Bank Capital: A Seawall Approach*

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We find that bank capital in the range of 15–23 percent of risk-weighted assets would have been sufficient to absorb losses in the vast majority of historic banking crises in advanced economies. Further capital increases would have had only marginal effects on preventing additional crises. Appropriate capital requirements may be below this range, as banks tend to hold capital in excess of regulatory minimums, and other bail-in-able instruments can contribute to banks' loss-absorption capacity. While the long-term social costs associated with this level of capital appear acceptable, the short-term costs of transitioning to higher bank capital may be substantial, which calls for a careful timing of such transition.

JEL Code: G20.

1. Introduction

A large part of the post-crisis policy debate has focused on the appropriate levels of bank capital. Proponents of stricter regulation emphasize the risks and inefficiencies associated with high leverage and point to the exorbitant costs of the crisis (Admati and Hellwig 2014). Opponents of higher capital requirements believe that

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Table 1. Basel I, Basel II, and Basel III Capital Requirements (percent of risk-weighted assets)

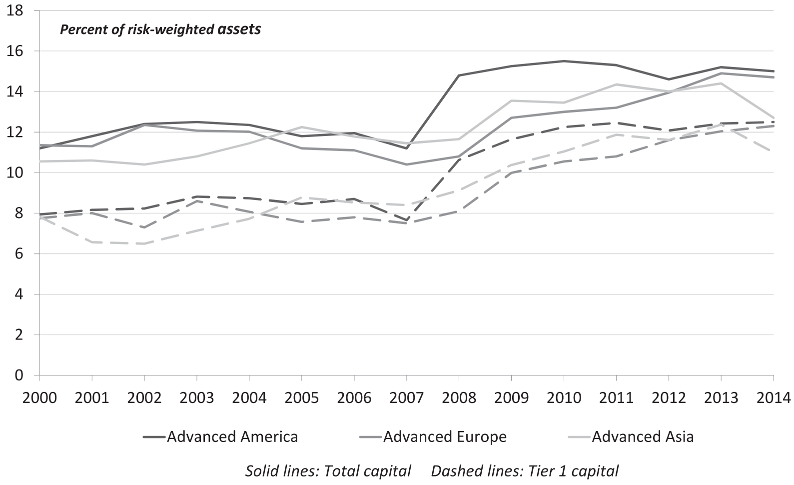
	Basel I	Basel II	Basel III[a]
Quantity of Capital			
Minimum Total Capital	8.0	8.0	8.0
Capital Conservation Buffer[b]	NA	NA	2.5
Minimum Total Capital Plus Conservation Buffer	NA	NA	10.5
Countercyclical Buffer[b]	NA	NA	0–2.5
Global Systemically Important Banks (G-SIB) Surcharge[b]	NA	NA	1–2.5
Minimum Total Capital Plus Conservation Buffer, Countercyclical Buffer, and G-SIB Charge	8.0	8.0	11.5–15.5
Leverage Ratio[c]	NA	NA	3.0
Quality of Capital			
Minimum Common Equity Capital[d]	NA	NA	4.5
Minimum Tier 1 Capital	4.0	4.0	6.0
Hybrid Capital Instruments with Incentive to Redeem[e]	Eligible	Eligible	Not Eligible

Source: Bank for International Settlements (2011, 2013).
[a]Effective as of 2019. [b]Consisting of tangible common equity. [c]Ratio of tier 1 capital to total assets. [d]Goodwill and deferred tax assets are to be deducted in the calculation of common equity tier 1 capital. [e]Hybrid capital instruments with an incentive to redeem through features such as step-up clauses, which under Basel II counted toward tier 2 capital and up to 15 percent of the tier 1 capital base, are no longer eligible as capital. Under Basel III only dated subordinated debt is deemed tier 2 capital.

these would increase the cost of financial intermediation and hinder economic activity (Institute of International Finance 2010). Some also caution that tighter regulation might push intermediation out of the banking system and into unregulated entities, possibly increasing systemic risk.

According to the prevalent view, pre-crisis bank capitalization proved insufficient to absorb crisis-related bank losses. In response, Basel III raised minimum bank capital requirements from 8 percent to up to 15.5 percent of risk-weighted assets, when all surcharges are activated (table 1). It also introduced a leverage ratio requirement

Figure 1. Tier 1 and Total Capital Ratios for Large Global Banks since 2000



and raised the quality of capital by tightening eligibility requirements for instruments included in the numerator of regulatory ratios (including requiring a larger fraction of regulatory capital to consist of tangible common equity). Some jurisdictions opted for even higher standards. For example, Switzerland is enforcing 19 percent capital ratios for its largest banks. These changes have boosted bank capital ratios throughout the advanced economies (figure 1).

Against this background, a key question for bank regulation is whether these reforms have gone too far or not far enough. Put differently, what is the socially optimal bank capitalization? Providing an answer to this question in its general form is likely impossible. That would require defining a social welfare function, estimating the effect of bank capital on the cost and availability of credit, the probability and severity of banking crises, and the effect of banking crises on output and output volatility. The results of such an exercise would be highly dependent on the models and parameters chosen: the rigor would conceal a large degree of judgment.

This paper takes a different, less ambitious path to evaluating bank capital ratios. We ask what capital buffers would have been sufficient to absorb bank losses through equity in a large majority of past banking crises. Once the sufficient bank capital ratios are established, we verify that the costs of implementing such capital ratios appear acceptable. We call this “a seawall approach”: akin to the analysis that goes into building a seawall, we assess the height of a wall that can absorb plausible large waves, then confirm that the cost of such a seawall is bearable. This reduced-form perspective has the benefit of reducing the number of assumptions relative to general equilibrium models, thus increasing the robustness and transparency of our findings.

Our seawall approach leads to robust results. We find that bank capital in the range of 15–23 percent of risk-weighted assets would have absorbed bank losses in most past banking crises in advanced economies. The marginal benefits of bank capital decline once banks’ capital ratios reach 15–23 percent of risk-weighted assets. The reason is that the more extreme crises are rare and would require substantially more capital to manage them. The 15–23 percent inflection region for the marginal benefits of bank capital is robust to various alternative estimates—among others, using data on bank loan losses or on public recapitalizations of banks, considering bank loan losses or also securities losses, using industry-average bank capital or individual bank capital, etc. As such, a sharp inflection in the marginal benefits of bank capital in the 15–23 percent risk-weighted capital ratio range suggests that, for a wide range of possible costs of bank capital, optimal bank capital is within that range.

The inflection point in the marginal benefits of bank capital is less pronounced and occurs at higher capital ratios for emerging market and developing economies, where banking crises have often been associated with larger bank losses. This asymmetry highlights the complementarity of capital and institutional improvements (in regulation, supervision, and resolution) in reducing expected losses in a possible banking crisis. Further, reminiscent of the debate on sovereign debt sustainability, it stresses the correlation between the magnitude and frequency of macroeconomic shocks and the size of the buffers necessary to confront them.

It is important to be careful in relating our findings to capital regulation. First, our results are in terms of actual bank capital rather than minimum capital requirements. Banks tend to maintain buffers over minimum capital requirements, and can draw on those buffers in stressed periods. Second, tighter liquidity regulation and more stringent overall supervision (including detailed stress-testing) of banks in the wake of the crisis could have reduced bank risk for any given level of bank capital, compared with pre-crisis levels. Third, while this paper focuses exclusively on bank capital as a means to absorb bank losses, other bail-in-able instruments can contribute to loss-absorption capacity. For these reasons, optimal capital requirements can be somewhat below the 15–23 percent range identified in our analysis. This makes our findings consistent with the upper range of Basel III capital requirements and with the total loss-absorbing capacity (TLAC) standards for systemic bank institutions (Bank for International Settlements 2016).[1] Finally, we abstract from the beneficial effect higher capital might have on bank risk taking and expected nonperforming loans (NPLs).

The paper proceeds as follows. Section 2 reviews the literature on the benefits and costs of bank capital. Section 3 presents estimates of bank capital ratios sufficient to absorb losses in past banking crises using alternative "seawall" approaches. Section 4 discusses the robustness of these estimates. Section 5 reviews evidence on the costs of bank capital. Section 6 concludes.

2. Theoretical Background: The Benefits and Costs of Bank Capital

Higher bank capital has several benefits from a financial stability perspective, but might also impose costs on banks and society. In an idealized Modigliani-Miller (1958; henceforth MM) world without tax deductibility of interest rate costs, bankruptcy costs, or agency problems, bank leverage does not affect social welfare (or bank profits). In this world, capital requirements are at the same time costless and irrelevant. In practice, however, several frictions imply that the MM paradigm does not apply (at least to banks), and that capital may affect the way banks behave and their profitability. In particular, asymmetric information entails significant agency problems and externalities magnify the social cost of bank failure. Then, capital

[1]See Zhou et al. 2012 and Flannery 2014 for a discussion of the relative benefits and costs of bail-in-able instruments compared with bank equity in providing loss-absorption capacity.

can play an important role in aligning banks' incentives with social welfare.

2.1 Benefits

First, capital serves as a buffer that absorbs losses and reduces the probability of bank failure. This protects bank creditors and, in systems with explicit or implicit public guarantees, taxpayers. Second, capital has a preventative role by improving incentives for better risk management. When asymmetric information prevents creditors from pricing bank risk-taking at the margin, banks operating under the protection of limited liability will tend to take excessive risks. Capital can limit these excesses by increasing shareholders' "skin in the game"—the amount of equity at risk in the event of bank failure (Marcus 1984; Myers and Majluf 1984; Keeley 1990; Esty 1998; Hellman, Murdock, and Stiglitz 2000; Matutes and Vives 2000; Repullo 2004). This includes the role of bank capital in helping minimize market discipline distortions associated with deposit insurance and implicit government "too-big-to-fail" guarantees.[2]

Market forces push banks to maintain some positive level of capital. For example, higher capital helps banks attract funds (Holmstrom and Tirole 1997), maintain long-term customer relationships (Allen, Carletti, and Marquez 2011), and carry risks essential to lending (Calem and Rob 1999; Perotti, Ratnovski, and Vlahu 2011). However, it is widely accepted that these forces are not sufficient to ensure that the market equilibrium bank capital levels deliver a welfare-maximizing allocation. Put differently, the frictions discussed above imply that the private return to capital is lower than the social return. Thus, banks will tend to hold less capital than what is socially optimal. This provides a rationale for regulation aimed at increasing bank capital relative to the laissez-faire equilibrium (this typically comes in the form of risk-weighted minimum capital requirements and more recently of caps on leverage ratios).

[2]Some have argued that how bank ownership is distributed matters. When bank equity is held by outside investors with high risk preferences or concentrated ownership, it may increase bank risk-taking (Laeven and Levine 2009). Indeed, passive outside investors are likely to have a limited disciplining role.

2.2 Costs

In analyzing the costs of bank capital, it is important to distinguish between the transition and steady-state impact of higher capital requirements. The costs associated with the transition to heightened capital requirements are not relevant at the steady state. These are costs stemming from raising new external equity or/and reducing the growth of assets. Equity issuance is subject to non-negligible underwriting fees, usually of 5–7 percent. Also, there are signaling costs: issuing equity may require substantial discounts when incumbent investors and managers have information about the firm that new equity investors do not have (Myers and Majluf 1984). Therefore, one would expect that any rapid increase in mandatory capital ratios would take place at least partially through an adjustment of bank assets, with potentially large negative effects on credit and macroeconomic performance.

In principle, the signaling cost should be low for gradual, regulatory increases in bank capital that affect the whole financial system (and therefore imply no hidden information on individual bank conditions). And the transition costs could be mitigated by giving banks time to adjust their balance sheets gradually. This might enable banks to increase capital using retained earnings or external capital issuance timed to beneficial market conditions. The caveat is that the benefits of regulatory gradualism might be limited if market pressures force banks to adjust to new capital standards rapidly.

The steady-state costs of higher capital requirements are those that occur after a permanent change in the funding mix of banks is completed. Some of the costs associated with a heavier reliance on equity are similar for banks and nonfinancial firms. For example, in many jurisdictions, debt has a more favorable tax treatment then equity (De Mooji 2011). Aside from tax issues, equity can be costlier if, due to some frictions, a decrease in leverage does not lower the banks' required return on equity. Yet the nature of these frictions requires a deeper discussion to understand the social welfare implications of higher bank capital.

The most notable reason why lower bank leverage may not pass through into a lower required return on equity is that deposits and other debt liabilities often benefit from subsidized safety net protections, including deposit insurance and too-big-to-fail subsidies that benefit bank debt more than bank equity (Kane 1989). Junior debt holders and uninsured depositors suffered minimal losses during the recent crisis, especially when compared with shareholders. As a result, banks' overall costs of funding may increase with greater equity finance. Yet this increase in banks' cost of funding is primarily a private cost to banks. While it might affect the cost and availability of bank credit, at the same time it reduces the distortions associated, for example, with the fiscal and incentives effects of expected bailouts.

Other notable costs stem from the fact that whereas for a nonfinancial firm leverage is a funding decision, for a bank its debt is also an output. The literature suggests that some economic agents, so-called cash investors, value bank debt for its high (often immediate, for deposits) liquidity and safety. When banks replace debt with equity, this destroys some economic value intrinsic to bank debt (Song and Thakor 2007; DeAngelo and Stulz 2013; Allen, Carletti, and Marquez 2015).[3] This reduces the cash investors' surplus, along with bank profits, and can harm bank borrowers through a higher cost of credit.

The existing literature has put forward several reasons why some investors value liquid and nominally safe assets such as bank debt. The hypotheses include liquidity insurance and convenience (Bryant 1980; Diamond and Dybvig 1983; Gorton and Pennacchi 1990; Caballero and Krishnamurthy 2008), agency costs in the money management of corporations and sovereigns that make them eschew any investment risk (Caballero and Krishnamurthy 2008), or the usefulness of risk-insensitive claims as a transactions medium (Dang et al. 2017). Empirical studies document the demand for safe and liquid assets (Gorton, Lewellen, and Metrick 2012), confirming the presence of cash investors in financial markets.[4] Krishnamurthy and Vissing-Jorgensen (2012) and Greenwood, Hanson, and Stein (2015) estimate the risk-adjusted premium of Treasuries over other bonds

[3]Of course, banks need to maintain some equity to ensure that their debt is safe and liquid in most states of the world (Hellwig 2014). But equity above that would crowd out socially valuable bank debt.

[4]The hypothesis of investors' preference for safe and liquid assets is often used also in the analysis of shadow banking; see Gennaioli, Shleifer, and Vishny (2012, 2013) and Claessens, Ghosh, and Mihet (2013).

to be −50 to −70 basis points; this can be taken as an estimate of the funding cost advantage inherent in safe and liquid bank debt too.

Finally, a related but separate issue is the role short-term debt can play in disciplining banks (Calomiris and Kahn 1991; Diamond and Rajan 2000; Kashyap, Rajan, and Stein 2008). This relates more to the composition of bank debt than bank leverage per se. The argument is that without demandable debt that gives creditors the ability to "run" on weak banks, banks would engage in riskier behavior. However, the crisis has led some to question the role that short-term debt can play in protecting financial stability: it provided little discipline before the crisis but contributed to extreme, across-the-board, runs once the crisis hit (Krishnamurthy 2010; Huang and Ratnovski 2011; Gorton and Metrick 2012). Moreover, it is unclear why market discipline cannot be provided by only small amounts of short-term bank debt.

2.3 Systemic Implications

The analysis of the costs and benefits of bank capital acquires additional dimensions when the focus shifts from the stability of individual institutions to that of the financial system as a whole. Individual bank distress may propagate to other banks through direct interbank exposures, fire sales, and contagious panics (Allen and Gale 2000; Gale and Özgür 2005; Admati et al. 2010; Admati and Hellwig 2014). Then, a bank's higher capitalization, by reducing the probability of its distress, helps avoid the associated systemic spillovers.

Moreover, competitive pressures may act as a systemic multiplier of the beneficial effects of individual banks' capital. Weak or "zombie" banks taking excessive risks (including by reducing lending standards and intermediation margins) may force healthy ones to engage in similar practices to protect their market share. And, to the extent that bank shareholders and creditors cannot fully evaluate a bank's risk-adjusted performance, similar pressures will bear as bank managers at healthy banks attempt to match the riskier banks' profitability (Caballero, Hoshi, and Kashyap 2008).

The level and distribution of capital across a banking system may also matter. Sufficient aggregate capital may enable strong banks to acquire weak institutions (Acharya, Engle, and Richardson 2012). In other cases, healthy banks may curtail lending if they expect macroeconomic conditions to be negatively affected by the reduction in credit supply due to weakness at other banks (Bebchuk and Goldstein 2011). Related, the risk of contagion associated with weakness at a systemic bank may reduce the incentives for acting prudently at other banks (Dell'Ariccia and Ratnovski 2013).

On the cost side, higher bank capital requirements may affect the allocation of activities across different financial intermediaries. In particular, "too high" capital requirements may trigger a migration of activities from banks to less-regulated parts of the financial system and thus increase systemic risk (Goodhart 2010; Martin and Parigi 2013; and Plantin 2015).[5]

2.4 The Balance of the Benefits and Costs of Higher Bank Capital

The papers that examine the balance of the benefits and costs of higher bank capital reach varying conclusions, depending on their assumptions and methodologies. At one end of the spectrum, Admati et al. (2010) and Admati and Hellwig (2014) argue that higher bank capital is not socially costly thanks to a nearly complete MM offset. Moreover, they argue that higher bank capital enhances the liquidity of bank debt. This compensates for its lower volume and keeps the value of safe asset premiums in the banks' cost of funding essentially constant. Overall, they argue for a 20 percent bank leverage ratio, corresponding to a 35 percent bank risk-weighted capital ratio. Our analysis suggests that additional capital beyond the 15–23 percent range has low benefits in terms of preventing additional banking crises.

[5]Another argument against "too high" bank capital is that while higher capital requirements reduce bank risk, they may at the same time increase borrowers' risk. This may occur when high capital requirements dampen interbank competition, increasing the cost of credit and inducting risk-shifting by bank borrowers (Boyd and De Nicolo 2005; Hakenes and Schnabel 2011). Or it may occur when high capital makes banks tolerant of risky lending, and firms take risk without the fear of being denied credit (Gornall and Strebulayev 2018).

On the opposite end of the spectrum, the Institute of International Finance (IIF) (2010) argues that any increases in bank capital can substantially affect the availability and cost of bank credit. In this argument, the focus is heavily on the transitional costs of higher bank capital, highlighting two concerns. The first is that heavy equity issuance may be costly during times of high economic and regulatory uncertainty. Whereas the IIF conjectures that increases in bank capital are therefore undesirable, we suggest that the cost of equity is minimized when higher bank capital requirements are imposed gradually. The second IIF concern is that the past costs of equity issuance affect the required rate of return on bank equity going forward. This argument appears less valid when the increase in bank capital is a one-off event. Overall, as we highlight in our analysis, the relatively healthy post-crisis dynamics of bank credit do not validate the IIF (2010) views.

Among other papers, Miles, Yang, and Marcheggiano (2013), Firestone, Lorenc, and Ranish (2017), and Barth and Miller (2018) use a common method but alternative data sets to assess the benefits and costs of bank capital. The benefits of bank capital are estimated from historical data (including those from the 19th century) on the link between bank capital, the probability of banking crises, and output losses in banking crisis. The caveat is that historical data may misrepresent the contemporary link between bank capital and the probability of banking crises, while the estimation of output losses relies on the assumptions regarding the counterfactual. Both papers allow for an incomplete MM offset in the cost of bank capital. The estimated optimal risk-weighted bank capital is 16–20 percent in Miles, Yang, and Marcheggiano (2013), within our range; 13–26 percent in Firestone, Lorenc, and Ranish (2017), wider than our range; and 26 percent in Barth and Miller (2018), above our range. The Bank for International Settlements (BIS) (2010) and Cline (2016) use a common model-based method to assess the benefits of higher bank capital, and also allow for an incomplete MM offset in the cost of bank capital. Their estimates of optimal bank capital are 10–12.5 percent and 12–14 percent, respectively, below our range. The Federal Reserve Bank of Minneapolis (2017) replicates the analysis of our paper and suggests optimal bank capital of 23 percent, at the top of our range.

3. Bank Capital: A Seawall Approach

The analysis above suggests that bank capital levels position a banking system on a tradeoff between financial stability and the cost of financial intermediation. Implicit in this tradeoff is the notion that there exists an "optimal" level of capital that maximizes some aggregate welfare function with output growth and volatility as ultimate arguments and bank stability and the cost and availability of credit as intermediate ones.

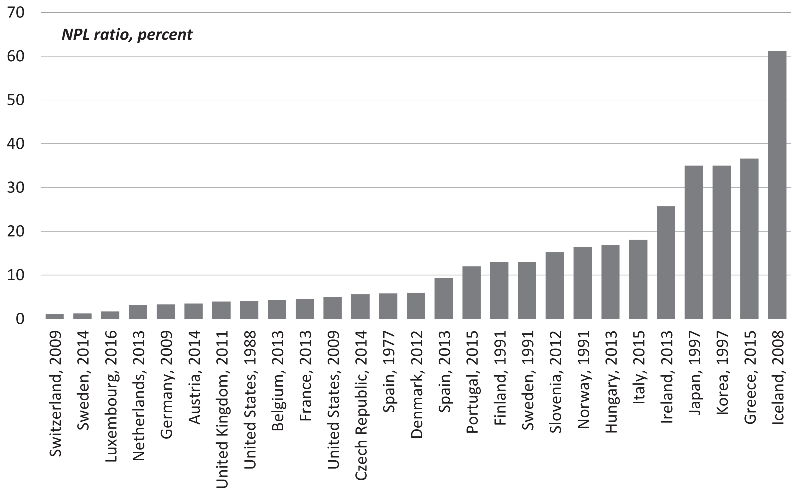
Estimating this optimal level of bank capital is, however, a complex task. It requires defining a social welfare function, estimating the effect of bank capital on the cost and availability of credit, the probability and severity of banking crises, and the effect of credit availability and banking crises on output and output volatility. Such an exercise would require simplifying assumptions, likely making its results too model-, bank-, and sample-specific to provide convincing policy guidance.

Against this background, we take a different, less ambitious path to evaluating the pros and cons of higher/lower bank capital ratios. We ask what capital buffers would have been sufficient to absorb all bank losses through equity in most of past banking crises. We think of this as a "seawall approach": choosing the height of a seawall that historically most often would have been sufficient. We perform this analysis based on two types of data. First, in section 3.1, we use data on nonperforming loan ratios in past banking crises and ask how much bank capital would have been enough to absorb the loan losses. Second, in section 3.2, we use data on public recapitalizations of banks and ask how much capital would have been enough to prevent those. It turns out that the results based on two different types of data are very similar, giving us comfort as to the robustness of our findings. Once the "sufficient" bank capital ratios are established, we verify in section 5 that the costs of implementing such capital ratios are acceptable.

3.1 Bank Capital Sufficient to Absorb Bank Loan Losses

The first approach considers the capacity of banks to absorb loan losses. We consider NPL ratios in past banking crises and ask how much capital banks would have needed to absorb loan losses and

Figure 2. Peak NPL Ratios in Banking Crises in OECD Countries



maintain positive equity, thus avoiding losses to creditors (cf. Ratnovski 2013). We base the analysis on the historic banking crises NPL data for OECD (Organisation for Economic Co-operation and Development) countries from a newly updated data set by Laeven and Valencia (2018). Figure 2 summarizes this data, showing peak NPL ratios during respective crises.[6]

To convert NPLs into bank capital ratios needed to absorb loan losses, we proceed in four steps. Each step is associated with assumptions on specific conversion parameters. We rely on the literature to establish the baseline parameters and the confidence range (stressed scenario) parameters. Overall, this approach implies that the resulting "sufficient" loss-absorbing capital is better discussed in terms of ranges rather than point estimates.

First, we convert NPLs into loan losses, by adjusting the nonperforming loan ratio for loss given default (LGD). Unfortunately, there is limited cross-country data on loss given default. For the baseline, we use estimates for the United States suggesting that the mean

[6]We abstract, in this exercise, from potential differences in accounting and prudential requirements regarding NPLs across countries and over time, an issue that is hard to circumvent.

loss given default over 1970–2003 was about 50 percent on average in normal times (Schuermann 2004; Shibut and Singer 2014; Johnston Ross and Shibut 2015). In a robustness scenario, we allow for LGD of up to 75 percent, to reflect possibly higher LGD in systemic banking crisis times. Second, we establish a share of bank losses that can be absorbed by prior provisioning. In the United States, loan loss provisioning averaged about 1.5 percent historically. In Spain, dynamic provisioning achieved similar buffers prior to the 2008 financial crisis (Saurina 2009). Therefore, loan loss reserves of about 1.5 percent seem a reasonable assumption. Third, we compute capital ratios that would enable banks to absorb the estimated losses and remain in positive equity. For this, we take bank capital equivalent to loan losses net of provisions and add an additional 1 percent of capital as a margin of safety in the baseline. The idea is that positive post-crisis bank capital enables the government to sell off the weak bank without a fiscal injection (which is essential to sell a bank with negative capital). In a robustness scenario, we allow for a higher margin of safety. Finally, we convert resulting unweighted capital needs into risk-weighted capital by applying a 1.75 ratio of total assets to risk-weighted assets (RWA), corresponding to the average such ratio for U.S. banks (Avramova and Le Lesle 2012). In another robustness scenario, we use a 2.5 ratio, corresponding to this ratio in Spanish banks (the highest in OECD countries).

Overall, the baseline formula that converts loan losses in a banking crisis into the risk-weighted capital ratios needed to absorb them is

$$\text{Bank capital} = (\text{NPL} * \text{LGD} - \text{Provisions} + \text{Margin of safety}) * (\text{TA} \,/\, \text{RWA}).$$

Table 2 illustrates our calculation. In the baseline (column 1), a hypothetical 18 percent NPL ratio corresponds to 9 percent loan losses, and loan losses net of provisions of 7.5 percent of total loans. To cover with a margin of safety 7.5 percent loan losses net of provisions, a bank needs an 8.5 percent leverage ratio, corresponding to approximately 15 percent risk-weighted capital ratio. Higher LGD, lower risk weights, or higher margins of safety (columns 2–4) increase the corresponding bank capital ratio to up to 23 percent.

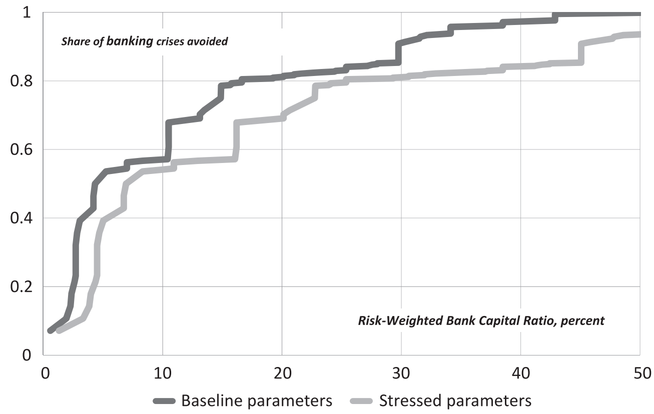
Table 2. Example: Capital Needed to Absorb NPLs Equal to 18 Percent of Assets (all values in percent)

	Baseline (1)	**Higher LGD (2)**	**Higher TA/RWA (3)**	**Higher M.O.S. (4)**
NPL during a Banking Crisis	18.0	18.0	18.0	18.0
Loss Given Default	50.0	**75.0**	50.0	50.0
Loan Losses (1*2) (Mean Point)	91.0	13.5	9.0	9.0
Absorbed by Prior Provisioning	1.5	1.5	1.5	1.5
Loan Losses Net of Provisions (3–4)	7.5	12.0	7.5	7.5
Margin of Safety (Residual Capital)	1.0	1.0	1.0	**3.0**
Capital-to-Assets Ratio or Leverage Ratio (5+6)	8.5	13.0	8.5	10.5
Total Assets/RWA	175.0	175.0	**250.0**	175.0
Capital Ratio (Percent of RWA) (7*8)	14.9	22.8	21.3	18.4

We then use the transformation above applied to the distribution of NPL ratios in past banking crises to transform a given bank capital ratio into the share of banking crises in which it could fully absorb loan losses. Figure 3 reports the share of advanced-economy banking crises in which banks would have maintained positive equity as a function of hypothetical bank risk-weighted capital ratios. We plot the function for the baseline (light gray line) as well as for a stressed scenario corresponding to LGD of 75 percent (as in column 2 of table 2, darker line). A line for a stressed scenario corresponding to lower risk weights (column 3 of table 2) is similar to the higher-LGD scenario.[7] A higher margin of safety (column 4 of table 2) yields results

[7]To the extent that such higher total assets to risk-weighted assets conversion ratio corresponds to safer bank portfolios, it would arguably correspond to lower loss-given-default estimates, thus partly compensating for its direct effect on bank capital needs. Note that we use historic conversion ratios that account

Figure 3. Share of Banking Crises without Creditor Losses in OECD Countries



in between the baseline and the stressed scenario; varying the margin of safety within reasonable bounds does not significantly affect the range of estimated bank capital needs.

The baseline schedule suggests that, in OECD countries, the marginal benefit of additional capital from a loss-absorption point of view is relatively high until a 15 percent risk-weighted capital ratio (which enables banks to absorb losses in more than 80 percent of banking crises). The marginal benefit of additional capital declines rapidly after that. This means that attempting to absorb bank losses in a few exceptionally extreme crises requires very high capital ratios. For the stressed scenario, the inflection point is close to 23 percent of risk-weighted assets. Notably, the baseline result is relatively close to the model-based estimates in BIS (2010) that suggest that capital of 15 percent would avoid imposing losses on creditors in about 90 percent of banking crises.[8]

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for the fact that some banks may engage in "strategic risk-weighting" (Enrich and Colchester 2012; Mariathasan and Merrouche 2014).

[8]It is useful to compare the parameters underlying our analysis with the parameters from recent U.S. and European bank stress tests. In the 2015 U.S. stress test (Board of Governors of the Federal Reserve System 2015), the "severely adverse scenario" led to 4.5 percent loan losses and a loss of 5.5 percentage points of risk-weighted bank capital. In the 2014 European Banking Authority (EBA) stress test (EBA 2014), the "adverse scenario" led to 2.3 percent loan losses that

3.2 Capital Sufficient to Avoid Public Recapitalizations of Banks

The next approach uses alternative data and considers how much capital banks would have needed to avoid public recapitalizations during past crises. The working assumption is that, historically, post-crisis bank recapitalizations brought banks to the minimum level of capital needed for viability. If this assumption is correct and if, prior to the crisis, banks had had capital equivalent to the sum of actual pre-crisis capital and the post-crisis public capital injection, then, other things remaining equal, no public recapitalizations would have been required.

We combine data from Bankscope on average capital ratios by country in 2007 in banking systems of OECD countries that experienced a crisis over the period 2007–13 with data from Laeven and Valencia (2018) on the fiscal outlays associated with bank recapitalizations (with both variables being expressed as percentages of total risk-weighted assets of the banking system in each country). The sum of pre-crisis bank capital levels and public bank recapitalization injections is shown in figure 4.

Figure 5 uses the data summarized in figure 6 to relate hypothetical pre-crisis bank capital levels to the share of public recapitalization events that they would have helped avoid. Consistent with our previous findings, the marginal benefit of additional capital in terms of avoiding public recapitalization episodes is relatively high until 15–17 percent risk-weighted capital ratios (which help avoid public recapitalizations in 75 percent of banking crises). The marginal benefit of bank capital declines rapidly after that. The results from data on public bank recapitalization expenses are therefore highly consistent with our previous estimates based on NPL data—both confirm

induced a loss of 4.4 percentage points of bank capital. Two observations are worth emphasizing: First, loan losses corresponding to the 85th percentage of banking crises (as used in our analysis) are two to four times as high as losses in the U.S. and European stress tests (which, being stress tests over plausible outcomes, consider relatively milder scenarios than those of a full-blown crisis). This highlights the conservative nature of our estimates. Second, our analysis employs a coefficient of 1.75 to convert loan losses into losses in risk-weighted capital; this is in between the coefficients of 1.25 and 1.9 implied by U.S. and European stress tests. (A smaller coefficient in U.S. stress tests is a product of low predicted losses on bank securities holdings.)

Figure 4. Pre-crises Bank Capital and Fiscal Recapitalization Expenses in Banking Crises from 2007 Onward

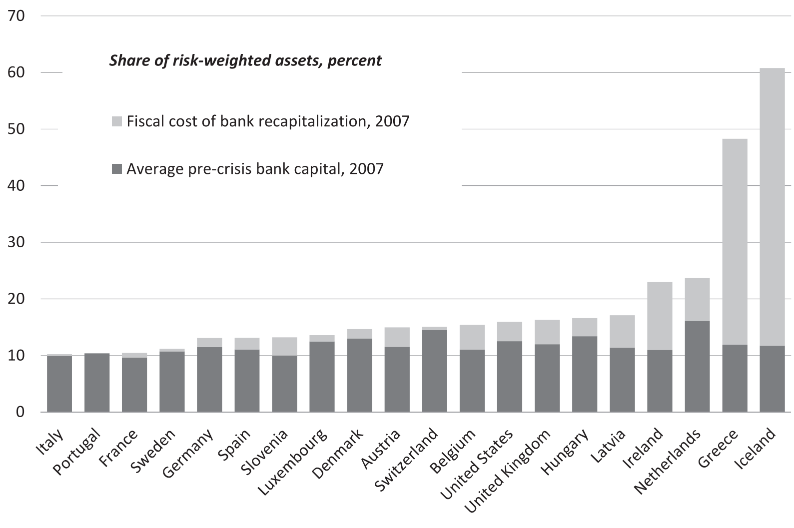
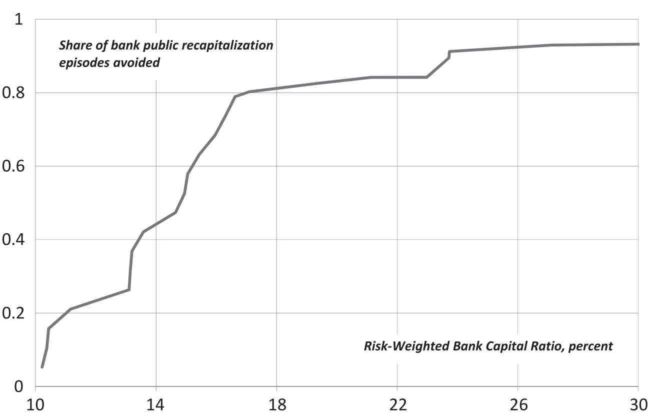


Figure 5. Share of Public Recapitalization Avoided, Depending on Hypothetical Pre-crisis Bank Capital Ratios



that bank capital in the range of 15–23 percent of risk-weighted assets would have enabled banks to absorb loan losses and would have allowed avoidance of public recapitalizations of banks in about 80 percent of banking crises in advanced economies.

4. Robustness

The previous section estimated bank capital levels that would have been sufficient to absorb losses in most historic banking crises in advanced economies. We offered estimates based on two alternative types of data: NPLs and public bank recapitalizations. The fact that the alternative methods produced very similar results helps assuage concerns related to the parameter uncertainty in our analysis. In this section, we explore the robustness of our results further.

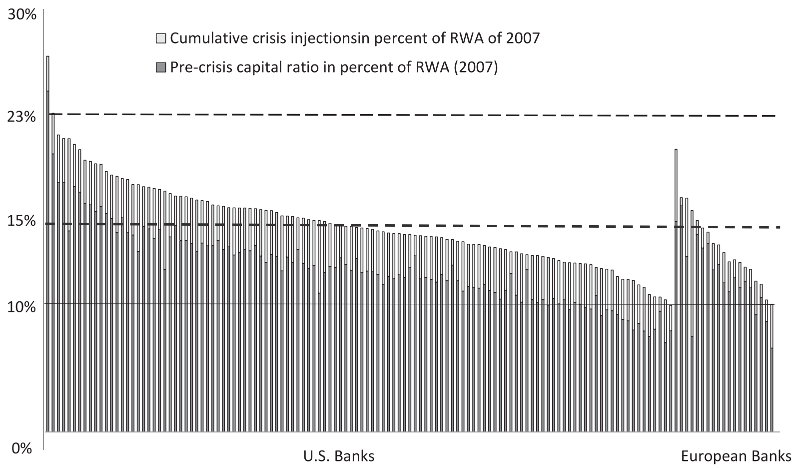
4.1 Loan Losses versus Securities Losses

Our analysis based on NPL ratios equates bank losses with loan losses; more precisely, we assume that banks accrue losses uniformly across different assets on their balance sheet. This implies that we will tend to overestimate capital needs when losses are concentrated on loans and underestimate them when they are concentrated on securities (such as was the case for many advanced economies in the global financial crisis). However, securities losses during the global financial crisis (Berrospide 2013) and in the Federal Reserve's "severely adverse scenario" stress tests (Board of Governors of the Federal Reserve System 2015) are close to or below the loan losses, suggesting that loan loss estimates can be extrapolated to securities losses. Further, both loan losses and securities losses during the global financial crisis and in the "severely adverse" stress test are below our estimates of the 80th percentile of loan losses in OECD banking crises, suggesting that our estimates of the capital needs are in any case sufficiently conservative.

4.2 Aggregate Losses versus Losses in Individual Banks

Our analysis is based on average NPL ratios and average bank recapitalization expenditures in the banking system. In practice, losses or

Figure 6. Pre-crisis Bank Capital and Capital Injections during the Crisis

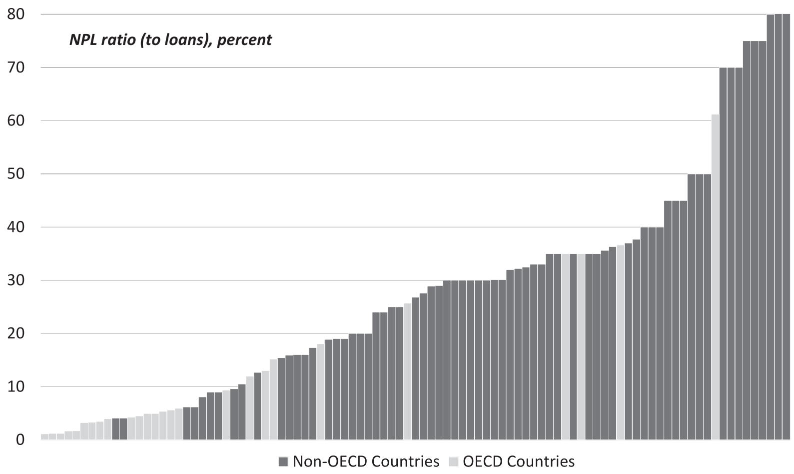


recapitalization needs at individual banks may differ from the country mean, and thus our methodology will underestimate the level of capital necessary to preserve positive equity across the entire system. (Still, the average level of capital remains informative as to the overall capacity of the banking system to absorb losses and may affect the authorities' ability to confront the crisis, including by facilitating takeovers of weaker banks by stronger ones.) To assess the robustness of our findings to the distribution of bank capital needs, we examine bank-level government capital injections during the recent crisis in large European and U.S. banks.[9]

Figure 6 plots, at the bank level, the sum of the pre-crisis capital and capital injections during the crisis (both in percent of pre-crisis RWA, similar to figure 4). The figure suggests that a capital of 15 percent in 2007 would have avoided the need for capital injection in almost 55 percent of cases in the United States and 75 percent

[9]The data on capital injections in European banks are taken from estimates by Fratianni and Marchionne (2013), merged with bank financials from SNL Financial, and only cover injections between November of 2008 and January of 2010. The data on U.S. injections are from SNL Financial and are based on the Troubled Asset Relief Program.

Figure 7. Nonperforming Loans as a Share of Loans: OECD Countries versus Non-OECD Countries

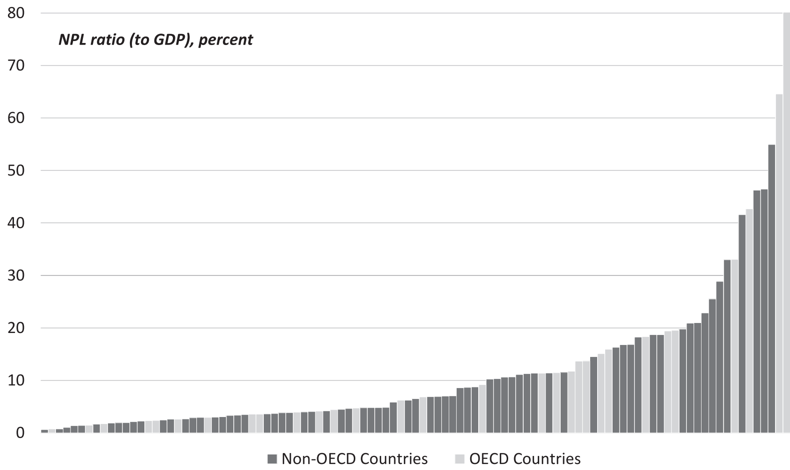


of cases in Europe (based on the available data), while a capital of 23 percent would have eliminated the need for injection in virtually all cases. While the 55 percent figure in the case of the United States might seem low, note that this is based on the lower bound of our range. Further, the Capital Purchase Program's terms were relatively attractive to avoid stigmatizing participating banks as being weak (Swagel 2009).

4.3 Advanced Economies versus Emerging Markets and Developing Countries

The analysis of section 3 focused on advanced economies only for comparability. Emerging market and developing countries have historically had higher NPL ratios in banking crises (figure 7, light gray bars). In principle, higher NPLs, all else being equal, call for higher levels of capital to absorb them. Applying the method of section 3.1 to convert NPLs into bank capital needed to absorb them suggests that capital ratios in the 15–23 percent range would have been sufficient to absorb losses in only about half of all banking crises in non-OECD economies. This is not surprising once one observes that in these countries, macroeconomic shocks tend to be larger, credit

Figure 8. Nonperforming Loans as a Share of GDP: OECD Countries versus Non-OECD Countries



tends to be less diversified, and institutional factors lead to larger loss-given-default ratios.

Consistent with this view, non-OECD countries (on average) have been imposing higher capital requirements on banks. In 2010, the minimum capital ratios in OECD countries were almost uniformly 8 percent. In contrast, the median minimum capital ratio in non-OECD countries was 10 percent. Moreover, almost a quarter of non-OECD countries had a minimum capital ratio of 12–15 percent, or 50 percent higher than what was typical in OECD countries (Barth, Caprio, and Levine 2013).

An offsetting factor to higher bank losses during banking crises is that, historically, non-OECD countries tended to have much smaller banking systems relative to gross domestic product (GDP) than OECD countries. This leads to NPLs as a share of GDP rather than as a share of bank loans being comparable in banking crises in advanced and other economies (figure 8). This means that when bank losses exceed the absorption capacity provided by capital, their effect on the economy (and thus the fiscal accounts) is likely also to be smaller. Everything else being equal, the ex post cleanup operations are likely to be less onerous than in countries with larger banking systems. For instance, given the smaller size of their banking systems, had non-OECD countries imposed bank capital ratios in the 15–23 percent range, in 80 percent of banking crises losses exceeding the absorption capacity of bank capital would have been within 3 percent of GDP, usually a manageable fiscal burden. Consequently, desirable bank capital levels in OECD and non-OECD countries might be closer than they appear from the first-brush NPL ratios analysis.

There are, however, two caveats to this conclusion. First, the potential fiscal costs of bank cleanups in emerging economies are destined to increase beyond this estimate, as many have recently experienced rapid credit growth, making current ratios of bank credit to GDP higher than past averages suggest. Second, the estimate should not give rise to complacency, as bank losses in the remaining 20 percent of banking crises (often, twin crises) would have been substantial. Further, if we took the higher capital needs in non-OECD countries at face value, a strategy complementing higher capital ratios would be to reduce potential NPLs through institutional improvements (in regulation, supervision, and resolution).

4.4 Dealing with Severe Banking Crises

In focusing on the banks' ability to absorb losses in most banking crises, our approach omits the issue of cleanup costs in the left tail of most severe banking crises where even higher bank capital does not provide sufficient loss-absorption capacity. While rare, the severe crises might also be the costliest. In a way, this omission is an inherent limitation of our seawall approach: a real seawall also might not protect from a truly large tsunami or an earthquake. Ex post government intervention might be essential in truly severe crises (Geithner 2014). Still, even for very severe banking crises, high bank capital would decrease ex post cleanup costs and provide the authorities additional breathing space for a more orderly resolution.

5. The Costs of Higher Bank Capital

Section 3 showed that capital in the range of 15–23 percent of risk-weighted assets would have absorbed bank losses in the majority of past banking crises, and higher capital ratios are relatively ineffective in preventing additional banking crises. The inflection of marginal benefits of bank capital points to capital in the 15–23 percent range as a plausible "optimal" bank capital that may enhance financial stability and reduce expected crisis-associated fiscal outlays. Yet, we said nothing about the effects that this higher capital would have on the availability and cost of bank credit, and, ultimately, on macroeconomic performance. In this section, we verify that the costs of bank capital in the 15–23 percent range appear manageable. To this end, we review the literature on the costs of bank capital (summarized in table A.1 in the appendix), and discuss in this section its main findings.

5.1 Steady-State Cost of Capital

It is useful to separate the steady-state and the transitional costs of higher bank capital. The econometric literature on the steady-state costs of bank capital is relatively thin, reflecting the difficulty in estimating such costs. Because of relatively stable capital regulation over the past few decades, most econometric studies exploit the cross-sectional and time-series variation of bank capital within a given regulatory framework. Here, based on U.S. data, the literature generally finds that a 1 percentage point higher tier 1 capital ratio is associated with loan rates that are 2.5 basis points higher: a very modest relationship. A caveat is that, since this variation reflects banks' endogenous choices (banks optimizing how much capital to hold over the regulatory minimums), we can expect the effect of an exogenous, regulatory-mandated increase in capital to be larger than the econometric estimates obtained in such studies.[10]

Given the limitations of econometric frameworks in the absence of exogenous variation in bank capital, other studies rely on calibrated models to assess the steady-state costs of bank capital. The key parameter of these models is the degree of the assumed Modigliani-Miller offset: to what extent a policy-imposed increase in the capital requirement would increase the total funding costs of banks. An increase in a firm's capital reduces its riskiness and thus

[10]These estimates are consistent with prima facie historical evidence, showing that spreads between the reference and lending rates were not higher in periods when banks were much more highly capitalized (see Miles, Yang, and Marcheggiano 2013 for evidence from the United Kingdom and the United States).

its cost of borrowing. As discussed in section 2, Modigliani and Miller (1958) show that under a set of ideal assumptions, this effect fully offsets any potential increase in the total funding cost from a shift in funding structure, making an increase in capital essentially costless to banks and inconsequential to lending rates. Therefore, the degree to which MM holds is a crucial question. Overall, most studies that allow for some MM offset find extremely small effects: the impact of a 1 percentage point increase in capital requirements on lending rates is about 2 basis points (bps), consistent with empirical studies. Studies that assume that MM offset does not exist suggest an effect of up to 13 bps—still a reasonably modest one. The effects of this increase in the cost of bank funding on lending can be compensated in the long term, for example, through more accommodative monetary policy.

The effect of higher bank capital on safe assets creation also appears modest. Assume that bank balance sheet size is fixed, and the increase in bank capital reduces one-for-one the volume of bank deposits. Then, an increase in bank capital from 14 percent of risk-weighted assets, an average across large banks today, to 23 percent, the top of our range, implies a reduction in the volume of bank deposits by (23–14)/1.75 = 5.1 percent of bank liabilities (where 1.75 is the average risk weight; see table 2). Forgoing a 70 bps safety premium possibly associated with bank deposits (set at the top of the range in Krishnamurthy and Vissing-Jorgensen 2012 and Greenwood, Hanson, and Stein 2015) on that volume of bank liabilities would increase bank cost of funding by a modest 3 bps. This brings the total effect of higher bank capital on the cost of lending to 5–16 bps, depending on the MM offset.[11]

Modest steady-state costs of higher bank capital imply low additional incentives to migrate activities out of the regulated banking system. This mitigates the theoretical concerns about a possible expansion of shadow banking. Indeed, there is little evidence

[11]Some argue that the economy exhibits a relatively inelastic demand for safe assets (Gorton, Lewellen, and Metrick 2012; Gorton and Ordonez 2013). This raises the question of what assets can substitute for a reduced volume of bank deposits in safe assets supply. Yet this concern also appears manageable. For example, in the United States, a decline in safe assets supply of the magnitude of 5.1 percent of bank liabilities can be compensated by increasing the volume of outstanding Treasury bills and notes by 8 percent (all data as of end-2017).

of migration to shadow banking in countries implementing higher than Basel leverage requirements, such as Switzerland. Further, to the extent that the migration of activities to shadow banking represents regulatory arbitrage, it can be reduced or prevented by more comprehensive bank regulation (Claessens and Ratnovski 2014).

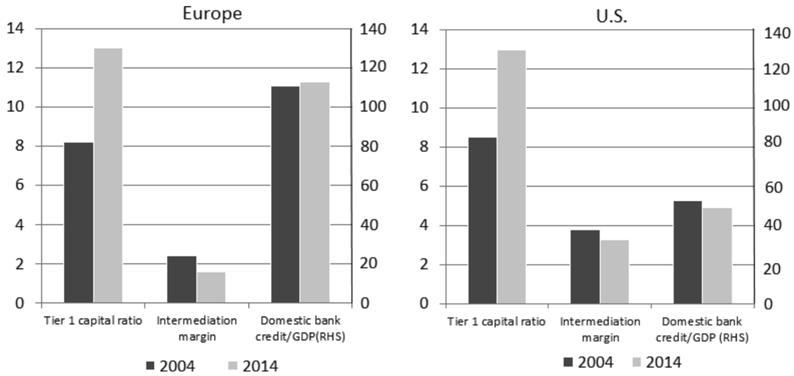
Based on these estimates, it would be relatively easy to argue for even higher bank capital ratios than the 15–23 percent range suggested in the previous section. Still, given that banking crises of extreme magnitudes are rare, it is difficult to see such extremely high levels of bank capital as a policy priority. Also, there is some risk that the costs of bank capital may increase nonlinearly in the level of capital—for example, for some adverse effects from its impact on bank business models. This calls for caution in extrapolating observed low costs of capital into the costs of capital at substantially higher levels.

5.2 Costs of Transitioning to Higher Capital

A larger empirical literature (generally employing tighter identification strategies than the literature on steady-state costs) documents the transitional costs of changes in bank capital. This literature often exploits bank-level shocks to capital—resulting either from losses or idiosyncratic (bank-level) regulatory actions—to identify the exogenous effects of tighter capital regulation on the availability and cost of bank credit. The literature finds that a 1 percentage point increased capital requirement is associated with a 5–8 percentage point contraction in lending volumes over the short run (see, for instance, Peek and Rosengren 2000; Aiyar, Calomiris, and Wieladek 2014; Brun, Fraisse, and Thesmar 2014; Eber and Minoiu 2015).

The problem with these estimates is that they rely on sudden changes in bank capital: events that mostly characterize banks that are in some state of distress. Many of the challenges associated with raising capital under these circumstances are not relevant for evaluating the effects of gradual changes in capital regulation that would affect an entire banking system. For instance, in the short run, distressed banks may be more likely to meet tighter regulatory requirements by reducing the asset side of their portfolios more than they would if they were fully sound and could raise capital gradually over time. Similarly, the stigma attached to a bank trying to raise capital

Figure 9. Bank Capital Ratios and Credit Provision, Pre- and Post-Crisis



in isolation is unlikely to apply in a context of systemwide regulatory reform. It follows that estimates based on short-lived bank-level shocks are likely to overestimate the transition costs of higher capital requirements. The literature also does not provide a guide as to how these transition costs vary depending on macroeconomic conditions and between rapidly growing emerging markets and advanced economies.

Also, there is evidence that transition costs tend to be lower if one allows banks to adjust to the new regime more gradually. For instance, calibrated models for several OECD countries suggest that, on average, over eight years, a transition to a 1 percentage point higher capital requirement is associated with a 17 bps increase in lending, a 1.5 percent decline in lending volume, and a 0.16 percent drop in GDP compared with the baseline (Macroeconomic Assessment Group 2010).

Consistent with these considerations, an analysis of the increase in capital requirements in the wake of the global financial crisis suggests that the effects of tighter regulation on intermediation margins and the overall supply of bank credit have been limited (Cecchetti 2014). For instance, average risk-weighted capital ratios at large banks in the United States and Europe increased by almost 5 percentage points between 2004 and 2014. But credit-to-GDP ratios and intermediation margins remained virtually unchanged (figure 9). Overall, this suggests that transition costs are likely manageable.

6. Conclusions

This paper contributed to the debate on the optimal capital levels in banks. We took a seawall approach. First, we considered how much capital would have been enough to absorb bank losses in a majority of historical banking crises. Second, we reviewed existing literature that suggests that the costs of such capital levels would be acceptable.

The key result of the paper is that bank capital in the range of 15–23 percent of risk-weighted assets would have absorbed bank losses in most past banking crises in advanced economies. This range was obtained based on two alternative sets of bank data (NPLs and public recapitalization), offering comfort that the results are robust to the modeling assumptions employed. Increases in capacity to absorb losses beyond this are likely to provide limited benefits. Hence, given the uncertainty surrounding the long-term welfare costs of bank capital, bank capital in the 15–23 percent range appears appropriate for banks in advanced economies.

The 15–23 percent estimate can be taken with a conservative bend. The estimate does not consider the potential reduction in risk-taking induced by higher capital through "skin-in-the-game" effects: the impact of higher bank capital on the incentives of bank shareholders and managers (Laeven and Ratnovski 2014). Further, capital requirements consistent with 15–23 percent bank capital may be below this range, as banks tend to hold buffers over the regulatory minimums, tighter post-crisis banking regulation in aspects other than bank capital (such as more stringent stress tests) may have reduced bank risk for any given level of bank capital, and because part of bail-in-able capacity might be provided by instruments other than bank capital (such as subordinated debt).

The 15–23 percent range is close to, if slightly above, the upper limit of the Basel III capital requirements, and is very similar to the Financial Stability Board's total loss-absorbing capacity standards, as well as the Federal Reserve's proposal of 9.5 percent of total leverage exposure for global systemic banks.[12] The range is also consistent with the 8 to 20 percent optimal bank capital range established in most calibrated dynamic general equilibrium models

[12]See http://www.federalreserve.gov/newsevents/press/bcreg/20151030a.htm.

(Van den Heuvel 2008; Nguyen 2013; Begenau 2014; Martinez-Miera and Suarez 2014; Mendicino et al. 2015).[13]

The estimated loss-absorption needs can be refined to allow for heterogeneity across banks and over time. Banks that are not systemically important (those that can be allowed to fail without major spillover effects) could be allowed to hold lower capital and loss-absorption capacity. Similarly, most banking crises follow periods of rapid credit growth, suggesting a role for countercyclical buffers (Borio 2014; Claessens 2015).

We find that the results on optimal bank capital are more nuanced for emerging markets and low-income countries. On the one hand, banking crises in these countries have historically been associated with greater bank losses. On the other hand, because banking systems in these countries tend to be smaller than those in advanced economies, losses in excess of capital will likely represent a smaller share of GDP and thus might have more limited macroeconomic effects. In this context, the relative role of greater loss-absorption capacity and improvement in governance and institutions aimed at reducing losses in crises should be the subject of future research.

In emerging market and developing economies, tighter bank capital standards can be complemented by institutional improvements (in regulation, supervision, resolution, and governance) to reduce possible losses in banking crises. In advanced economies, higher bank capital requirements may provide stronger incentives for regulatory arbitrage and increase the risk of activities migrating to unregulated or less regulated financial intermediaries (such as insurance companies or broker-dealers). In that context, it is essential that tighter capital and loss-absorption requirements are complemented with measures that widen the perimeter of prudential and macroprudential regulation.

The paper also reviewed empirical evidence on the costs of higher bank capital. The evidence overwhelmingly suggests that the steady-state (long-run) social costs of higher bank capital requirements,

[13]The calibrated welfare effects of varying bank capital within that range in terms of higher lending rates and lost consumption are relatively small. The relatively wide range of the estimates for the optimal level of capital reflects the many degrees of freedom in model design and parameter calibration. It is also consistent with a similarly wide 15–23 percent range of estimates obtained in our analysis.

within our estimated range, are likely to be small. The costs of transitioning to higher bank capital might be substantial, but also might be lower when capital adjustment is staggered or takes place in the upswing of the credit cycle. Overall, the cost of higher bank capital corresponding to our estimates appears acceptable.

Appendix

Table A.1. Estimates of the Steady-State and Transitional Effects of Higher Capital Requirements on the Cost of Bank Credit

Paper	Data and Method	Cost of Capital
A. Steady-State Impact		
Elliott (2009)	U.S. banks, 2009:Q1–2009:Q2, calibration	4 pp ↑ in ratio of equity over unweighted assets leads to ↑ in lending rate by 80 bps.
Bank of England (2010)	U.K. banks, calibration.	1 pp ↑ in capital req. leads to ↑ in lending rate by 7 bps.
Bank for International Settlements (2010)	OECD banks, 1993–2007. Dynamic general equilibrium model.	1 pp ↑ in capital req. leads to ↑ in lending rate by 13 bps.
Berrospide and Edge (2010)	U.S. banks, 1992–2008. Empirical estimation.	1 pp ↑ in capital req. leads to ↑ in loan growth by 0.7–1.2 pp.
Kashyap, Stein, and Hanson (2010)	U.S. banks, 1976–2008. Calibration assuming tax effect and MM effect.	10 pp ↑ in capital req. leads to ↑ in lending rate by 25–45 bps.
King (2010)	OECD banks, 1993–2007. Calibration assuming no changes in return on equity and cost of debt and a full pass-through of cost of funding.	1 pp ↑ in capital req. leads to ↑ in lending rate by 15 bps.
de Resende, Dib, and Perevalov (2010)	Canadian banks. Dynamic general equilibrium model.	6 pp ↑ in capital req. leads to ↑ in lending rate by 7.5 bps, ↓ in lending by 0.24%, and ↓ in GDP by 0.07%.

(*continued*)

Table A.1. (Continued)

Paper	Data and Method	Cost of Capital
A. Steady-State Impact		
Santos and Winton (2010)	U.S. banks, 1987–2007. Empirical estimation. They test the hypothesis that less-capitalized banks charge higher rates on borrowers with no access to public debt markets.	5 pp ↑ in capital req. leads to ↓ in lending rate to credit-constrained firms by 15 bps.
Cosimano and Hakura (2011)	Banks in advanced economies, 2001–09. Empirical estimation.	1.3 pp ↑ in leverage ratio leads to ↑ in lending rates by 16 bps and ↓ in loan growth by 1.3% in the long run.
Schanz et al. (2011)	U.K. banks, 2006–09. Calibration.	1 pp ↑ in capital req. leads to ↑ in lending rate by 7.4 bps and ↓ in permanent GDP by 0.04%.
Slovik and Cournède (2011)	OECD banks, 2004–06. Calibration assuming no MM effect and a full pass-through.	1 pp ↑ in capital req. leads to ↑ in lending rate by 16 bps.
de Ramon et al. (2012)	U.K. banks, 1992–2010. Empirical estimation.	1 pp ↑ in aggregate capital ratio leads to ↑ in lending spreads by 9.4 bps.
Francis and Osborne (2012)	U.K. banks, 1996–2007. Empirical estimation.	3 pp ↑ in capital req. leads to ↓ in lending by 7% compared with the baseline.
Junge and Kugler (2012)	Swiss banks, 1999–2010. Calibration.	Halving leverage leads to ↑ in cost for nonfinancial sector by 0.6–1.5 bps and ↓ in permanent annual GDP by 0.04–0.05%.
Miles, Yang, and Marcheggiano (2013)	U.K. banks, 1997–2010. Calibration assuming half MM effect and one-third pass-through.	Halving leverage leads to ↑ in lending spread by 6 bps and ↓ in GDP by 0.15%.
Buch and Prieto (2014)	German banks, 1965–2009. Empirical estimation.	1 pp ↑ in capital req. leads to ↑ in bank loans by 0.22% in the long run.

(*continued*)

Table A.1. (Continued)

Paper	Data and Method	Cost of Capital
	A. Steady-State Impact	
Cohen and Scatigna (2014)	Large banks in advanced and emerging economies, 2009–12. Empirical estimation.	1 pp ↑ in capital ratio leads to ↑ in asset growth rate over the subsequent three years by 3 pp.
Martinez-Miera and Suarez (2014)	Dynamic general equilibrium model.	↑ in capital req. from 7% to 14% leads to ↑ in loan rate by 1.5 pp and ↓ in GDP by 8.5%, but also ↑ in aggregate net consumption of 0.9%.
Baker and Wurgler (2015)	U.S. banks, 1971–2011. Empirical estimation.	10 pp ↑ in tier 1 ratio leads to ↑ in cost of capital by 100–130 bps.
Brooke et al. (2015)	U.K. banks, 1997–2004. Calibration assuming MM effect and a full pass-through.	1 pp ↑ in tier 1 ratio leads to ↑ in lending rate by 5–10 bps and ↓ in permanent annual GDP by 0.01–0.05%.
Cline (2015)	U.S. banks, 2001–13. Calibration assuming half MM effect and a full pass-through.	15 pp ↑ in leverage ratio leads to ↑ in lending rate by 62 bps and ↓ in future path of GDP by 1.08 pp.
Kisin and Manela (2016)	U.S. banks, 2002–07. Empirical estimation.	1 pp ↑ in capital req. leads to ↑ in lending rate by 0.3 bps and ↓ in loan by 0.15%.
Begenau and Landvoigt (2017)	U.S. banks, 1999–2015. Dynamic general equilibrium model.	5 pp ↑ in capital req. leads to ↑ in lending by 3.6%, but has insignificant effect on GDP.
Clark, Jones, and Malmquist (2017)	U.S. banks, 1996–2012. Empirical estimation.	Halving leverage leads to ↑ in cost of capital by 14 bps for largest banks and ↓ in real GDP by 4.4 bps.
Dell'Ariccia, Laeven, and Suarez (2017)	U.S. banks, 1997–2011. Empirical estimation.	1 pp ↑ in capital req. leads to ↑ in lending by 0.6 pp.
Firestone, Lorenc, and Ranish (2017)	U.S. banks, 1988–2014. Calibration assuming half MM effect and a full pass-through.	1 pp ↑ in capital req. leads to ↑ in lending rate by 7 bps and ↓ in long-run GDP by 7.4 bps.

(*continued*)

Table A.1. (Continued)

Paper	Data and Method	Cost of Capital
	A. Steady-State Impact	
Barth and Miller (2018)	U.S. banks, 1892–2014. Empirical estimation.	↑ in leverage ratio from 4% to 15% leads to ↑ in cost of capital by 30 bps.
Gambacorta and Shin (2018)	International banks in advanced economies, 1994–2012. Empirical estimation.	1 pp ↑ in leverage ratio leads to ↓ in debt financing by 4 bps and ↑ in annual loan growth by 0.6 pp.
	B. Transitional Impact	
Furfine (2010)	U.S. banks, 1989–97. Dynamic general equilibrium model.	1 pp ↑ in capital req. leads to ↓ in lending growth rate by 5% in the first quarter.
Macroeconomic Assessment Group (2010)	Member countries using Financial Services Authority approach.	1 pp ↑ in capital req. implementation over eight years leads to, by 35th quarter, ↑ in lending spreads by 17 bps, ↓ in lending volume by 1.5%, and ↓ in GDP by 0.16% on average.
de Resende, Dib, and Perevalov (2010)	Canadian banks. Dynamic general equilibrium model.	6 pp ↑ in capital req. with a phase-in of four years leads to ↑ in lending spreads by 2 bps, ↓ in lending by almost 2%, ↓ in investment by 2.7%, and ↓ in GDP by 0.38%.
Institute of International Finance (2010)	G-3 banks, 2001–09. Calibration using a series of macro-banking-economic models.	2 pp ↑ in capital req. + other measures lead to, over the first five years, ↑ in lending spreads by 132 pp, ↓ in GDP growth by 0.6 pp per year on average.
Maurin and Toivanen (2012)	European banks, 2005–11. Empirical estimation.	1 pp capital gap dampens lending growth by 2–2.3 pp in median term.

(*continued*)

Table A.1. (Continued)

Paper	**Data and Method**	**Cost of Capital**
B. Transitional Impact		
de Ramon et al. (2012)	U.K. banks, 1992–2010. Empirical estimation.	1 pp ↑ in aggregate capital ratio leads to ↑ in lending spreads for household sector by 6.7 bps and for corporate sector by 19 bps.
Aiyar, Calomiris, and Wieladek (2014)	U.K. banks, 1998–2007. Empirical estimation.	1 pp ↑ in capital req. leads to cumulative ↓ in loan growth rate by 5.7 pp over the first three quarters.
Bridges et al. (2014)	U.K. banks, 1990–2011. Empirical estimation.	1 pp ↑ in capital req. leads to ↓ in household secured loans by 0.9 pp and commercial real estate lending by 8 pp over the first year. The first effect vanishes within three years, but the commercial real estate lending is reduced by 1.3 pp permanently.
Brun, Fraisse, and Thesmar (2014)	French banks, 2006–12. Empirical estimation.	1 pp ↓ in capital ratio leads to ↑ in loan size by 5 pp over the short period.
Corbae and D'Erasmo (2014)	U.S. banks, 2000–10. Dynamic general equilibrium model.	2 pp ↑ in capital req. leads to ↑ in loan interest rate by 50 bps and ↓ in loan supply by nearly 9%.
Mesonnier and Monks (2014)	European banks, 2011–12. Empirical estimation.	1 pp ↑ in capital req. leads to ↓ in annual loan growth rate by 1.2–1.6 pp over nine months.
Noss and Toffano (2016)	U.K. banks, 1986–2010. Empirical estimation.	15 pp ↑ in aggregate capital ratio leads to ↓ in lending by 1.4 pp and ↓ in GDP by 0.25% after 16 quarters.

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