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Model-Based Capital Regulation: Where Do We Stand and Where Should We Go from Here?

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Abstract

This article examines the evolution and challenges of model-based capital regulation in banking, discussing its impact on banking system resilience and financial stability. Introduced with Basel II, model-based regulation sought to link capital requirements to asset risk but encountered practical issues like discretion in banks' risk reporting, complexity, and procyclicality, weakening its effectiveness. Large banks often exploited modeling discretion to reduce capital requirements, lowering equity levels and amplifying systemic risk, as evidenced in the global financial crisis of 2008. While greater distance between banks and supervisors limits discretion, the findings underscore the advantages of simpler frameworks, such as leverage ratios, for enhancing transparency and stability. Political economy considerations, however, complicate international regulatory alignment, as national regulators balance stability objectives with considerations about domestic competitiveness. The article concludes that streamlined regulation paired with strong and robust equity standards would bolster financial stability and calls for further research on regulatory frameworks and systemic risk.

1. INTRODUCTION

The setting of minimum capital requirements has been a focus of bank regulation at least since the 1988 Basel I standard made a first attempt of harmonizing regulatory standards at the international level.[1] The primary reason for imposing minimum capital requirements lies in the social costs associated with bank failures, as banks play a critical role in providing external funding to the real economy. In the absence of regulation, banks may opt for suboptimal capital levels because they do not internalize externalities that their failure may impose on the economy. Moreover, the presence of implicit and explicit guarantees further incentivizes banks to maintain lower equity levels than what would be socially optimal. Broadly speaking, capital regulation aims to ensure that banks have enough equity at stake (or skin in the game), providing a cushion to avoid losses for depositors, debtholders, the deposit insurer, or society as a whole and preventing banks from making excessively risky investments at the expense of these other stakeholders (for a review of the literature on the functions of bank capital, see Thakor 2014).

How much bank capital is optimal from a social perspective has been subject to considerable debate (e.g., Diamond & Rajan 2000, 2001; Admati et al. 2010; Miles, Yang & Marcheggiano 2013; Admati & Hellwig 2024a). One aspect in these discussions is whether the amount of required bank equity should depend on the riskiness of the bank's assets, since riskier assets have, in principle, the potential to impose larger losses on the bank. As already pointed out by Peltzman (1970), under the notion that bank regulation's ultimate objective is to prevent bank failure, "more adequate capital and a less risky asset portfolio are substitutes in the eyes of the regulators, and their examination activities are geared to achieving an appropriate mix of the two" (p. 3). This line of argument is also reflected into the design of the Basel I standard, which established a formal link between asset risk and capital requirements by assigning bank assets into five different risk groups (or buckets) with preassigned risk weights, ranging between 0% and 100%, and essentially determining the required amount of equity financing for the respective asset exposure class.

The principle of risk-based capital regulation gained ever more prominence since Basel I, most notably with the standard's 1996 extension to market risk, and then the development of the so-called internal ratings–based (IRB) approach for credit risk in the 2006 Basel II standard. In both extensions, banks were allowed to use their own internal risk models to determine the riskiness of their assets, where riskier assets are then associated with higher capital requirements. Specific modeling approaches include, for example, value-at-risk models to determine capital requirements for trading book positions, credit risk models estimating a borrower's probability of default (PD), or the loan-specific loss given default for banking book positions. Supervisors review and approve the corresponding risk models, to ensure that they accurately reflect the true underlying risks of a bank's exposures.

While the model-based approach was theoretically compelling, its implementation coincided with a significant decline in banks' equity levels in the run-up to the global financial crisis of 2008 (GFC). Critics argued that this decline was facilitated by the model-based approach, which—they claimed—was exploited by large banks as a device to reduce capital requirements.[2] Since then, the approach has continued to evolve, and, in 2017, the Basel Committee agreed on several corrective measures such as risk weight floors to constrain risk modeling and address identified shortcomings. However, 8 years after the agreement of these so-called Basel endgame reforms, they still need to be implemented in major jurisdictions around the globe, with banks lobbying heavily to

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[1]In this article, we use the terms "capital," "own funds," and "equity" interchangeably, as the setting of minimum own funds or equity requirements for banks is usually referred to as "capital regulation."

[2]For a summary of evidence supporting this argument, see, for example, Admati & Hellwig (2024a).

water down key elements of the package. Thus, the benefits and costs of model-based capital regulation remain subject to fierce debate among banks, regulatory and supervisory authorities, and academics.

Since model-based regulation started to appear in the mid-1990s, numerous academic studies have theoretically discussed its conceptual merits and empirically examined its effectiveness and practical implications. Against this background, this article reviews the literature of the last 30 years, recalling the main objectives and theoretical underpinnings of model-based regulation, documenting practical challenges and implementation issues, and discussing its overall effectiveness and implications for financial stability.

Specifically, our article is structured as follows. Section 2 discusses the concept of model-based regulation from a theoretical perspective. Section 3 describes the evolution of model-based regulation within the Basel framework. Section 4 analyzes six distinct challenges associated with model-based regulation: reporting discretion, risk endogeneity, technical modeling challenges, procyclicality, composition of loan supply, and complexity associated with the approach. Section 5 discusses overall lessons learned and a possible way forward, while Section 6 concludes.

2. CONCEPTUAL DISCUSSION ON THE MERITS OF RISK-BASED CAPITAL REGULATION

The emergence of model-based regulation is closely associated with a regulatory desire to establish a tight link between banks' asset risk and the required amount of equity financing. The conceptual thinking behind this is that riskier assets can be expected to suffer higher losses, so that a larger cushion in terms of equity is needed to protect creditors. While accounting provisions are in principle supposed to cover for expected losses (and can thus cater to observed differences in asset risk), capital regulation is based on the notion that it is inherently difficult to foresee all future losses, so that an additional buffer to protect against unexpected losses (which may also be asset specific) is necessary. In addition, risk-sensitive capital requirements are supposed to promote stronger risk management practices in the banking sector by incentivizing banks to keep developing their internal risk models.

Theoretical papers that are often cited to motivate the emergence of risk-based capital regulation are the ones by Kahane (1977), Koehn & Santomero (1980), and Kim & Santomero (1988), which argue that a lack of risk differentiation in regulatory standards may incentivize banks to engage in riskier activities. Model-based regulation is based on the economic principle "He who pollutes should be taxed": The higher the risk on a specific position, the higher the capital charge. By tying capital charges to actual asset risk, banks are no longer penalized for holding very safe assets on their balance sheets, so that the distortion in the allocation of credit that accompanied the simple flat tax feature of Basel I is eliminated (for further discussion, see Behn, Haselmann & Vig 2022).

A more practical concern on insufficiently risk-sensitive requirements from the regulatory side was that securitization and financial innovation enabled regulatory capital arbitrage under the Basel I standard, as banks securitized the safest parts of their loan portfolios and parked them in off-balance-sheet special purpose vehicles (SPVs) to reduce capital requirements, while keeping only riskier exposures in the loan book on the balance sheet (Jones 2000). It was believed that such capital arbitrage could be prevented by establishing a closer link between capital requirements and asset risk, and the credit value-at-risk model developed by Gordy (2003) provided the basis for assigning capital charges for credit risk at the instrument level, based on estimates from banks' internal risk models, as ultimately enshrined in the Basel risk weight formula (Basel Committee on Banking Supervision 2005).

While the initial argument that more stringent capital standards without risk differentiation could lead to an increase in bank risk-taking drew a lot of attention, it was subsequently questioned on several grounds (for a review of the literature, see Santos 2000). It also conflicted with conventional arguments that higher capital levels should constrain risk-taking behavior as they increased skin in the game for shareholders and bank managers, which should incentivize them to act prudently (e.g., Merton 1977; Keeley & Furlong 1990; Hellmann, Murdock & Stiglitz 2000). As for the concern on capital arbitrage, an alternative solution could have been to align the regulatory treatment of off-balance-sheet exposures in SPVs with that of on-balance-sheet exposures, rather than increasing risk differentiation among balance sheet exposures. In addition, commentators pointed out important challenges for risk-based capital standards, for example, relating to the measurability and endogeneity of risk, potential procyclicality, or the associated complexity (Daníelsson et al. 2001; Hellwig 2010; King 2010; Haldane & Madouros 2012).

Empirically, in the GFC, unweighted capital ratios have been found to be better predictors of bank performance than Basel-style risk-based metrics (Brealey, Cooper & Kaplanis 2012; Haldane & Madouros 2012; Demirguc-Kunt, Detragiache & Merrouche 2013). Since then, some papers have argued that a combination between risk-based and simple leverage requirements may be needed to ensure bank stability (e.g., Blum 2008; Kiema & Jokivuolle 2014; Acosta-Smith, Grill & Lang 2024), which is also reflected in the design of the most recent Basel III standard. This outcome is still criticized by Admati & Hellwig (2024a), who consider current leverage ratio requirements as being too low and argue—along the lines of classical skin in the game considerations—that if unweighted capital requirements are set at sufficiently high levels, banks would not be incentivized to engage in riskier activities to begin with, making regulatory differentiation of asset risk unnecessary.

3. THE EVOLUTION OF CAPITAL REGULATION SINCE THE 1980s

While the literature discussing the relative merits of risk-based and non-risk-based capital regulation is ambiguous, as discussed above, the principle of risk-based capital regulation has been deeply rooted in regulatory standards since the late 1980s.

The initial Basel I standard of 1988 is already based on the principle of risk-based regulation. Focusing on credit risk, the standard prescribed that bank assets should be sorted into several broad risk buckets, which then determined the associated risk weights and hence the capital requirements (Basel Committee on Banking Supervision 1988). The 1996 amendment of the standard extended this principle to the category of market risk, where—for the first time—banks were allowed to use their own internal (value-at-risk) risk models to determine the corresponding capital requirements (Basel Committee on Banking Supervision 1996). The most fundamental change then came with the adoption of the Basel II standard in 2006, which extended the usage of internal risk models also to credit risk [via the IRB approach, under which banks had to estimate borrower- and loan-specific risk factors such as the PD or the loss given default], revised and expanded the approaches for market risk, and introduced operational risk as a third risk category for which capital requirements could also depend on internal risk models (Basel Committee on Banking Supervision 2006).

While the subsequent Basel III standard expanded the framework's perimeter into several directions (for example, via liquidity and leverage regulations or macroprudential capital buffers), it also put several constraints on the usage of internal risk models, most notably via the Basel III finalization package adopted in 2017 (Basel Committee on Banking Supervision 2010, 2017a). Specifically, to address identified shortcomings of model-based approaches, the revised standard constrains or removes the usage of internal models for certain asset classes or risk categories and introduces an output floor that constrains the extent to which banks can lower their capital requirements relative to the standardized approaches (SAs). While these are important innovations

that speak to the findings discussed in this review article, they are still in the process of being implemented in many jurisdictions around the globe, with key elements still under discussion at the national level (see Section 5).

4. PRACTICAL CHALLENGES FOR MODEL-BASED CAPITAL REGULATION

The discussion in the previous sections has shown that while risk-based capital regulation may have some theoretical advantages, it is far from clear that such regulation is preferable to simpler leverage requirements from a conceptual perspective. The literature provides ambiguous insights on this point. To complete the picture, in this section, we discuss several practical challenges that may undermine the effectiveness of a risk-based regulatory approach reliant on banks' internal risk models.

4.1. Reporting Discretion and Reliability of Internal Risk Estimates

As noted by Kashyap, Rajan & Stein (2008, p. 445), "clearly, a system of risk-based capital works well only insofar as the model used by the bank . . . yields accurate and not easily-manipulated estimates of the underlying economic risks." Almost from the initial application of model-based regulation onward, commentators had doubted that this condition would be met via reliance on the estimates from banks' internal risk models (e.g., Daníelsson et al. 2001; Hellwig 2010; Haldane 2013; Admati & Hellwig 2024a). The empirical evidence from the last decade largely confirms these initial doubts.

Specifically, Mariathasan & Merrouche (2014) find that the adoption of model-based regulation is associated with a reduction in regulatory capital for a sample of 115 large banks across 21 OECD countries. The reduction in regulatory capital is particularly pronounced for weakly capitalized banks and in countries where the legal framework for supervision is weak.

Berg & Koziol (2017), using loan-level data from the German credit register, highlight inconsistencies in model-based risk estimates across banks, showing that weakly capitalized banks assign lower IRB risk weights than better capitalized ones, even after controlling for borrower characteristics. Similarly, Plosser & Santos (2018) find that within loan syndicates in the United States, banks with less regulatory capital report lower risk estimates, indicating an effort to reduce capital requirements. Their findings also show that these lower risk estimates have less explanatory power for interest rates, indicating that banks' self-reported risk measures may not reflect all the available information of the bank.

Behn, Haselmann & Vig (2022) demonstrate how, in the aftermath of the GFC, banks optimized their internal models to reduce capital requirements. Exploiting the staggered rollout of the IRB approach and using granular loan-level data from Germany, they show that banks reported systematically lower risk estimates when using the IRB approach rather than the more traditional SA, even for the same borrower in the same period. Observed underreporting of risk estimates under IRB is stronger in cases where gains from underreporting are greater, while interest rates appear to reflect the true underlying risks of the loans more faithfully.

Underreporting of risk is not limited to regulatory credit risk models. Begley, Purnanandam & Zheng (2017) demonstrate that banks significantly underreport trading book risk, particularly when they are weakly capitalized. This underreporting is more pronounced during periods of elevated systemic risk, making the self-reported risk measures least informative when they are most needed.

Moreover, there appears to be cross-subsidization across different risk classes. Specifically, Abbassi & Schmidt (2018) show that underreporting of credit risk in loan portfolios is

particularly pronounced when trading book risk is elevated and thus pushing up capital requirements. Again, the effects are strongest for banks in which regulatory capital is scarce. This finding illustrates the discretion that banks have in operating different types of models and their tendency to exploit this discretion when they need regulatory capital.

While it is challenging to pin down the precise mechanism behind the observed underreporting of risks in regulatory models, the most plausible interpretation is that banks consciously exploited their discretion to reduce capital requirements. Several empirical observations support this notion. First, loan pricing under model-based regulation tends to reflect true riskiness (Plosser & Santos 2018; Behn, Haselmann & Vig 2022). Second, studies consistently show that banks with less regulatory capital are more likely to underreport their risk estimates, and more generally, that underreporting is more pronounced when there are more gains from it in terms of reducing required capital (Mariathasan & Merrouche 2014; Begley, Purnanandam & Zheng 2017; Berg & Koziol 2017; Plosser & Santos 2018; Behn, Haselmann & Vig 2022).

The persistence of underreporting raises questions about why supervisors struggled to prevent this behavior.[3] One aspect seems to be a limited ability to conduct cross-sectional comparisons of large data sets in real time. Supervisors often rely on parameter learning, which requires long time series of data before manipulation can be identified (Collin-Dufresne, Johannes & Lochstoer 2016). There is also evidence suggesting that penalties imposed on banks when underreporting is detected may be too low to induce faithful reporting in the first place (Lucas 2001). Moreover, cross-country evidence indicates that underreporting is more prevalent in countries with lax supervision (Mariathasan & Merrouche 2014; Böhnke et al. 2023), indicating that supervisory capture or discretion may also play a role.

The establishment of the Single Supervisory Mechanism (SSM) in Europe offers a valuable case study on supervisory discretion in the context of model-based regulation. When the SSM was introduced, banks in the euro area with assets above €30 billion were transferred to supranational supervision, while smaller banks remained under national oversight. Haselmann, Singla & Vig (2022) use data from the German credit register to investigate whether banks supervised by different authorities report systematically different risk estimates for the same borrower. Their findings suggest that national supervisors tend to be more lenient than the SSM, requiring less regulatory capital for identical loans from banks in their jurisdiction.[4] This is consistent with complementary findings by Altavilla et al. (2020), showing that supranational supervision was effective in reducing excessive risk-taking. The findings highlight that the organizational design of supervisory institutions significantly influences supervisory outcomes. Notably, increasing the distance between supervisors and the supervised institutions appears to reduce—at least partially—the discretionary reporting behavior of banks, a phenomenon documented in several studies cited in this section.[5]

Interestingly, the new supervisory framework not only leads to banks reporting more conservative risk parameters under model-based regulation but also addresses biases in the relative treatment of banks. Under local supervision, Haselmann, Singla & Vig (2022) demonstrate that larger banks tended to receive preferential treatment compared to smaller banks. However, the

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[3]Behn, Haselmann & Vig (2022) provide a comprehensive discussion of possible reasons in their section VI.

[4]This speaks to findings by Agarwal et al. (2014), demonstrating in a US setting that supervisors can interpret identical rules very differently, with supervisors closer to a bank being too lenient.

[5]Specifically, the SSM incorporates institutional features designed to increase this distance. For example, the head of a supervisory team assigned to a bank must not originate from the same country where the bank is headquartered. Additionally, a rotation policy ensures that supervisors are regularly reassigned to different institutions. These measures foster greater independence between banks and their supervisors.

central supervisory structure eliminates such biases, resulting in a more standardized application of model-based regulation. These findings underscore how the discretion inherent in model-based regulation interacts profoundly with the enforcement of financial regulations, shaping both reporting behavior and supervisory consistency.

4.2. Risk Endogeneity

The issues documented in the previous subsection can be attributed to a specific feature of model-based regulation under the Basel standard, namely self-reporting of risk estimates by the supervised entities. Besides these design issues, there are also more general challenges for model-based regulation, i.e., challenges that would occur also under a different regime of modeling risk (e.g., a regime in which risk models are provided by the regulator or the supervisor). One of these challenges relates to the Lucas critique or Goodhart's law, which says that statistical relationships tend to break down when used for policy purposes.

Applied to the case of bank regulation, the analogy would be that risk models tend to break down once used for calculating capital requirements. The reason behind this is that many of the risks involved are endogenous to the regulation, as the latter may alter banks' behavior and thus impact the underlying risks that are being regulated. The observation that risks may change is exemplified by Admati & Hellwig (2024a), who note that a key consequence of risk-weighting assets is that banks are incentivized to concentrate their investments in assets deemed safe by the framework. When certain asset classes require less regulatory capital, banks are encouraged to invest disproportionately large amounts into these assets, which can become problematic if the investment becomes excessive.[6]

Along the lines of Goodhart's law, Rajan, Seru & Vig (2015) argue that statistical default models (such as those used under model-based regulation) may fail to account for shifts in the relationships between variables when underlying agent behavior changes. The securitization of subprime mortgages prior to the GFC is a good example. As securitization levels increased, also driven by regulatory incentives, lenders were incentivized to originate loans that appeared favorable based on the characteristics reported to investors of the securitized assets, even when unreported factors suggested lower borrower quality (see also Keys et al. 2010). This shift in lender behavior altered the underlying data-generating process, distorting the relationship between reported risk factors and actual loan defaults and eventually leading to a breakdown of the model. As discussed by Behn, Haselmann & Vig (2022), model-based capital regulation may have similar effects, as it may change incentives for banks to capture negative soft information in their credit risk estimates.

Another striking example of how model- or indicator-based regulation may be undermined by changes in bank behavior is the practice of "window dressing behavior," which gained prominence in regulatory discussions lately.[7] Specifically, several papers document that large banks tend to reduce certain activities around regulatory reporting dates (e.g., Behn et al. 2022; Garcia, Lewrick & Sečník 2023). Inter alia, this helps to reduce additional capital requirements under the framework for Global Systemically Important Banks (G-SIBs), which depend on a composite indicator that is largely determined by these activities (the so-called G-SIB score). This practice appears highly problematic from a financial stability perspective, as it not only may lead to a distortion in capital

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[6]Admati & Hellwig (2024a) point to sovereign assets as a case in point.
[7]See, e.g., Basel Committee on Banking Supervision (2024). Window dressing behavior may also affect other types of regulation, including simple leverage ratio requirements, as the key issue is about banks' desire to appear safer or less systemically important at regulatory reporting dates [on window dressing of the leverage ratio, see, e.g., Basel Committee on Banking Supervision (2019)].

requirements across banks but also may adversely affect financial market functioning (Bassi et al. 2024).

4.3. Model Risk and Reliance on Historical Data

Besides risk endogeneity, simple technical or empirical challenges may also undermine models' ability to adequately account for the risks they are supposed to capture. As noted by Hellwig (2010), the empirical basis for risk modeling is often insufficient, as many of the time series that are being used are very short or exhibit substantial nonstationary features, especially when it comes to estimating correlations. These issues are particularly pronounced for credit risk models that aim to predict rare default events, compared with market risk models that usually rely on relatively abundant market risk data with a higher frequency.

Indeed, Giesecke et al. (2011) study US corporate default risk over the past 150 years and find that defaults are not evenly distributed over time. Instead, long periods of relatively few defaults are followed by episodes with significant clustering of default events. This has two implications for model-based regulation: First, estimates need to be based on a sufficiently long time series that also includes crisis times to yield valid (through-the-cycle) average risk parameters.[8] Second, even if risk estimates are based on long time series, average risk parameters may still severely underestimate peak default rates under adverse conditions, given correlations in default events.[9]

The issue described above is not confined to the corporate sector but may also affect the validity of risk estimates in other exposure classes. For example, in Europe some countries have observed long periods of booming real estate markets without any signs of crisis. Authorities in some of these countries have taken action to limit the resulting risk weight deflation (i.e., reduction in capital requirements) for mortgage loans under the IRB approach (see, e.g., Committee on the Global Financial System 2023a,b). But only history will show whether these interventions were sufficient, should an episode with clustered default events occur at some point in the future. More generally, what this discussion illustrates is that sectors characterized by more cyclical default patterns can be temporarily subsidized under model-based regulation, compared to sectors with more constant default rates.

The basic underlying conceptual problem remains the same in all of these cases: While the Basel standard is in principle calibrated such that "an institution is expected to suffer losses that exceed its level of . . . capital on average once in a thousand years" (Basel Committee of Banking Supervision 2005, p. 11), this principle is valid only if the data used to calibrate the risk models also incorporate tail events, as they can be expected to occur once every thousand years, and if default correlations are properly accounted for. As highlighted by Colliard (2019), the probability of tail events tends to be underestimated when only a short sample period is available. Moreover, technical challenges may interact with the issues in relation to reporting discretions that are described in Section 4.1. For example, anecdotal evidence suggests that some banks have down-weighted periods of high defaults in their models, relative to low-default periods, to reduce their capital requirements.

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[8]To address this, the Basel regulatory framework requires risk models to incorporate at least 5 years of historical data. While regulators encourage the use of longer time series, the minimum regulatory requirement remains confined to just 5 years.

[9]The Basel standard aims to account for this via a correlation parameter in the risk weight formula (see Basel Committee of Banking Supervision 2005). For corporate firms, this factor essentially depends on a firm's idiosyncratic PD (correlation assumed to be lower with a higher level of PD) and on its size (correlation assumed to be higher for larger firms). Whether this suffices to properly account for the issue of clustering in default events spelled out above is at least doubtful.

While market risk is in principle better suited to be captured by risk models, given an abundance of data with a high frequency, technical challenges have also been documented for the value-at-risk models that are dominant in this risk category. Such challenges include, for example, an inability to adequately capture extreme downward risk or systemic risk events, problems with aggregating risks and accounting for correlations, or specification and model risk more generally (see, e.g., Artzner et al. 1999; Daníelsson 2008; Coval, Jurek & Stafford 2009).

With respect to operational risk, it has by now been recognized that this type of risk is not well suited for modeling, since it relates, for example, to losses arising from fines for misconduct or poor systems and controls, which are inherently difficult to predict. Consequently, the Basel III standard has largely abolished the use of models for this risk category (Basel Committee on Banking Supervision 2017a,b).

4.4. Procyclicality

Another issue that was prominently discussed during the design phases of the Basel standard relates to potential procyclicality of the model-based approach (e.g., Borio, Furfine & Lowe 2001; Daníelsson et al. 2001; Goodhart, Hofmann & Segoviano 2004; Kashyap & Stein 2004; Gordy & Howells 2006; Rochet 2008; Repullo, Saurina & Trucharte 2010). While a certain degree of cyclicality is inherent in banking activity, the concern was that linking capital requirements to asset risk could strengthen this tendency and thus amplify business cycle fluctuations. Specifically, risk-weighted assets may rise during economic downturns if asset risk measures are sensitive to economic conditions. This can depress risk-based capital ratios at a time when demonstrating strength may be considered most important by banks and investors. Consequently, capital-constrained banks that are unable or unwilling to raise new equity in such times might be forced to reduce lending, which would exacerbate the downturn.

Repullo & Suarez (2013) examine the properties of different types of capital regulation with a dynamic stochastic general equilibrium model. Their findings suggest that risk-based regulation à la Basel II/III generally makes banks safer but also implies more cyclical variation in capital requirements, which can produce credit rationing among capital-constrained banks when recessions arrive. Behn, Haselmann & Wachtel (2016) examine this issue empirically, exploiting the staggered introduction of Basel II in Germany in their regression setup. They demonstrate that capital requirements for loans under model-based regulation increased substantially following the exogenous increase in credit risk that hit the German economy after the collapse of Lehman Brothers in September 2008. In response, banks (in particular, capital-constrained banks) reduced loans under the IRB approach by 2.1 to 3.9 percentage points more than loans under the more traditional standard approach with fixed capital charges, which also had real consequences in terms of aggregate firm borrowing.

With the Basel III standard, the Basel Committee has recognized procyclical features of the regulatory framework and introduced corrective measures, for example, the countercyclical capital buffer that can be released (and hence reduce capital requirements) when risks materialize. These modifications reflect a shift toward a more macroprudential approach to prudential regulation that increasingly gained ground after the GFC (e.g., Hanson, Kashyap & Stein 2011). Time-varying capital requirements, as initially proposed by Kashyap & Stein (2004), are a key element of this new approach, as they allow banks to draw down their capital buffers when an adverse shock hits, enabling them to operate with less pressure to shrink their assets and thus avoiding potentially harmful effects for the real economy.

Empirical evidence on the benefits of time-varying macroprudential policy is inter alia provided by Jiménez et al. (2017), who show that dynamic provisioning policies in Spain in the early 2000s helped to smooth credit supply over the cycle and supported firm performance in bad times.

More recent evidence from the pandemic confirms that capital requirement releases in response to adverse shocks can be effective in supporting banks to maintain lending to the real economy (e.g., Couaillier et al. 2022; Bedayo & Galán 2024). Nevertheless, the Basel III standard also continues to rely on model-based risk estimates for determining capital requirements that may exert procyclical effects (Fiordelisi et al. 2022), partly offsetting the capital relief provided by buffer releases in stressed conditions.

The pandemic also illustrated that concerns about procyclicality arising from model-based risk estimates are not confined to capital regulation, as there was substantial discussion about potential procyclicality of banks' International Financial Reporting Standard 9 (IFRS 9) accounting models.[10] As a consequence, the European Central Bank recommended that banks make use of the flexibility embedded in IFRS 9 to avoid excessive procyclical effects that could result from mechanical application of the models (European Central Bank 2020).

4.5. Effects on the Composition and Volume of Lending

Besides affecting lending adjustments in response to shocks, model-based regulation may also have an impact on the composition and the overall volume of lending. For example, Behn, Haselmann & Vig (2022) document that IRB models are better than previous risk models at differentiating defaulting from non-defaulting borrowers, consistent with the objective of promoting stronger risk management practices among banks. They document that this improved risk differentiation coincides with a shift in lending from borrowers with higher reported risk estimates toward borrowers with lower estimates under IRB, which appears desirable under the presumption that the previous regime with a flat capital requirement induced excessively risky lending. At the same time, the underreporting of actual default risk was greatest for these apparently safe borrowers with low risk estimates, undermining the intended shift toward safer lending. Similarly, Haselmann, Singla & Vig (2022) document that IRB banks shift lending away from firms with higher risk estimates, with such borrowers increasingly turning to smaller banks under the more traditional SA. Besides the issues already discussed above, this also poses questions on the possible concentration of risks on specific types of banks.[11]

With respect to the overall volume of lending, Behn, Haselmann & Vig (2022) illustrate that large German banks that adopted the IRB approach substantially benefitted from the associated reduction in capital requirements and expanded their loan volumes relative to smaller banks that remained under the SA. While higher lending can be beneficial for economic activity, it may also endanger financial stability when it becomes excessive, and, as noted above, the Basel III standard includes explicit tools such as the countercyclical capital buffer to account for this. In any case, it appears that large banks benefitted from the reform at the expense of smaller banks and subsequently became even more dominant in the market for corporate loans. This observation seems counterproductive when assessed in the light of "too-big-to-fail" issues, which are another prominent theme in regulatory work over the past decade (see, e.g., Financial Stability Board 2021).

4.6. Complexity

In a world with no informational and enforcement problems, a complex regulation such as model-based regulation should unambiguously improve welfare. The conclusion, however,

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[10]For an early review of the literature, see Basel Committee on Banking Supervision 2021; on the use of risk models for other purposes, see further discussion in Section 6.

[11]Rather than within the banking sector, risks might also migrate outside the banking sector. In this respect, Benetton, Buchak & Robles-Garcia (2022) demonstrate how substitution of banking activities by nonbank financial intermediaries (i.e., shadow banks) can complicate regulatory oversight and supervision.

becomes murkier in a world with informational and incentive constraints. As argued by Glaeser & Shleifer (2001), coarser regulation can be the optimal regulatory choice and may actually dominate more sophisticated and complex forms of regulation in the presence of enforcement constraints. Model-based regulation has been widely recognized as a key factor contributing to regulatory complexity, even in the regulatory sphere itself (see, e.g., box B in European Systemic Risk Board 2019).

A famous example that is often used to demonstrate the increase in regulatory complexity is based on the number of pages in the Basel standard. As pointed out, e.g., by Haldane & Madouros (2012), the Basel I Accord comprised only 30 pages, reflecting its relative simplicity. The number of pages increased more than tenfold with Basel II, to 347 pages, and with the adoption of the Basel III agreement in 2010 the framework further ballooned to 616 pages. As noted by Haldane & Madouros (2012) and Admati & Hellwig (2024a), the primary driver behind this growing complexity is the detailed, model-based risk-weighting scheme embedded within the Basel framework.[12]

Proponents usually argue that the ever-increasing complexity of the regulatory framework is simply a reflection of the ever-increasing complexity of the financial system itself. In other words, it is a symptom of a rat race between regulators and the financial industry, rather than a source of concern in itself. While there is certainly some merit in this argument, it is still likely that a high degree of regulatory complexity comes at a cost, for several reasons.

First, the intricacy of the model-based approach likely contributes to greater opacity. This, in turn, may facilitate the type of underreporting documented in Section 4.1 and thus contribute to a reduction in capital requirements. A symptom of this is so-called risk weight optimization, by which banks and consulting firms have developed various techniques and modeling choices that help to minimize the resulting capital requirements (Admati & Hellwig 2024a). Indeed, Behn, Haselmann & Vig (2022) find that underreporting of risk estimates is more pronounced under the more complex advanced IRB approach, compared with the somewhat simpler foundation IRB approach, where banks rely on regulatory parameters for some of the estimates. Moreover, opacity makes regulation more difficult to understand for external stakeholders and outsiders, which may increase the risk of regulatory capture (Rochet 2010). Finally, Hakenes & Schnabel (2012) present a microeconomic model that illustrates how banks may leverage such opacity to present more sophisticated arguments in favor of reducing capital requirements, which may be more difficult for regulators to counter.

Second, the high degree of complexity is likely associated with increased compliance costs for banks. Haldane & Madouros (2012, p. 10) note that "the costs of constructing and maintaining this regulatory skyscraper are not trivial." A study by McKinsey (Härle et al. 2010) estimates that, for a midsize European bank, Basel III compliance could require up to 200 full-time employees. With around 350 European banks holding over €1 billion in assets, this translates to over 70,000 new full-time positions solely for Basel III compliance.

Third, these rising compliance costs may inhibit market entry and reduce competition. From a bank's perspective, compliance costs are often fixed costs, which larger banks can spread over a broader asset base, giving them an advantage over smaller banks. Singla (2023) examines how regulatory complexity drives increased market concentration in the US corporate sector, finding that more regulation and greater complexity are associated with lower market-entry elasticity.

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[12]The length of the Basel rulebook, if anything, understates its complexity. The move to internal models, and from broad asset classes to individual loan exposures, has resulted in a ballooning in the number of estimated risk parameters. For a large, complex bank, this has meant a rise in the number of calculations required from single figures a generation ago to several million today (Haldane & Madouros 2012).

Most likely, the inherent complexity of model-based regulation results in similar effects for the financial sector, and, indeed, Behn, Haselmann & Vig (2022) document that larger banks benefitted from the introduction of model-based regulation and considerably expanded market shares at the expense of smaller banks that stuck with the more traditional form of regulation (see Section 4.5).

Paradoxically, regulatory and supervisory authorities may also benefit from complex rules, in the sense that they are likely to obtain additional funding and resources. For example, the number of financial supervisors has increased significantly since the introduction of model-based regulation. Haldane & Madouros (2012) report that in the 1980s, there was one UK regulator for roughly every 11,000 employees in the financial sector. By 2011, this ratio had dropped to one regulator per 300 financial employees. In the United States, the combined regulatory workforce of the Federal Deposit Insurance Corporation, Office of the Comptroller of the Currency, Federal Reserve (the Fed), and Securities and Exchange Commission now totals around 18,500—roughly three regulators per bank.

Nevertheless, complexity of regulation has increasingly become of concern also in the regulatory and supervisory community in recent years, often in relation to multiple regulatory requirements that apply to banks in parallel (e.g., European Systemic Risk Board 2021; Basel Committee on Banking Supervision 2022). Public debates are increasingly shifting toward potential efforts to simplify the framework. Perhaps not surprisingly, the banking lobby is trying to capture these debates to push for deregulation rather than mere simplification, very much in the spirit of the model on regulatory capture that is presented by Hakenes & Schnabel (2012). For example, lobby organizations tend to equate simplification with "removing significant gold-plating … over international standards" or "securing a level playing field with other jurisdictions" (European Banking Federation 2024), whereas specific sources of complexity in regulation such as the model-based approach are usually defended by practitioners and industry representatives, as they allow them to reduce capital requirements relative to less complex approaches (Epperlein & Ruiz 2025). Against this background, while there is certainly merit in streamlining and simplifying regulations where this is possible without compromising on banking sector resilience, one needs to be careful that such efforts do not result in deregulation.

5. LESSONS LEARNED AND THE WAY FORWARD

Overall, the literature reviewed in this article provides mixed theoretical arguments on the merits of model-based capital regulation, while substantial practical challenges appear to prevent the regulation from achieving first-best outcomes. This reminds one of an argumentation put forward by Glaeser & Shleifer (2001), whereby sophisticated forms of regulation may help to improve welfare in a world without information and enforcement problems, while the conclusion becomes much murkier in the presence of the latter.

While it appears that capital requirements under model-based regulation are lower than they would be in its absence, other elements of the regulatory framework have been strengthened considerably in recent years, particularly with the Basel III reforms developed after the GFC. In addition, with its Basel III finalization package published in December 2017, the Basel Committee has already taken substantial steps in constraining the reliance on models in regulation, and—via the so-called output floor—limiting the degree to which banks can use modeling to reduce capital requirements relative to the simpler standard approaches (see Basel Committee on Banking Supervision 2017a,b). However, 8 years after its publication, the framework still needs to be implemented in major jurisdictions around the world, and recent initiatives at the national

level suggest that the banking lobby may at least partially succeed with its pushes to water down key elements of the reform package.[13]

It should also be noted that, while the revised Basel III framework constrains banks' discretion in applying internal risk models, it does not simplify capital regulation. Rather, the introduction of the output floor and other regulatory constraints further adds to the complexity of regulation, thus potentially compounding the issues discussed earlier. The banking lobby generally pushes back against such complexity in cases where it leads to higher requirements—as in the case of the output floor—while the opposite is true in cases where complexity helps to minimize the resulting capital requirements (Admati & Hellwig 2024a; see also Section 4.6). Against this background, regulators should strive to assess how the existing framework can be simplified without compromising on the overall level of capital, which would likely involve less reliance on the underlying sources of complexity, such as the model-based approach itself (which necessitated the output floor in the first place).

Political economy considerations and implementation challenges as described above may help to explain why regulators have not shifted further toward simpler and further strengthened rules for determining capital requirements, e.g., as advocated by Admati & Hellwig (2024a), and instead continue to rely on model-based regulation also under Basel III. Haselmann et al. (2022) examine the process of adoption of the Basel II and Basel III standards. They reveal that while stronger regulation through a simple leverage ratio has been discussed, this proposal was notably weakened during Basel Committee working group negotiations. Their findings indicate that national regulators are more likely to oppose regulatory proposals if these would disproportionately impact the largest banks headquartered in their country. Although regulators generally support new regulations—even those that may disadvantage their domestic banks—they tend to resist measures that could place their home banks at a competitive disadvantage internationally.

These findings highlight a key tension for regulators: While they generally aim to design a strict regulatory framework to ensure financial stability, they also seek to avoid harming their domestic banks.[14] In this context, international standard-setting bodies, such as the Basel Committee, can act as coordination mechanisms that help regulators navigate this tension. By delegating rule-setting to an international body, regulators may adopt stricter regulations than they might implement independently within their own jurisdictions. Nevertheless, as the discussion above

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[13]In the United States, the Fed has made considerable adjustments to its so-called Basel endgame proposal, substantially reducing the capital impact relative to the initial proposal issued for public consultation (see, e.g., Barr 2024). The revisions followed up on a substantial lobbying campaign from the banking industry, claiming that implementation of the initial proposal would have substantial costs for the economy and the American people (see, e.g., **https://stopbaselendgame.com/**). Further adjustments are expected now that the new US administration took office. Similarly, in the United Kingdom, the Prudential Regulation Authority published a revised and nearly final policy statement on the implementation of outstanding Basel III reforms, reducing the capital impact compared with the initial proposal such that overall capital requirements will remain unchanged with the reform. Moreover, the Prudential Regulation Authority decided to postpone implementation of the package by a year to January 2027, to allow for "more time for greater clarity to emerge about plans for its implementation in the United States" (Bank of England 2025). In Europe, the finance ministries of France, Germany, and Italy recently sent a letter to the European Commission, asking it to put strong emphasis on the "competitiveness of the financial sector, particular banking," and to consider adjustments to planned regulations in order to reduce the burden for banks, also in view of developments in other jurisdictions (see Politico 2024).

[14]Recently, this has also been reflected in the mandates of prudential authorities. For example, in the United Kingdom, the Prudential Regulation Authority—besides its primary objective of promoting the safety and soundness of regulated firms—has a new secondary objective since 2023, requiring it, so far as reasonably possible within its primary objective, to also facilitate the international competitiveness of the UK economy (including, in particular, the financial services sector) and its growth over the medium- to long-term.

illustrates, implementation challenges remain, as the Basel Committee cannot impose the rules directly but rather must rely on their domestic adoption.

However, these findings also underscore the challenges of advancing simpler regulatory standards, such as moving away from model-based approaches. When new proposals disproportionately affect large banks in certain countries, regulators representing those banks are likely to resist such changes. This dynamic illustrates the influence of political economy forces on international standard-setting and highlights the complexity of interactions between these forces and the institutional design of the regulatory process. Further research is needed to better understand these dynamics and their implications.

Besides regulation itself, the supervisory setup also matters. Recent research highlights that the reporting discretion exercised by banks under model-based regulation is closely linked to the design of supervisory institutions. The introduction of a supranational supervisor in the eurozone, which increased the distance between supervisors and the supervised entities, has been associated with more conservative reporting of risk parameters. Additionally, this shift eliminated biases in the treatment of different banks—a pattern previously observed under model-based regulation enforced by local supervisors (Haselmann, Singla & Vig 2022). Further research is needed to explore the interplay between model-based regulation and various designs of supervisory frameworks. Existing evidence indicates that increasing the distance between regulators and the entities they oversee—such as through the rotation of supervisory teams—can reduce banks' discretionary practices. For instance, research on loan officer rotation (see Fisman, Paravisini & Vig 2017) provides valuable insights into how such measures can mitigate potential biases and enhance supervisory effectiveness.

Given the challenges associated with capital regulation based on internal risk models, several alternative regulatory approaches have been proposed, including model-free frameworks and those centered on market equity metrics.[15] Since bank defaults are often preceded by a collapse in market equity while book capital remains stable, the market value of equity relative to assets has been considered as a supplementary measure to traditional capital requirements, at least to provide sufficient early warning signals in cases of distress. Admati & Hellwig (2024a) examine the potential role of market-based indicators in assessing bank solvency and financial stability. Likewise, Sarin & Summers (2016) argue that market equity ratios provide more timely and accurate indications of bank health than conventional regulatory capital measures. However, regulation based on market values also has downsides, as the market measures of equity tend to be much more volatile than book measures, which may induce additional stress and undesirable adjustment actions by banks under adverse conditions.

On the supervisory side, stress tests are increasingly being used to calibrate at least parts of the risk-based capital requirements. For example, in the United States, the Fed's supervisory stress test is used to calibrate the stress capital buffer, whereas in the European Union, the European Banking Authority stress test serves as a guidance for setting the microprudential Pillar 2 Guidance. While these exercises allow supervisors to point out and address specific risks in banks' balance sheets,

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[15]One such proposal by Meiselman, Nagel & Purnanandam (2023) suggests using banks' reported profitability as an indicator of systemic risk exposure. The rationale behind this approach is that risky debt claims, which offer high yields in good times, tend to have high systematic risk exposure during downturns. Other strategies involve leveraging on outside investors' assessments of a bank's risk to determine its cost of capital. A notable example is the mandatory issuance of convertible bonds. Bolton, Kartasheva & Jiang (2023) demonstrate that the presence of such bonds can be effective in providing bail-in debt when needed, as seen in the case of Credit Suisse's distress. Others argue that convertible bonds are inferior to common equity and that it would be preferable to directly require higher levels of the latter (e.g., Admati & Hellwig 2024a).

they may be at risk of missing out on risks that are hard to capture ex ante.[16] In addition, they often also rely on inputs provided by banks themselves and may thus be subject to similar incentive problems and shortcomings as those discussed in this article. In any case, the corresponding buffers and requirements are set in terms of risk-weighted assets, calculated with help of internal risk models for banks using the IRB approach.

In sum, the evidence presented here suggests that—although well-intended—the model-based approach to capital regulation appears to suffer from severe practical challenges that undermine its effectiveness, also due to its inherent complexity. It is likely that an enhanced focus on simpler rules—either via a simple leverage ratio requirement or possibly with some less granular form of risk differentiation that does not rely on banks' internal models—would bring benefits in terms of financial stability. Such frameworks could still comprise possibilities to adjust requirements in a time-varying manner, as in the current risk-based framework, to avoid requirements becoming overly binding under stressed conditions. A simplified framework would also enhance transparency, as the complexity and discretion inherent in model-based regulation make it difficult for external stakeholders to accurately assess a bank's capital adequacy. Importantly, simplification of regulation should not be equated with an easing of requirements, as it is sometimes implied by the banking industry. As noted by Admati & Hellwig (2024b), current leverage ratio requirements still appear to be too low, and claims that substantially increasing them would bear enormous costs for the economy and society are often based on false claims and misleading arguments.

6. CONCLUSION

This review article summarizes the experience with model-based capital regulation over the past 30 years. The reviewed literature suggests that—from a conceptual perspective—there could be both up- and downsides associated with model-based regulation. From a practical perspective, studies have found that severe implementation challenges—relating to reporting discretion and incentives to underreport risks, risk endogeneity, technical modeling issues, procyclicality of the estimates, and complexity—undermine the effectiveness of the approach in achieving its objectives of promoting bank and financial stability. Overall, the evidence suggests that a simplified regulatory framework—putting more emphasis on simpler leverage requirements or other non-model-based measures—may enhance stability.

Notably, the use of internal risk models may have implications going beyond capital regulation. For instance, model-based risk estimates for corporate loans are now applied to assess loan quality when loans are used as collateral in the Eurosystem's monetary policy operations. In this respect, Calza et al. (2021) document that banks' IRB systems tend to underestimate credit risk for loans used as collateral, especially for large loans, compared to central banks' in-house credit assessment systems. This underestimation appears to be linked to banks' liquidity constraints rather than their capitalization, indicating a collateral-related channel that may affect risk assessments in IRB systems.

Another big area of risk modeling relates to accounting, where expected credit loss approaches such as IFRS 9 have enhanced the role of internal risk models in determining banks' loan loss provisioning. Concerns about possible side effects or downsides of such approaches are similar to those on model-based capital regulation, for example, relating to the role of discretion in risk

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[16]An increasing number of macroprudential authorities are addressing this issue via a more proactive and earlier buildup of specific buffer requirements, inter alia to capture for the possibility of large and disruptive systemic shocks that are inherently difficult to predict ex ante, e.g., as illustrated by the shocks induced by the pandemic or the outbreak of war in Ukraine. For further discussion see, e.g., European Central Bank, European Systemic Risk Board (2025).

modeling or possible procyclicality of the approach (see, e.g., European Systemic Risk Board 2019; Basel Committee on Banking Supervision 2021). While some studies have started to examine the issue empirically (e.g., López-Espinosa, Ormazabal & Sakasai 2021; Bischof et al. 2022; Behn & Couaillier 2023), the impact of model-based approaches in accounting (and beyond) on bank lending and overall financial stability certainly remains an area for further research.

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LITERATURE CITED

Abbassi P, Schmidt M. 2018. A comprehensive view on risk reporting: evidence from supervisory data. *J. Financ. Intermed.* 36:74–85

Acosta-Smith J, Grill M, Lang JH. 2024. The leverage ratio, risk-taking and bank stability. *J. Financ. Stab.* 74:100833

Admati A, DeMarzo P, Hellwig M, Pfleiderer P. 2010. Fallacies, irrelevant facts, and myths in the discussion of capital regulation: Why bank equity is not expensive. Work. Pap. 2065, Stanford Graduate School of Business, Stanford University

Admati A, Hellwig M. 2024a. *The Bankers' New Clothes: What's Wrong with Banking and What To Do About It.* Princeton University Press

Admati A, Hellwig M. 2024b. The parade of the bankers' new clothes continues: 44 flawed claims debunked. Work. Pap., Stanford University

Agarwal S, Lucca D, Seru A, Trebbi F. 2014. Inconsistent regulators: evidence from banking. *Q. J. Econ.* 129(2):889–938

Altavilla C, Boucinha M, Peydró JL, Smets F. 2020. Banking supervision, monetary policy and risk-taking: big data evidence from 15 credit registers. Work. Pap. 2349, European Central Bank

Artzner P, Delbaen F, Eber JM, Heath D. 1999. Coherent measures of risk. *Math. Finance* 9:203–28

Bank of England. 2025. *The PRA announces a delay to the implementation of Basel 3.1.* News Release, Jan. 17. **https://www.bankofengland.co.uk/news/2025/january/the-pra-announces-a-delay-to-the-implementation-of-basel-3-1**

Barr M. 2024. *The next steps on capital.* Speech given at the Brookings Institution, Washington, DC, Sept. 10. **https://www.federalreserve.gov/newsevents/speech/barr20240910a.htm**

Basel Committee on Banking Supervision. 1988. *International convergence of capital measurement and capital standards.* Standard, Bank for International Settlements

Basel Committee on Banking Supervision. 1996. *Amendment to the capital accord to incorporate market risks.* Standard, Bank for International Settlements

Basel Committee on Banking Supervision. 2005. *An explanatory note on the Basel II IRB risk weight functions.* Rep., Bank for International Settlements

Basel Committee on Banking Supervision. 2006. *Basel II: international convergence of capital measurement and capital standards: a revised framework—comprehensive version.* Standard, Bank for International Settlements

Basel Committee on Banking Supervision. 2010. *Basel III: a global regulatory framework for more resilient banks and banking systems.* Standard, Bank for International Settlements

Basel Committee on Banking Supervision. 2017a. *Basel III: finalising post-crisis reforms.* Standard, Bank for International Settlements

Basel Committee on Banking Supervision. 2017b. *Finalising Basel III—in brief*. Rep., Bank for International Settlements

Basel Committee on Banking Supervision. 2019. *Revisions to leverage ratio disclosure requirements*. Standard, Bank for International Settlements

Basel Committee on Banking Supervision. 2021. The procyclicality of loan loss provisions: a literature review. Work. Pap. 39, Bank for International Settlements

Basel Committee on Banking Supervision. 2022. *Evaluation of the impact and efficacy of the Basel III reforms*. Rep., Bank for International Settlements

Basel Committee on Banking Supervision. 2024. *Basel Committee consults on measures to address window-dressing in the G-SIB framework*. Press Release, Mar. 7, Bank for International Settlements

Bassi C, Behn M, Grill M, Waibel M. 2024. Window dressing of regulatory metrics: evidence from repo markets. *J. Financ. Intermed.* 58:101086

Bedayo M, Galán J. 2024. The impact of the countercyclical capital buffer on credit: evidence from its accumulation and release before and during COVID-19. Work. Pap. 2411, Banco de España

Begley TA, Purnanandam A, Zheng K. 2017. The strategic underreporting of bank risk. *Rev. Financ. Stud.* 30(10):3376–415

Behn M, Couaillier C. 2023. Same same but different: credit risk provisioning under IFRS 9. Work. Pap. 2841, European Central Bank

Behn M, Haselmann R, Vig V. 2022. The limits of model-based regulation. *J. Finance* 77(3):1635–84

Behn M, Haselmann R, Wachtel P. 2016. Procyclical capital regulation and lending. *J. Finance* 71(2):919–56

Behn M, Mangiante G, Parisi L, Wedow M. 2022. Behind the scenes of the beauty contest—window dressing, and the G-SIB framework. *Int. J. Cent. Bank.* 18(5):301–42

Benetton M, Buchak G, Robles-Garcia C. 2022. Wide or narrow? Competition and scope in financial intermediation. Discuss. Pap. 17497, Centre for Economic Policy Research

Berg T, Koziol P. 2017. An analysis of the consistency of banks' internal ratings. *J. Bank. Finance* 78:27–41

Bischof J, Haselmann R, Kohl F, Schlueter O. 2022. Limitations of implementing an expected credit loss model. LawFin Work. Pap. 48, Goethe University

Blum J. 2008. Why 'Basel II' may need a leverage ratio restriction. *J. Bank. Finance* 32:1699–1707

Böhnke V, Ongena S, Paraschiv F, Reite EJ. 2023. Back to the roots of internal credit risk models: Does risk explain why banks' risk-weighted asset levels converge over time? *J. Bank. Finance* 156:106992

Bolton P, Kartasheva AV, Jiang W. 2023. The Credit Suisse CoCo wipeout: facts, misperceptions, and lessons for financial regulation. Res. Pap. 23-32, Swiss Finance Institute

Borio C, Furfine C, Lowe P. 2001. *Procyclicality of the financial system and financial stability: issues and policy options*. Work. Pap. 01, Bank for International Settlements

Brealey R, Cooper IA, Kaplanis E. 2012. International propagation of the credit crisis: lessons for bank regulation. *J. Appl. Corp. Finance* 24:36–45

Calza A, Hey J, Parrini A, Sauer S. 2021. Corporate loans, banks' internal risk estimates and central bank collateral: evidence from the euro area. Work. Pap. 2579, European Central Bank

Colliard JE. 2019. Strategic selection of risk models and bank capital regulation. *Manag. Sci.* 65(6):2591–2606

Collin-Dufresne P, Johannes M, Lochstoer LA. 2016. Parameter learning in general equilibrium: the asset pricing implications. *Am. Econ. Rev.* 106(3):664–98

Committee on the Global Financial System. 2023a. Macroprudential policies to mitigate housing market risks. Country case study: Belgium. Work. Pap. 69, Annex C, Bank for International Settlements. **https://www.bis.org/publ/cgfs69_be.pdf**

Committee on the Global Financial System. 2023b. Macroprudential policies to mitigate housing market risks. Country case study: Luxembourg. Work. Pap. 69, Annex C, Bank for International Settlements. **https://www.bis.org/publ/cgfs69_lu.pdf**

Couaillier C, Reghezza A, Rodriguez d'Acri C, Scopelliti A. 2022. How to release capital requirements during a pandemic? Evidence from euro area banks. Work. Pap. 2022/2720, European Central Bank

Coval J, Jurek J, Stafford E. 2009. Economic catastrophe bonds. *Am. Econ. Rev.* 99:628–66

Daníelsson J. 2008. Blame the models. *J. Financ. Stab.* 4:321–28

Daníelsson J, Embrechts P, Goodhart C, Keating C, Muennich F, et al. 2001. An academic response to Basel II. Spec. Pap. 130, Financial Markets Group

Demirguc-Kunt A, Detragiache E, Merrouche O. 2013. Bank capital: lessons from the financial crisis. *J. Money Credit Bank.* 45:1147–64

Diamond D, Rajan R. 2000. A theory of bank capital. *J. Finance* 55(6):2431–65

Diamond D, Rajan R. 2001. Liquidity risk, liquidity creation, and financial fragility: a theory of banking. *J. Political Econ.* 109(2):287–327

Epperlein E, Ruiz I. 2025. Why the survival of internal models is vital for financial stability. *Risk.net*, Mar. 5. **https://www.risk.net/comment/7961154/why-the-survival-of-internal-models-is-vital-for-financial-stability**

European Banking Federation. 2024. European banks: financing a competitive and thriving Europe. *EBF Board Highlights*, Nov. 27. **https://www.ebf.eu/ebf-media-centre/updates/ebf-board-highlights-november-2024/**

European Central Bank. 2020. *ECB Banking Supervision provides further flexibility to banks in reaction to coronavirus.* Press Release, Mar. 20. **https://www.bankingsupervision.europa.eu/press/pr/date/2020/html/ssm.pr200320~4cdbbcf466.en.html**

European Central Bank, European Systemic Risk Board. 2025. *Using the countercyclical capital buffer to build resilience early in the cycle: joint ECB/ESRB report on the use of the positive neutral CCyB in the EEA.* Rep., European Central Bank and European Systemic Risk Board

European Systemic Risk Board. 2019. *Regulatory complexity and the quest for robust regulation.* Rep. 8, Advisory Scientific Committee, European Systemic Risk Board

European Systemic Risk Board. 2021. *Report of the Analytical Task Force on the overlap between capital buffers and minimum requirements.* Rep., Dec.

Financial Stability Board. 2021. *Evaluation of the effects of too-big-to-fail reforms: final report.* Rep., Apr. 1

Fiordelisi F, Fusi G, Maddaloni A, Marques-Ibanez D. 2022. Pandemic lending: micro and macro effects of model-based regulation. Work. Pap. 374, Sustainable Architecture for Finance in Europe

Fisman R, Paravisini D, Vig V. 2017. Cultural proximity and loan outcomes. *Am. Econ. Rev.* 107(2):457–92

Garcia L, Lewrick U, Sečnik T. 2023. Window dressing and the designation of global systemically important banks. *J. Financ. Serv. Res.* 64:231–64

Giesecke K, Longstaff F, Schaefer S, Strebulaev I. 2011. Corporate bond default risk: a 150-year perspective. *J. Financ. Econ.* 102:233–50

Glaeser E, Shleifer A. 2001. A reason for quantity regulation. *Am. Econ. Rev.* 91:431–35

Goodhart C, Hofmann B, Segoviano M. 2004. Bank regulation and macroeconomic fluctuations. *Oxf. Rev. Econ. Policy* 20:591–615

Gordy M. 2003. A risk-factor model foundation for ratings-based bank capital rules. *J. Financ. Intermed.* 12:199–232

Gordy M, Howells B. 2006. Procyclicality in Basel II: Can we treat the disease without killing the patient? *J. Financ. Intermed.* 15:395–417

Hakenes H, Schnabel I. 2012. Regulatory capture by sophistication. SSRN Work. Pap. 2531688

Haldane A. 2013. *Constraining discretion in bank regulation.* Speech given at the Federal Reserve Bank of Atlanta Conference on "Maintaining Financial Stability: Holding a Tiger by the Tail(s)," Atlanta, Apr. 9

Haldane A, Madouros V. 2012. The dog and the frisbee. In *Proceedings of the 36th Economic Policy Symposium on "The Changing Policy Landscape."* Federal Reserve Bank of Kansas City. **https://www.kansascityfed.org/JacksonHole/documents/6926/DogFrisbee_Haldane_JH2012.pdf**

Hanson S, Kashyap A, Stein J. 2011. A macroprudential approach to financial regulation. *J. Econ. Perspect.* 25(1):3–28

Härle P, Lüders E, Pepanides T, Pfetsch S, Poppensieker T, Stegemann U. 2010. Basel III and European banking: its impact, how banks might respond, and the challenges of implementation. Work. Pap. Risk 26, McKinsey & Company

Haselmann R, Sarkar A, Singla S, Vig V. 2022. The political economy of financial regulation. LawFin Work. Pap. 45, Goethe University

Haselmann R, Singla S, Vig V. 2022. Supranational supervision. LawFin Work. Pap. 50, Goethe University

Hellmann T, Murdock K, Stiglitz J. 2000. Liberalization, moral hazard in banking, and prudential regulation: Are capital requirements enough? *Am. Econ. Rev.* 90:147–65

Hellwig M. 2010. Capital regulation after the crisis: Business as usual? Preprint, Max Plank Institute for Research on Collective Goods 2010/31. **https://homepage.coll.mpg.de/pdf_dat/2010_31online.pdf**

Jiménez G, Ongena S, Peydró J-L, Saurina J. 2017. Macroprudential policy, countercyclical bank capital buffers, and credit supply: evidence from the Spanish dynamic provisioning experiments. *J. Political Econ.* 125(6):2126–77

Jones D. 2000. Emerging problems with the Basel Capital Accord: regulatory capital arbitrage and related issues. *J. Bank. Finance* 24:35–58

Kahane Y. 1977. Capital adequacy and the regulation of financial intermediaries. *J. Bank. Finance* 1:207–18

Kashyap A, Rajan R, Stein J. 2008. Rethinking capital regulation. In *Proceedings of the 2008 Economic Symposium on "Maintaining Stability in a Changing Financial System."* Federal Reserve Bank of Kansas City. **https://www.kansascityfed.org/Jackson0Hole/documents/3175/2008-KashyapRajanStein031209.pdf**

Kashyap A, Stein J. 2004. Cyclical implications of the Basel II capital standards. *Econ. Perspect.* 28(1):18–33

Keeley M, Furlong F. 1990. A reexamination of mean-variance analysis of bank capital regulation. *J. Bank. Finance* 14:69–84

Keys B, Mukherjee T, Seru A, Vig V. 2010. Did securitization lead to lax screening? Evidence from subprime loans. *Q. J. Econ.* 125:307–62

Kiema I, Jokivuolle E. 2014. Does a leverage ratio requirement increase bank stability? *J. Bank. Finance* 39:240–54

Kim D, Santomero A. 1988. Risk in banking and capital regulation. *J. Finance* 43(5):1219–33

King M. 2010. *Banking: From Bagehot to Basel, and Back Again*. Speech given at the Second Bagehot Lecture, Buttonwood Gathering, New York City, Oct. 25

Koehn M, Santomero A. 1980. Regulation of bank capital and portfolio risk. *J. Finance* 35(5):1235–44

López-Espinosa G, Ormazabal G, Sakasai Y. 2021. Switching from incurred to expected loan loss provisioning: early evidence. *J. Account. Res.* 59:757–804

Lucas A. 2001. Evaluating the Basle guidelines for backtesting banks' internal risk management models. *J. Money Credit Bank.* 33:826–46

Mariathasan M, Merrouche O. 2014. The manipulation of Basel risk-weights. *J. Financ. Intermed.* 23:300–21

Meiselman B, Nagel S, Purnanandam A. 2023. Judging banks' risk by the profits they report. NBER Work. Pap. w31635

Merton R. 1977. An analytical derivation of the cost of deposit insurance and loan guarantees: an application of modern option pricing theory. *J. Bank. Finance* 1:3–11

Miles D, Yang J, Marcheggiano G. 2013. Optimal bank capital. *Econ. J.* 123:1–37

Peltzman S. 1970. Capital investment in commercial banking and its relationship to portfolio regulation. *J. Political Econ.* 78:1–26

Plosser M, Santos J. 2018. Banks' incentives and inconsistent risk models. *Rev. Financ. Stud.* 31:2080–112

Politico. 2024. Letter to the European Commission. *Politico.eu*, Sept. 24. **https://www.politico.eu/wp-content/uploads/2024/10/03/Letter-to-DG-Berrigan_241002_152826.clean_.pdf**

Rajan U, Seru A, Vig V. 2015. The failure of models that predict failure: distance, incentives, and defaults. *J. Financ. Econ.* 115:237–60

Repullo R, Saurina J, Trucharte C. 2010. Mitigating the pro-cyclicality of Basel II. *Econ. Policy* 25(64):659–702

Repullo R, Suarez J. 2013. The procyclical effects of bank capital regulation. *Rev. Financ. Stud* 26:452–90

Rochet J. 2008. Procyclicality of financial systems: Is there a need to modify current accounting and regulatory rules? *Financ. Stab. Rev.* 12:95–99

Rochet J. 2010. The future of bank regulation. In *Balancing the Banks: Global Lessons from the Financial Crisis*, ed. M Dewatripont, JC Rochet, J Tirole. Princeton Univ. Press

Santos J. 2000. Bank capital regulation in contemporary banking theory: a review of the literature. Work. Pap. 90, Bank for International Settlements

Sarin N, Summers L. 2016. Understanding bank risk through market measures. *Brookings Pap. Econ. Act.* Fall:57–109

Singla S. 2023. Regulatory costs and market power. LawFin Work. Pap. 47, Goethe University

Thakor AV. 2014. Bank capital and financial stability: an economic trade-off or a Faustian bargain? *Annu. Rev. Financ. Econ.* 6:185–223