding how the empirical studies are different in terms of the banks investigated, which aspects have been more deeply analyzed and how the results vary not only across studies, but also within the same study, when focusing on sub-samples or specific characteristics of banks (eg according to the level of *ex-ante* capital) or sub-periods.

[10] The table extends the framework introduced by Matejašák *et al.* (2009).

Table 2: Main empirical studies on the impact of regulatory pressure on capital and risk and the relationship between the two

Authors	Year	Sample and period	Research question	Methodology	CAP	RISK	REG	Impact of regulatory pressure on CAP	Impact of regulatory pressure on RISK	Relation between CAP and RISK
Shrieves and Dahl	1992	1,800 banks Assets> $100 million 1984–1986	Test the algebraic sign of the relationship between capital and risk	2SLS	Equity/RWA	RWA/Total assets; NPLs/ Total Loans	1 if CR<7% and 0 otherwise	+ for B	−for B	+ for B
Jacques and Nigro	1997	2,750 FDIC Insured banks Assets> $100 million 1991–1992	Test the first effects of risk-based capital standards	3SLS	Total capital (Tier 1+ Tier 2)/ total RWA	RWA/Total assets	RPL = (1/CR – 1/7.25) if CR<7.25% and 0 otherwise; RPG = (1/7.25 – 1/TRCR) if CR≥7.25% and 0 otherwise	+ for B	−for B	0 and+for B
Hovakimian and Kane	2000	123 listed banks first quarter 1985-fourth quarter 1994	Study the effects of regulation on banks' behavior					not investigated	not investigated	
Aggarwal and Jacques	2001	1,685 US banks Assets> $100 million 1991–1996	Test the effectiveness of FDICIA and PCA	3SLS	Tier 1 leverage ratio; Tier 1 risk-based capital ratio; total risk-based capital ratio	RWA/Total assets; NPLs/ Total Assets	PCAA = 1 if the bank is classified as adequately capitalized and 0 otherwise; PCAU = 1 if the bank is classified as undercapitalized and 0 otherwise	+ for A,+for U in 1991; 0 for A, 0 for U in 1992; 0 for A, 0 for U in 1993–1996.	+ for A,+for U in 1991; 0 for A, 0 for U in 1992; −for A, – for U in 1993–1996.	+ and – in 1991; + and – in 1992; + in 1993–1996.

Rime	2001	154 Swiss banks 1989–1996	Analyze if Swiss banks react to constraints on capital imposed by regulation. Examine how banks adjust their capital ratio (increasing capital or decreasing risk)	3SLS	Capital/Total assets; Capital/RWA	RWA/Total assets	REG = 1 if CR<σ (CR-8%); PCAA = 1 if the bank is classified as adequately capitalized and 0 otherwise; PCAU = 1 if the bank is classified as undercapitalized and 0 otherwise	0 for A + for U	0 for A 0 for U	0
Heid *et al.*	2003	570 German savings banks 1993–2000	Evaluate how German banks adjust their capital and risk under regulation	2SLS, 3SLS, dynamic panel data methodology	Total capital/ Total assets	RWA/Total assets	REG = 1 if std capital buffer≤ median std buffer across the sample and 0 otherwise	− and 0 for B	+ and 0 for B	0
Bichsel and Blum	2004	18 Swiss banks Jan 1990- March 2000	Investigate the relationship between changes in leverage and risk	Option pricing framework; Two-step FGLS procedure	Capital/Asset, in terms of market and accounting value	Standard deviation of the market value of equity	Non-explicitly modeled	not investigated	not investigated	+
Das and Ghosh	2004	27 public sector banks 1995/96-2000/01	Evaluate the behavior in terms of capital and risk	SUR, 2SLS	Capital/RWA	RWA/Total Assets	REG = 1 if CR<8% and 0 otherwise	− for B	−for B	−for B

Table 2: (*Continued*)

Authors	Year	Sample and period	Research question	Methodology	CAP	RISK	REG	Impact of regulatory pressure on CAP	Impact of regulatory pressure on RISK	Relation between CAP and RISK
Godlewski	2005	2,779 banks from 30 emerging market economies 1996–2001	Evaluate the relationship between capital and credit risk taking	2SLS, 3SLS	Equity/Total assets	NPLs/ Total loans	REG = 1/CR-1/min req if CR<min and = 1/min-1/CR otherwise; REG also included in a series of environmental variables	+ for A; 0 for U; +for A; – for U	0 for A; – for U; 0 and +for A; – for U	–for B
Lindquist	2004	147 Norwegian banks 1995–2001	Examine several important hypothesis on the importance of capital ratios	GLS	Capital buffer	Credit risk	SUP (supervisory scrutiny) = number of inspections	0 for savings; +for commercial	not investigated	–for B
Murinde and Yaseen	2004	98 banks from 11 countries (Middle East and North African Region) 1995–2002	Study the effects of Basel capital requirements on risk and capital	3SLS	Total capital (Tier 1+Tier 2) /Total RWA; Capital/Total assets	RWA/ Total assets	REG = 1 if CR<σ (CR-8%) and 0 otherwise; REG = RPG = 1/8-1/CR if CR≥8% and 0 otherwise	–for B; +for U	–for B; 0 for U	–for B; 0 for B
Hussain and Hassan	2005	300 banks from 11 developing countries 2001–2004	Study the impact of Basel I on banks from developing countries	GMM, 3SLS	Total capital/ RWA; Tier1/ RWA	RWA/ Total assets	REG = 8%-CR if 8% and 0 otherwise	–and 0 for B	–and 0 for B	–for B

Iwatsubo	2007	35 Japanese private banks 1990–2000	Arguing and testing if a non-linear relationship exists between capital and risk	GMM	Capital/RWA	Real estate loans/Total loans	Not explicitly modeled	not investigated	not investigated	Changes from + for B to – for B as franchise value diminishes
Van Roy	2005	586 banks form G10 countries Assets> $100 million 1988–1995	Investigate the reaction of G10 banks to the introduction of Basel capital requirements	2SLS, 3SLS	Capital/Assets (total capital or tier 1 capital)	RWA/Assets (credit risk ratio)	REG = 1 if CR<8%+σ(CR) and 0 otherwise	− and 0 for B	+ and 0 for B	− for B
Bouri and Ben Hmida	2006	Tunisian deposit and universal banks Jan 1992 – Aug 2005	Evaluate the effectiveness of Basel I and the way banks adjust their capital ratios	2SLS, 3SLS	Capital stock equity/RWA	RWA/Total assets; Loan loss reserves/Total loans to the economy	REG = min-CR if CR<min and 0 otherwise	0 for B (interacted with CAP)	+ and 0 for B	−and 0 for B
Floquet and Biekpe	2008	2,940 banks from 44 emerging market economies 1995–2003	Investigate the relationship between capital and risk both for ratios and levels	3SLS	Total book equity/Total assets	NPLs/Total loans	REG: overall capital stringency measure	na	na	RATIOS: – and + and 0 for B depending on the country; overall 0 for B; LEVELS: generally + for single countries; overall + for B

Table 2: (*Continued*)

Authors	Year	Sample and period	Research question	Methodology	CAP	RISK	REG	Impact of regulatory pressure on CAP	Impact of regulatory pressure on RISK	Relation between CAP and RISK
Kleff and Weber	2008	2,971 German banks 1992–2001	Examine how German banks determine capital and if the models suggested by previous literature hold for German banks	GMM	CAP1 = equity/Total assets; CAP2 = Tier 1+Tier 2 Capital/Total assets; CAP3 = Tier 1/Total assets	RWA/Total assets	REG = 1 if CAP1<6% and 0 otherwise; REG = 1 if CAP2< 7% and 0 otherwise; REG = 1 if CAP3<4% and 0 otherwise	0 and + for B	not investigated	+ and 0 for t − and 0 for t−1
Ahmad *et al.*	2009	42 Malaysian financial institutions 1995–2002	Evaluate how banks take their decisions on capital and if these are influenced by risk and/or regulation	Pooled OLS, FGLS	Tier 1+Tier 2/ RWA	NPLs/Total loans; Z-risk = [ROA +Equity/TA]/σ (ROA)	REG = 1 if CR<industry average and 0 otherwise	−for B	not investigated	+ for B
Matejašák *et al.*	2009	508 EU banks 683 US banks 2000–2005	Examine the behavior of European and US banks and the role of regulatory pressure in determining decisions on capital and risk	2SLS, 3SLS	Total regulatory capital/RWA	RWA/Total assets	REG = 1 if CR<8%+σ(CR) and 0 otherwise	+ for B (EU) 0 and + for B (US)	0 for B (EU) −for B (US)	+ for B

Gropp and Heider	2010	327 US and EU-15 listed banks 1991–2004	Examine if capital requirements effectively determine capital ratios		Book leverage = 1-(book value of equity/book value of assets); Market leverage = 1-[market value of equity (= number of shares ∗ end of year stock price)/market value of bank (= market value of equity +book value of liabilities)]	Asset risk = annualized standard deviation of daily stock price returns ∗ (market value of equity/ market value of bank)	Not explicitly modeled	0 for B	not investigated	not investigated
Memmel and Raupach	2010	81 large German banks Oct 1998-Dec 2006	Examine the behavior of banks in determining capital ratios	Partial adjustment model	Tier 1/RWA of banking book; total capita/ RWA of banking book; own funds/ RWA of banking and trading book	RWA	Not explicitly modeled	Regulatory pressure has an important role	not investigated	not investigated
Athanasoglou	2011	Around 115 South Eastern European banks 2001–2009	Examine the relationship between capital and risk for SEE banks	GMM, 3SLS	Equity/Total assets; Total regulatory capital ratio	NPLs/gross loans	Not explicitly modeled			0 and + for B; 0 for A; + for U

Table 2: (*Continued*)

Authors	Year	Sample and period	Research question	Methodology	CAP	RISK	REG	Impact of regulatory pressure on CAP	Impact of regulatory pressure on RISK	Relation between CAP and RISK
Camara *et al.*	2013	1,451 European banks 1992–2006	Investigate the impact of changes in capital on the risk-taking behavior	GMM, 2SLS	Total capital/ Total assets (further decomposed into Equity, Subordinated debt and hybrid instruments)	RWA/Total assets; NPLs/net loans	Modeled according to the level of the capital ratio, differentiating between adequately, undercapitalized and strongly undercapitalized	Not investigated	−for U	0 and + for B; −for moderately U
Berger and Bouwman	2013	US banks from 1984: Q1 to 2010: Q4; for a total of 57,243 small, 1,946 medium, and 1,400 large-bank observations	Study the effect of capital measured prior to a crisis on bank performance during a crisis	Logit survival; OLS	Equity capital/ gross total assets; tier 1 capital ratio; total regulatory capital ratio	Credit risk, defined as the bank's Basel I risk-weighted assets divided by gross total assets	Captures the relative supervisory authority	Not investigated	Not investigated	Not investigated

In the table:
+: significantly positive; −: significantly negative; 0: not significant.
B: banks; A: adequately capitalized; U: undercapitalized.
2SLS: two-stage least squares; 3SLS: three-stage least squares; FGLS: feasible general least squares; GMM: generalized method of moments; OLS: ordinary least squares; SUR: seemingly unrelated regression.
CR: capital ratio; NPLs: non-performing Loans; REG: regulatory variable; RWA: risk-weighted assets.

The samples investigated generally relate to US or European banks, although some recent studies focus on emerging countries (Godlewski, 2005; Hussain and Hassan, 2005), the Middle East and Africa (Murinde and Yaseen, 2004; Bouri and Ben Hmida, 2006), and also Asia (Iwatsubo, 2007; Ahmad *et al.*, 2009). The empirical methodology takes into consideration the possible endogeneity problem that arises when modeling banks' simultaneous decisions on capital and risk; most of the studies employ 2- or 3-Stage Least Squares (SLS) or the generalized method of moments (GMM).

The definition of capital, risk, and regulation generally is not homogeneous across studies, but the most commonly used variables are reported in Table 3. For capital ratio, the studies usually employ equity to total assets, or the risk-weighted capital ratio. The former is the most basic notion of capital ratio, but excludes other capital instruments such as Tier 2, while the latter considers the notion of capital ratio as in the regulatory framework, inclusive of all the items of the regulatory capital base, but is sensitive to the risk weightings. Risk exposure is commonly measured as non-performing loans or RWA to total assets. The first is suitable for more traditional banks, where the lending constituted the main source of risk, while RWA includes the exposure of the bank to all types of risks mentioned by the regulation. But as for the regulatory capital ratio, RWA is influenced by the risk weights applied. Finally, regulatory pressure is generally computed as the distance to the regulatory minimum or by one or more dummy variables identifying well, adequately and low capitalized banks.

The results of each study reviewed are shown in Table 2, which summarizes the sign of the impact of regulation on capital and risk, and also the sign of the relationship between capital and risk.

Most of the studies assume that a change in regulation affects both capital and risk decisions and investigate the underlying mechanisms. With reference to the impact on capital, most of the studies find a positive impact of regulation, suggesting that banks subject to more regulatory pressure, tend to increase their capital ratio (Shrieves and Dahl, 1992; Jacques and Nigro, 1997), although some more recent investigations find a negative effect (Heid *et al.*, 2003; Das and Ghosh, 2004; Ahmad *et al.*, 2009). On the impact of regulatory pressure on risk exposure, findings suggest that a negative relationship exists (Shrieves and Dahl, 1992; Jacques and Nigro, 1997), but also in this case, contrasting evidence finds a positive or insignificant effect (Heid *et al.*, 2003; Van Roy, 2005; Bouri and Ben Hmida, 2006).

Several of the empirical studies reviewed seem to support, therefore, the effectiveness of regulation on banks' behavior, but results can vary according to the specific time period analyzed (Aggarwal and Jacques, 2001), the country investigated (Matejašák *et al.*, 2009) or the specialization considered

Table 3: Variables generally used to describe capital ratios, risk exposure and regulatory pressure in the empirical studies

Variable	Description
Capital ratio	
Total regulatory capital ratio (trcr)	It is the ratio computed according to capital regulation as total regulatory capital to risk-weighted assets. Sometimes it is split into Tier 1 and Tier 2 capital ratio.
Equity to Total Assets (E/TA)	It considers only equity as capital and therefore it is less related to the regulatory provisions than trcr. However, it is not influenced by the risk-weighting of the assets and captures the highest quality capital instruments.
Risk	
RWA (Risk Weighted Assets)	It expresses the overall riskiness of the bank, as formulated in the regulatory requirements. It is generally used as a ratio (RWA to total assets)
NPLs (Non-Performing Loans)	It captures only credit risk and represents an *ex-post* measure. This variable can be more suitable for banks which follow a traditional model as credit risk is the main source of risk exposure for these banks. It generally enters a ratio, such as NPLs/total assets, NPLs/net loans
Standard deviation of the market value of equity	It considers the risk of the bank perceived by the market. It would be a good measure of risk if markets were efficient and able to correctly evaluate the riskiness of the specific intermediary. Moreover, it is applicable only to listed banks.
Regulatory pressure	
REG	It is often modeled as a dummy variable, that takes value equal to 1 if the bank capital ratio is above a given threshold (usually 8%, considered the regulatory minimum), and 0 otherwise. Some studies compute REG as the difference between the bank's capital ratio and the minimum (8%). Others also consider the variation of past capital ratios.
REG according to PCA[a]	It considers two dummies. The first takes value 1 if a bank is adequately capitalized and 0 otherwise. The second takes value 1 if the bank is undercapitalized and 0 otherwise. This approach is useful in the framework of the Prompt Corrective Action (PCA), that classifies banks into five categories from well-capitalized to undercapitalized.
Number of inspection	This variable is able to capture the effective regulatory scrutiny, and might capture consequences deriving from information available only to the authority. It requires access to the detailed information on the authorities' activity. Additionally, inspections might not be related only to concerns about the capitalization but also to legal or compliance issues.

[a]The Prompt Corrective Action (PCA) was introduced with the Federal Deposit Insurance Corporation Improvement Act (FDICIA) in the United States and it classifies banks into five categories, depending on the capital ratio. Banks with the highest capital ratios are considered 'well capitalized'; the other banks have to face increasing restrictions and penalties as the capital ratio decreases. Additionally, FDICIA turned into mandatory the supervisory intervention towards banks which are undercapitalized.
See Table 2 for the list of studies that use each variable.

(Lindquist, 2004). Additionally, the impact of regulatory pressure varies depending on the *ex-ante* level of capital, as adequately and undercapitalized banks seem to be subject to different incentives (Rime, 2001; Godlewski, 2005; Murinde and Yaseen, 2004; Hussain and Hassan, 2005; Van Roy, 2005) and modify their behavior depending on the definition of capital (Kleff and Weber, 2008; Camara *et al.*, 2013).

The differences emerging in banks' behavior might be an effect of bank characteristics that can influence both capital and risk, and have therefore also been included in the analyses by the same empirical studies.

Bank size can have a negative effect on capital (Berger *et al.*, 2008), since larger banks have easier access to capital markets (Ahmad *et al.*, 2009), a greater flexibility in the use of hybrid instruments or subordinated debt to increase their capital ratios (Heid *et al.*, 2003) and might rely on public intervention (bail-out) in case of distress. A positive impact of size on capital can be found in case the asymmetries of information prevail (Gropp and Heider, 2010), inducing large banks to hold higher capital buffers to compensate for their increased complexity.

Despite results in general show a strong negative relationship between capital and size (Jacques and Nigro, 1997; Aggarwal and Jacques, 2001; Rime, 2001; Heid *et al.*, 2003; Kleff and Weber, 2008; Das and Ghosh, 2004; Lindquist, 2004; Murinde and Yaseen, 2004; Van Roy, 2005; Floquet and Biekpe, 2008; Matejašák *et al.*, 2009), both the explanations cited above are supported within the empirical studies, as a number of studies find a weak negative or insignificant relationship between size and capital decisions (Shrieves and Dahl, 1992; Godlewski, 2005; Hussain and Hassan, 2005; Ahmad *et al.*, 2009), and other studies find a positive relationship (Kleff and Weber, 2008, but limited to savings banks; Bouri and Ben Hmida, 2006, that concentrate on the Tunisian banking system).

Size is also expected to have an impact on risk. Larger banks are believed to be more diversified and this should contribute to a reduction of their risk exposure (Lindquist, 2004; Van Roy, 2005), although the evidence is mixed.

Specialization is also an important driver of banks decisions: savings and cooperative banks, for instance, face a number of restrictions in the way they can raise capital (Kleff and Weber, 2008).

In the determination of the capital ratio, liquidity is also considered to be a significant variable, but the direction of the relationship is still unclear (Jokipii and Milne, 2011; Athanasoglou, 2011). Recent studies confirm that banks might hold liquidity as insurance against shocks and use it as a buffer, limiting the need for additional capital (Jokipii and Milne, 2011), while other banks (such as small banks) might increase capital to compensate for a lack of liquidity (Distinguin *et al.*, 2013).

Earnings also contribute to the build-up of the capital base and therefore a high level of profitability might enable banks to increase their capital ratio. Additionally, as suggested by the literature, profitable banks might prefer to increase their capital through retained earnings, rather than equity as new issues might be negatively perceived by investors (Kwan and Eisenbeis, 1997; Rime, 2001; Van Roy, 2005; Matejašák *et al.*, 2009), unless the increase in capital is imposed by the authorities (Kashyap *et al.*, 2010).

The level of efficiency can also influence capital and risk decisions as less efficient banks might increase their risk exposure to compensate for the costs deriving from more stringent regulatory requirements. Banks with a higher level of efficiency and better management might be allowed to increase their leverage by the regulator (Altunbas *et al.*, 2007). Part of the literature models efficiency explicitly and evaluates the relationship between capital, risk, and efficiency (Kwan and Eisenbeis, 1997; Altunbas *et al.*, 2007; Deelchand and Padgett, 2009), while other contributions include efficiency as an explanatory variable both in the capital and risk equations (Camara *et al.*, 2013).

Other exogenous variables that have been considered in the empirical studies include the economic cycle, which is able to influence the level of risks and the ease of raising capital (Lindquist, 2004; Van Roy, 2005). During downturns, non-performing loans (NPLs) tend to increase, while during economic booms, banks tend to expand their assets and therefore increase their risk exposure.

CONCLUSIONS

The soundness of the banking system is a key element in the implementation of the prudential framework, especially with reference to capital regulation, that aims to control bank risk taking. Bank decisions on capital ratios can in fact have consequences for their stability and understanding how these decisions are taken is of utmost importance. Because of these reasons, capital and risk have always been a core topic in the banking literature and the research activity by academics has become even more intense with the revision of the regulatory framework following the latest financial crisis. This survey focuses on the main empirical studies investigating the role of regulation in influencing banks' capital and risk decisions, providing an update on the empirical banking literature and summarizing the evolution of the empirical modeling as in the most recent academic studies.

The numerous empirical investigations show that regulation effectively impacts banks' behavior, although specific factors can produce different incentives at the bank level. Among them, the *ex-ante* level of capital, the

specialization, the time period and country, and bank characteristics affect banks' behavior, producing mixed results. The study of capital and risk decisions helps in understanding the mechanisms driving capital ratio adjustments and this, in turn, might help the authorities to adjust and calibrate the design of capital requirements.

Given the contrasting evidence, and the importance of the topic, further research is needed as regulation evolves, in particular in relation to the link between capital and liquidity, the role of SIFIs, the question of shadow banking and the actual implementation of the Basel framework by the single authorities.

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