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Optimal bank capital requirements: What do the macroeconomic models say?

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Abstract

The optimal level of banks' capital requirements has been a key research topic since at least the introduction of the Basel rules in the late 1980s. In this paper, we review the literature, focusing on recent findings from quantitative structural macroeconomic models. While dynamic stochastic general equilibrium models capture second-round (general equilibrium) effects such as the feedback effects from macroeconomic outcomes back to financial intermediation and the dynamic evolution of the economy following regulatory changes, they suffer from tractability issues, including treatment of nonlinear effects, that typically force modeling simplifications. Additionally, studies tend to be concerned with determining the optimal level of fixed capital requirements. Only a handful offer estimates of the optimal size of the dynamic buffers. Since optimal dynamic macroprudential policies depend heavily on the nature of the underlying shocks, questions arise regarding the robustness and potential side effects of such policies. Despite progress, the optimal level of bank capital requirements – in either fixed or dynamic form – remains largely an open research question.

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1. Introduction

Research on banks' optimal level of equity capital and regulatory capital requirements proliferated with the introduction of the Basel rules in the late 1980s. They gained additional momentum in the wake of the Global Financial Crisis. Recent research has increasingly encompassed questions concerning macroprudential policies in broader contexts. Even with progress, the question of what constitutes the optimal level for bank capital requirements – either in static or time-varying (henceforth dynamic) form – has not been fully resolved. In the following discussion, we review this literature, building on earlier comprehensive reviews and recent findings from structural macroeconomic models.

We start by grouping studies on bank capital requirements into three categories.

The first group includes studies that provide a micro-founded rationale for the role of bank capital requirements. These identify and model the tradeoffs between various effects of capital requirements (such as the effect on bank lending versus the likelihood of a banking crisis) which are then used to determine, within the model, the optimal level of capital requirements. It is important in these models to specify the market failure (externality) that calls for regulation in the form of capital requirements to improve upon the unregulated market outcome. The market failure can often lead to excessive risk-taking and inefficient investments in the economy (defined as those having negative net present values) that are detrimental to welfare. These models are typically static theoretical models that analyze fixed capital requirements. They tend to focus on one mechanism at a time and abstract from general equilibrium effects. They also lack dynamics, which precludes the study of transition periods or trade-offs in the short and long run. Both features are rather restrictive as regards quantifying the optimal level of capital requirements.

This line of research is important to help understanding the purpose and effects of capital requirements and to guide the building of more realistic quantitative models and empirical studies. Due to their limited use as such in policy work, we do not devote much discussion to this part of the literature.[1]

The second group consists of empirical studies that typically use statistical tools. They seek to estimate the effects of capital requirements (impact studies) and determine the desirable or optimal level of bank capital. Their value lies in the fact that they quantify many of the key

[1] Martinez-Miera and Suarez (2014) review papers on the fundamental mechanisms underlying the need for capital requirements that apply to this first group. Key examples of such mechanisms are the incentives for highly leveraged institutions to engage in risk-shifting (and hence potentially excessive risk-taking in a welfare sense) and how implicit or explicit public guarantees such as deposit insurance can exacerbate these incentives. Jensen and Meckling (1976) provide the initial work on such risk-shifting, while Kareken and Wallace (1978) consider the effects of various regulatory schemes. A mechanism related to fire sales of assets and the resulting pecuniary externality is highlighted by e.g. Lorenzoni (2008) and Stein (2012). While this mechanism has rarely been used as a building block in structural and quantifiable macroeconomic models to study optimal capital requirements, it potentially could be quite valuable.

tradeoffs in determining optimal capital requirements and which way these tradeoffs tilt (e.g. whether costs of higher capital requirements would outweigh the benefits or vice versa).[2] Birn et al. (2020) and the related Basel Committee project on assessing the long-term economic impact of capital requirements (LEI) provide an extensive overview of this literature.

Papers in the third category develop full-fledged quantitative structural macroeconomic models. Papers in this group try to capture both first-round (partial equilibrium) and second-round (general equilibrium) effects of macroprudential policies, i.e. how the real economy affects the financial condition and stability of the banking sector and how all channels interact in general equilibrium. As the meta-analysis of Boissay et al. (2019) suggests, these effects can be substantial.

Typically referred to as Dynamic Stochastic General Equilibrium (DSGE) models, they include households and firms as their basic building blocks. They require a sufficiently comprehensive description of the financial sector to capture some of the key tradeoffs while determining the optimal level of bank capital. This model setup makes it possible to address the Lucas Critique, which says that one cannot correctly predict the consequences of a major policy change such as changing static capital requirements or implementing a macroprudential regulation without knowing the objectives and preferences of the agents in the economy. Hence, they are well suited for the study of policy scenarios, simulations, and counterfactuals, while keeping track of the mechanisms at work.

Capturing these effects, however, substantially increases the level of model complication. Thus, most studies make substantial modeling compromises to achieve problem tractability. A frequent simplification is to abstain from explicitly modeling externalities and efficient allocation and welfare considerations. In this setting, the macroprudential policy authority usually aims at minimizing the volatility of GDP, credit, or their combination in some form. Moreover, the simplification may mean that only a local equilibrium is studied or that the bank capital constraint is always binding. The simplification can even apply to the macroeconomy itself, and thereby is subject to similar caveats and objections such as DSGE models used for monetary analysis. For example, given that essentially all models in this literature are based on a rational expectations paradigm, agents know how the economy works and know the distributions and sources of risk. This leaves room neither for uncertainty regarding the true economic process and its sources of risk, nor for limited information. Technical challenges mean that many contributions highlight only the qualitative impact of macroprudential buffers (e.g. static or dynamic buffers), or at most a feasible range of values, without estimating their optimal point-levels. Finally, due to their simplifications, the models fail to distinguish among the different types of

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[2] There are a few quasi-experimental studies that aim to control demand and supply effects to extract clean estimates of effects of (changes in) capital requirements. These studies (e.g. Gropp et al., 2019) are designed to verify the qualitative effects of capital requirements. They are likely of limited use in quantitative policy work due to the specific empirical settings they typically consider.

bank capital present in Basel regulations. For instance, they work with simplified rules and typically merge different Basel capital categories, although not in a commonly agreed manner. They also have a menu of assets much more limited relative to the ones present in regulatory risk-weighting schemes.[3]

As Birn et al. (2020) stress, these very challenges are also what make this newest strand of literature quantifying optimal capital requirements in DSGE models so deserving of greater attention. Recent contributions (e.g. Elenev et al., 2021) attempt to overcome some of the above-mentioned problems. Several of these studies have already been compiled and reviewed in the BIS FRAME initiative (Boissay et al., 2019), which provides statistics on the range of estimates of the effects of capital requirements and liquidity requirements on various economic outcomes (e.g. banks' cost of funding, bank lending, investments, GDP, and the likelihood and costs of banking crises).

Here, we focus on models that explicitly include market failures, analyze optimal capital requirement levels from a welfare perspective, and highlight underlying mechanisms. Taking liberties with the established terminology, we use "macroprudential policy and regulation" as a general term encompassing both static capital requirements and dynamic capital requirements often referred to as "macroprudential" or "countercyclical" buffers.[4] Note, we do not systematically address that important part of the literature focuses on the interactions of monetary policy, macroprudential policy and financial stability. Examples of this strand of literature are found in e.g. Angelini et al. (2014), Collard et al. (2017), Martinez-Miera and Repullo 2019a, and Silvo (2019), as well as the recent reviews by European Central Bank (2021), Ajello et al. (2022) and Boyarchenko et al. (2022).

The paper is organized as follows. In section 2, we briefly discuss the empirical estimates of optimal bank capital requirements surveyed in earlier reviews. Section 3 discusses our findings from the literature studying bank capital requirements in DSGE models. Section 4 concludes with policy implications and suggestions for future research.

[3] DSGE models usually consider one-period corporate loans. Clerc et al. (2015) also consider one-period household mortgage loans, while Elenev et al. (2021) consider long-term corporate loans. Examples of DSGE models that include long-period household mortgage loans include Kydland et al. (2016), Andrés et al. (2017), Bluwstein et al. (2020), Kaplan et al. (2020), and Silvo and Verona (2020).

[4] Banks' static capital requirements are commonly referred to as microprudential requirements, while the dynamic capital buffer requirements introduced in Basel III are called macroprudential (or countercyclical) requirements. The latter requirements are presumably designated macroprudential (or countercyclical) because of their apparent purpose as a policy tool for dealing with excessive credit booms.

2. Empirical estimates of optimal bank capital requirements from earlier reviews

Basel Committee researchers regularly review the literature on optimal bank capital requirement levels (and dynamic buffers to a lesser extent). Birn et al. (2019) provide the most recent update. As an overview of their findings, we reproduce and simplify their Table 1 in Panel A of Table 1 of the current paper. The list mainly contains empirically oriented studies.

Table 1. Optimal bank capital and dynamic buffers estimated or inferred in the literature

Panel A: Studies covered in Birn et al. (2020)

Study	**Coverage**	**Optimum (Tier 1/RWA % unless noted otherwise)**
BCBS (2010)	BCBS members	10–15 (TCE/Basel II RWA)
Miles et al. (2013)	UK	16–20
Brooke et al. (2015)	UK	10–14
Fender and Lewrick (2016)	BCBS members	10–11 (CET1/RWA)
Firestone et al. (2017)	US	13–25
Cline (2017)	US, Japan, Western EU	12–14 (CET1/RWA)
Barth and Miller (2018)	US	25
Federal Reserve Bank of Minneapolis (2017)	US	23,5 (CET1/RWA)
Almenberg et al. (2017)	Sweden	10–24 (CET1/RWA)

Panel B: Macro - DSGE models

	Coverage	**Optimum (equity/RWA % unless notes otherwise)**	**Dynamic buffer**
Martinez-Miera and Suarez (2014)	not specified	14 (equity/non-RWA)	
Nguyen (2015)	US	8 (equity/non-RWA)	
Clerc et al. (2015)	Euro Area	10.2 (business loans) 5.1 (mortgage loans)	
Clerc et al. (2015)	Finland*	9.2 (business loans) 4.6 (mortgage loans)	
Akinci and Queralto (2017)	multi-country	around 17 (equity/non-RWA)	
Mendicino et al. (2018)	Euro Area	Basel II+2 pp (corporate loans) Basel II+1 pp (mortgages)	
Davydiuk (2019)	US	around 6 (equity/non-RWA)	+/- CCyB of 1 pp
Begenau (2020)	US	12.4	
Mendicino et al. (2020)	Euro Area	9.38 (equity/non-RWA)	
Malherbe (2020)	US		optimal CCyB of 1.12 pp
Elenev et al. (2021)	US	6	
Begenau and Landvoigt (2022)	US	around 16	

*Our own calculations

Source: Birn et al. (2019) (Panel A) and the current literature review (Panel B).

Some of the cited research estimates the optimal level of capital requirement by combining inputs from several partial equilibrium models (e.g. Miles and Marcheggiano, 2013). Birn et al. (2019) emphasize that the various studies reviewed use different assumptions and modelling frameworks, so estimates of optimal capital requirements obtained from them should be compared with caution.[5] For this reason, we abstain from providing average estimates of optimal capital requirements across different studies compiled in Table 1. However, in the next sections, we provide a few tentative thoughts based on our review of these estimates.

One conclusion from these earlier literature reviews is that more work with quantitative, structural general equilibrium macro models is welcome. This nascent strand of research has not been, at least to the best of our knowledge, systematically reviewed, and thus constitutes the focus of the next section.

3. Bank capital requirements in Dynamic Stochastic General Equilibrium models

The literature analyzing optimal levels of capital buffers took off as a response to the passing and gradual implementation of the Basel II regulatory framework, which overlapped partly with the outbreak of the Global Financial Crisis in 2007–2008. The emergence of the DSGE paradigm as the main policy tool before the crisis and the challenge the crisis itself posed to macromodelling made the DSGE framework a natural platform for study of these questions.

The estimates of optimal capital requirements based on DSGE models are summarized in Panel B of Table 1.

3.1 Static capital requirements

The major contribution of Van den Heuvel (2008) highlights the costs of capital regulation in a model where banks create liquidity by accepting deposits. It concludes that a 10% capital buffer in the US is detrimental for welfare as it is associated with a marginal cost much exceeding the marginal benefit of regulation. In that setup, while equity financing may in principle tap the gap, it is more costly and does not create the liquidity services as do deposits.

A few other recent studies calibrated to US data tend to signal higher optimal values. In Martinez-Miera and Suarez (2014), banks can invest in systemically safe and unsafe projects. They trade off risk against the perspective of how much equity they will have if they survive a bad aggregate shock. Hence, in good times banks build up capital, making it more abundant in the aggregate. This leads to more investments in systemically riskier firms (which overall produce smaller returns, but larger returns if the systemic shock fails to materialize). Static requirements make capital scarce both ex ante and ex post, reducing overall lending and becoming a cost to welfare. However, they also reduce investment in systemically risky firms and

[5] A novel approach is provided by Ambrocio et al. (2020), who survey academic experts on their views regarding optimal capital requirements.

hence limit losses when the systemic shock hits. The paper finds that an optimum at 14% increases permanent consumption by 0.9% relative to a 7% buffer, a number possibly stemming from the "last bank standing" effect.

Begenau (2020) develops a model in which, as commonly assumed, limited liability and government subsidies make banks take excessive risks. A key mechanism in the model stems from the fact that households have an explicit utility from holding deposits. Higher capital requirements reduce, ceteris paribus, banks' capacity to lend. In general equilibrium, however, they also reduce the deposit-issuing capacity of banks and make the deposit rate fall due to lower supply. The channel is so powerful that the overall cost for banks falls and allows them to expand credit. This net effect explains a relatively high welfare-maximizing risk-weighted capital requirement of 12.4%.

Begenau and Landvoigt (2022) incorporate the assumptions of bank bail-out protection of traditional banks, deposit insurance, and explicit utility by households from liquidity (deposits) – and then introduce the parallel existence of shadow banks. They find an optimal capital ratio can be as high as 16%, which suggests that shadow banks can partly mitigate a decline in credit caused by tighter capital requirements imposed on traditional banks.

A similarly high optimal value of capital requirement, around 17%, is suggested by Akinci and Queralto (2017). Their model, which features a small open economy, is solved in a non-linear fashion with occasionally binding constraints. Banks issue equity endogenously and are subject to a precautionary motive. However, they do not internalize the fact that holding more equity ex ante would contain the aggregate drop is asset prices and mitigate the rise in spreads in crisis times. Hence, this sub-optimally low equity choice is a pecuniary externality. The authors show that the overall welfare gain is nevertheless rather moderate.

The recent study by Elenev et al. (2021) suggests a lower level for the optimally set capital requirement (6% of risk-weighted assets). Significantly, the paper develops a model with fewer modelling compromises than most of the above-mentioned models. Both firms and banks are subject to frictions and there is a well-founded rationale for bank capital requirements and macroprudential policy. Equity, as opposed to debt, is subject to a tax and adjusting it is costly. Banks enjoy limited liability and are covered by deposit insurance and too-big-to-fail policies that are financed by government debt. Additionally, public debt serves as a substitute for private liquidity in bad times.[6] The model is solved with global methods, allowing the capture of non-linear effects in crisis times. The low optimal level of capital requirements may potentially

[6] As in Begenau (2020), the risk-free interest rate declines in bad times. Although the government issues bonds (which increases interest), the dominating factors are the precautionary demand for savings and shrinking supply of deposits.

be explained by certain model features, including log utility of consumers (assumed for tractability), high weight of savers in welfare calculations (due to their lower discount rate) and the fact that crises are actually quite rare.[7]

A relatively low 8% capital requirement is also suggested in an early paper by Nguyen (2015). In that study, banks take risks endogenously and can invest in firms which differ in their productivity. As frequently assumed, they are covered by implicit government guarantees so they prefer cheaper deposit financing. As in Elenev et al. (2021), issuing outside equity is costly due to flotation costs. While higher investment initially stimulates growth (which is endogenous), it ultimately becomes inefficient and welfare-reducing by eating up resources that could be consumed otherwise. A capital requirement increases the cost of financing for banks, shifting incentives towards equity, reduces investment in less productive goods, and increases consumption. When it is too high, some productive investment remains unfinanced, growth is stifled, and welfare falls along with consumption.

A few papers work with models calibrated using European data. These studies are all broadly based on the “3D” (three types of default) model proposed by Clerc et al. (2015), and hence share similar frictions and mechanisms. The framework includes lending to households (mortgages) and firms (business loans). Banks have limited liability and are also protected by deposit insurance. Both mechanisms make them prefer cheap deposits, take on excessive risk, and over-lever. This abundant credit makes bank customers over-levered as well. Despite deposit insurance, bank failure generates a transaction cost to depositors and adds a spread to the deposit rate. The spread is economy-wide (rather than bank-specific) due to asymmetric information and hence creates additional “bank funding externality” by incentivizing banks to take on more risk. While the optimal capital requirement reduces risk-taking and limits the deposit insurance subsidy, it increases the cost of funding and may restrict credit to the real economy if set too high. Overall, these exercises tend to report optimal capital requirement levels in the proximity of 10%. In particular, the original model by Clerc et al. (2015) recommends a 10.2% requirement for business loans and a 5.1% requirement for mortgage loans.

Mendicino et al. (2018) suggest that, from the point of view of borrowers’ welfare, the then-existing Basel II requirements should be increased by 1 percentage point for mortgage loans and 2 percentage points for corporate loans. Mendicino et al. (2020) suggest a similar increase of 1.38 percentage points on top of the Basel 8% requirement (relative to business loans).

DSGE models are well suited to distinguishing (and hence quantifying) the impact of introducing new macroprudential regulation over the short run from the long-term effects. This may be useful when considering the timing of the implementation of permanent rules and the risk of introducing them in times when the financial sector is weak, effectively making the regulation

[7] We thank Tim Landvoigt for pointing out these issues.

procyclical. For example, Aliaga-Diaz and Olivero (2012) zoom in on the US data from the early 1990s and consider the possibility that tighter regulation by itself might have precipitated a credit crunch. They find little evidence for this (although its absence may be explained by the structure of the US financial system and its limited reliance on traditional banks). Mendicino et al. (2020) evaluate the short-term losses and find that they may erode as much as 25% of long-term gains. de Nicolo et al. (2021) consider a permanent increase of capital requirement from 4% to 8% in a model with risky loans and find that, although there is a credit crunch in the short run, the long-term impact on lending is small. Moreover, banks build up equity beyond the required minimum due to flotation costs.

3.2 Dynamic capital requirements

A small group of papers attempt to quantify the optimal range of dynamic or countercyclical capital buffers (CCyBs). Several of these studies consider the effects of these buffers and whether their use is welfare-improving. From this perspective, an important contribution is Davydiuk (2021), who works with a model of an economy driven by productivity shocks and finds that optimal Ramsey policies keep the total capital requirement between 5% and 7%. The countercyclical component (as opposed to the static one) accounts for the largest share of welfare gains. Importantly, the buffer is a function not only of the credit gap and GDP, but also of the liquidity premium. The optimality of countercyclical buffers comes from the following mechanism. As commonly assumed, banks enjoy government guarantees and have limited liability, whereas deposits yield utility for households. Although a positive productivity shock per se reduces the riskiness of the system, banks' endogenous reaction overturns this impact. In good times, banks expand by raising more deposits, levering up, and investing more in inefficient projects. A countercyclical buffer improves allocation by reducing overall riskiness and shrinking access to deposits in times when they are abundant and generate little marginal utility.

The above-mentioned paper of Elenev et al. (2021) also finds that a capital requirement oscillating between 5% and 9% dominates a fixed one of 7%, implying a -/+2 pp range for the CCyB around the fixed capital requirement. This is due to a lower contraction in investment and consumption and lower spreads relative to the static case, despite somewhat higher financial system riskiness and loan losses. In their model, the welfare benefits accrue to savers at the expense of borrowers. This may reduce consumption inequality and increase wealth inequality.

Malherbe (2020), who also considers optimality of the CCyB, finds that the risk-weighted capital requirement should rise from 8% to 9.12% following an expansionary productivity shock. The key mechanism in that model comes from the fact that firms are effectively subject to decreasing returns to scale. Hence, from an aggregate point of view, bailout costs rise disproportionately faster that bank equity and lending. This means that when equity is higher (in good times), optimal capital requirement is higher. This "bank capital channel" mechanism dominates the fact that a positive TFP shock reduces default risk and calls for lower capital buffers ("expected productivity channel").

In general, allowing for a dynamic CCyB creates an additional layer of complexity to the model and the analysis. On top of the existing static capital requirement, one adds to the macroprudential rule a time-varying component (possibly with some persistence to smooth macroprudential policy changes). In the literature, this time-varying component has been modelled as a function of GDP, credit, or even asset prices. As all these variables may appear in various transformed forms such as levels, growth rates, ratios, or deviations from steady state levels, there is a multitude of countercyclical rules and this may affect their effectiveness (Bekiros et al., 2018; Liu and Molise, 2019). Their comparability is further complicated by a lack of a commonly agreed simple benchmark model (unlike in the case of the three-equation New Keynesian model for monetary policy) and the open-economy dimension (Clancy and Merola, 2017; Poutineau and Vermandel, 2017).

The cyclical nature of the regulation further increases the need to understand and being able to disentangle in real time the nature of the underlying shocks that give rise to these fluctuations (Angelini et al., 2014, 2015). In general, the optimal reaction to specific shocks depends on whether they are real or financial, and whether they originate in the banking sector, among savers or borrowers in the household sector, or in the housing or business sector. This builds parallels with the problem of reacting to supply versus demand shocks in monetary policy.

Some papers find advantages – at least from a qualitative perspective – in setting CCyBs. Alpanda et al. (2018) find that the effectiveness of buffers, relative to loan-to-value (LTV) regulation, depends on whether an LTV cap is applied to business investment or to household mortgages, and ultimately depends on the relative importance or persistence of these shocks. Similarly, according to Christensen et al. (2011), the CCyB may be more effective in counteracting financial shocks, but less so when productivity shocks dominate. Similar conclusions are reached by de Carvalho and Castro (2015) and by Benes and Kumhof (2015), who build a model calibrated to closely match Basel III rules and stress that the welfare gains from a CCyB come predominantly from mitigating borrower riskiness shocks. Angeloni and Faia (2013) find it optimal to pursue Basel III type of policies regardless of the conditions. A positive effect of the shift from Basel II to Basel III is found also in Corbae and D'Erasmo (2019). In their environment buffeted by productivity shocks, a CCyB gives the highest welfare gains in the long run (and the highest loss in the short run). Clerc et al. (2015) find a CCyB may effective in reducing bank failure risk, depending on whether the level of the static capital requirement is sufficiently high ex ante (10.5% in their exercise). If this “CCyB policy space” is too small before the shock, the resulting deep reduction of requirements may further expose banks, increase costs, and amplify losses. The CCyB may also be effective in an environment prone to financial bubbles that arise in a model with financial innovation shocks and bounded rationality (Corrado and Schuler, 2019).

More generally, the distributional effects of the CCyB policy are less clear. In Faria-e-Castro (2021), the implementation of the CCyB on the order of 2.5% would have greatly mitigated the financial panic of 2008. It would not necessarily have been Pareto-improving, however, because even with the improved welfare of borrowers, savers would have been worse off. Mendicino et al. (2018) find that when static buffers are sufficiently high, savers, but not borrowers, benefit from the CCyB.[8]

The effectiveness of the CCyB may also depend on the state of the economy. While its value added in normal times may be small (Angelini et al., 2014), it becomes much more potent in crisis times. These state-dependence considerations further confirm the need to study the problem in a non-linear fashion (e.g. Elenev et al., 2021).

Apart from the caveats highlighted in the studies above, some papers emphasize the risks of using the CCyB. For example, Paries et al. (2011) indicate that a policy which is optimal from the point of view of macroeconomic stabilization would imply unrealistically high increase (a five-fold increase in their paper) in volatility of bank leverage. In another above-discussed paper, Martinez-Miera and Suarez (2014) warn against the countercyclicality of capital requirements more explicitly. In their model, banks extract rents from scarce bank capital. When a negative shock hits, it wipes off much of the equity of the banking industry and makes bank equity even scarcer. This creates an incentive for any surviving atomistic bank to avoid systemic risk, protect their own capital ex-ante and be able to extract more rents in crisis times (“last bank standing” effect). However, if banks anticipate lowering of capital requirements in bad times due to the CCyB, they expect that capital will be more abundant and rents will drop. This increases the incentive to take on systemic risk before a crisis.

To sum up, the existing literature on CCyBs is still inconclusive and sensitive to model specifications. Some studies such as Davydiuk (2019) highlight large potential benefits, while others highlight possible tradeoffs between e.g. short- and long-run effects and distributional considerations. While the literature is still limited, it suggests that it may reasonable to set static, but somewhat higher, static buffers. For example, Canzoneri et al. (2021) find that increasing the

[8] In DSGE models with heterogeneous households (impatient borrowers and patient savers), capital requirements generally redistribute wealth between households and a Pareto-improvement solution is hard to achieve. Furthermore, the social welfare function is usually computed as a weighted average of the expected lifetime utility of the two classes of households. There is no commonly accepted criterion for the choice of the weights assigned to each agent, however, and the results depend on this choice.

static capital requirement from 10% to 11.5% comes very close to a policy maximizing social welfare instead of using a dynamic buffer requirement around the 10% level. The weak impact of the CCyB is also found in the Rios-Rull et al. (2020) model calibrated to Canadian data and the simulations by Kilponen et al. (2016) in their model of the Finnish economy. A similar ambiguity of conclusions concerning macroprudential regulation is also present in the class of collateral constraint models discussed by Ottonello et al. (2021).

3.3 Additional mechanisms

The above overview of recent contributions on optimal bank capital requirements reveals several common mechanisms and modelling techniques. One assumption is that households obtain utility from holding cash or other liquid assets such as deposits, thereby allowing the introduction of a meaningful welfare tradeoff when capital requirements are raised. Another is the inability of banks to raise external equity without additional costs, which amplifies the bite of capital requirements and strengthens the departure from Modigliani-Miller debt-to-equity ratio irrelevance. Limited liability of banks, deposit insurance, and other financial subsidies of banks are also commonly assumed mechanisms that give rise to potentially excessive risk-taking by banks.

However, the largest value added comes from those key assumptions that highlight novel distinct mechanisms that might be relevant in determining the optimal capital requirement. Some, such as the “last bank standing“ effect discussed in Martinez-Miera and Suarez (2014) and the decreasing returns to scale assumption of Malherbe (2020), have already been mentioned, but there are others also worthy of scrutiny.

One potentially crucial dimension is the emergence of the shadow banking sector (Begenau and Landvoigt, 2022; Martinez-Miera and Repullo, 2019b). The existence of shadow banks gives rise to an additional substitution margin with traditional banks. Not surprisingly, an increase in capital requirements, which only affects traditional banks, makes the traditional banks less competitive and shifts the optimal financing mix in favor of shadow banks. Although the rise of shadow banks in itself appears to make the system more fragile to shocks, it could also make traditional banks safer. Thus, optimal regulation needs to trade off these two effects.[9]

[9] The net impact of macroprudential regulation on the system’s riskiness results from the interplay of two mechanisms. A *higher capital requirement* reduces the comparative advantage of traditional banks stemming from government guarantees. Shadow bank debt becomes more abundant, reduces the convenience yield, and increases financing costs. Shadow banks react by reducing leverage and hence their risk exposure. The second, overturning effect comes from the overall *shrinking supply of deposits*. This increases the convenience yield and reduces the deposit rate on all bank debt, incentivizing shadow banks to leverage up. In net terms, shadow banks become riskier while the system as a whole is safer due to more equity-financed traditional banks..

On a more general level, Martinez-Meira and Repullo (2019b) highlight the possibility of "leakage" and unintended consequences of macroprudential regulation. Despite this potential side effect of regulation, the paper reports a relatively high 16% optimal bank capital requirement. This result may be explained by the type of trade-offs studied. In the model, productive firms are not subject to any frictions or credit constraints, so macroprudential regulation does not affect production. Instead, the optimal regulation trades off the risk of bank runs with the utility from liquidity provided by banks. Bank runs are costly in terms of bankruptcy and foregone consumption. Convenience from liquidity may not be a strong one, especially since it can be provided by shadow banks as well. Hence, the cost of a higher capital requirement is relatively small.

Empirical evidence on the shifting from traditional to shadow banks has been documented by Lee et al. (2021), who show that implementation of Basel III in Korea resulted in a 25% drop in regulated bank lending and was almost fully offset by shadow banks. The "leakage" idea is also pursued by Dempsey (2020), who develops a model for the US in which firms have access to bank loans and direct debt in the form of bonds and banks can issue outside equity. In their model, an increase of capital requirements from 8% to 26% eliminates bank failure altogether without affecting the level of investment.

Another side-effect of macroprudential policies is related with the structure of the banking system. Corbae and D'Erasmo (2019) develop a model in which banks are heterogeneous and differ in average operating costs, with smaller banks being less cost efficient. An increase of the static capital requirement from 4% to 8.5% increases the exit rate of small banks and concentration within the industry. Because raising equity is costly, banks with higher operating costs are the first to face negative profitability and declining charter value. While this reduces lending, it increases allocative efficiency in the banking sector by reducing average operating costs.

4. Policy implications

Compared to optimal monetary policy, the problem of optimal macroprudential regulation contains an extra layer of complexity. This is partly because it requires explicit modelling of the banking sector and market failures that the policy must correct. The lack of any simple, commonly agreed, framework to study macroprudential policies complicates comparison of models and understanding of the mechanics involved. Furthermore, different studies use different definitions of bank capital or simplify the risk-weighting scheme due to a limited menu of assets. As noted by Birn et al. (2020), it is not possible in practice to make different studies fully comparable in this respect. The lack of risk-weighting in many models, in turn, means that they do not properly capture the effective procyclical mechanisms embedded in capital requirements. On the other hand, endogenous default may partly mitigate this limitation.

Current DSGE models rely on a variety of simplifying assumptions. The role of each of these assumptions has so far not been widely explored. One obvious example is the departure from fully rational expectations and allowance for some form of short-sightedness or imperfections in information. Other common omissions include overlapping generations, an open economy dimension, the role of global banks, and international capital flows (Akinci and Queralto, 2017, being an early step in that direction). For instance, determining an appropriate balance between welfare effects on borrowers and savers of macroprudential policies – as discussed earlier – might be worth exploring in overlapping generations or life-cycle models. Issues such as interactions of various macroeconomic policies and the role of other forms of financing such as shadow banks and bond markets have started to receive limited attention.

Table 1 suggests that general equilibrium models (panel B) usually recommend lower capital buffers than partial equilibrium or purely empirical models (panel A). This observation may reflect the fact that DSGE models typically work with an explicitly defined welfare criterion. If, as is the case in many general equilibrium models, the reduction in lending reduces access to credit, it may be detrimental to welfare, hence warranting lower capital requirements.

As with the differences between supply and demand shocks in monetary policy, the source of the shock is also crucial in understanding the consequences of dynamic macroprudential policies. The effectiveness of the CCyB regulation following non-financial shocks is far from clear. Considering the lack of robustness and tentative nature of the results, as well as potential side effects (e.g. replacement of traditional bank lending by shadow banks and moral hazard), some papers suggest that it may be safer to consider somewhat higher, but static, capital buffers.

Optimal capital requirements also depend on interactions with other regulations and policies. The literature contains multiple attempts to quantify these effects, but more research is needed. For instance, liquidity requirements may help reduce the likelihood of a crisis and hence reduce the need of higher capital requirements. Similarly, prompt and effective recovery and resolution policies may mitigate output losses in a crisis (i.e. the cost of a crisis) and thereby reduce the need for higher capital requirements.[10]

Comparing results across models is ultimately a challenging task. Besides different modelling frictions and complicated mechanism interactions, the models are quite often i) calibrated using different data, ii) simulated using a different set of shocks, iii) simulated using different parametrizations of the shock processes, and iv) solved using different methods (e.g. global

[10] On the other hand, there is a risk, particularly with untested new frameworks, that bank recovery and resolution may create a false sense of security if it does not actually contain contagion from failed institutions during a crisis.

or local approximation) or with different assumptions (e.g. as regards how fast the economy reaches the new equilibrium after the implementation of a new policy regime). All these factors increase the sensitivity of the results. For example, nonlinear solution of the models may act as a two-edged sword. It may better capture the true crisis dynamics, yet make the results more state-dependent, creating additional room for sensitivity and error. Ideally, one would need to build a rather detailed model with several frictions and shut them down one by one to determine those that are critical and how sensitive the results are to each of these frictions. At the least, one should run comparable simulations using a number of models (as done by Guerrieri et al., 2019, in the context of analyzing the macroeconomic effects of capital shortfalls in the financial intermediation sector) to provide model-robust results.

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