Working Paper Series

WP 16-6 MARCH 2016

Benefits and Costs of Higher Capital Requirements for Banks

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Abstract

This study provides new estimates of the likely economic losses from banking crises. It also provides new estimates of the economic cost of increasing bank capital requirements, based on the author's earlier estimate (Cline 2015) of the empirical magnitude of the Modigliani-Miller effect in which higher capital reduces unit cost of equity capital. The study applies previous official estimates (BCBS 2010a) of the impact of higher capital on the probability of banking crises to derive a benefits curve for additional capital, which is highly nonlinear. The benefit and cost curves are examined to identify the socially optimal level of bank capital. This optimum is estimated at about 7 percent of total assets, with a more cautious alternative (75th percentile) at about 8 percent, corresponding to about 12 and 14 percent of risk-weighted assets, respectively. These levels are, respectively, about one-fourth to one-half higher than the Basel III capital requirements for the large global systemically important banks (G-SIBs).

JEL Codes: E44, G21, G28, G32

Keywords: Financial Regulation, Bank Capital Requirements, Capital Structure

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This paper seeks to contribute to the literature on optimal capital requirements for banks. Some prominent analysts have argued that extremely large increases in bank capital are desirable, because according to the Modigliani-Miller (1958) theorem, the mix between debt and equity should have no impact on the firm, and hence higher capital requirements would be costless to the economy while sharply reducing the risk of banking crises (Admati and Hellwig 2013). However, I show in Cline (2015) that for US banks, less than half of the Modigliani-Miller offset of lower equity unit cost attributable to less risk from less leverage is attained in practice. Because higher capital requirements would thus increase bank lending rates, raise the cost of capital to the economy, and reduce investment and output as a consequence, a key challenge for regulatory policy is to identify the optimal level of capital requirements.

Higher bank capital requirements reduce the probability of banking crises. Combining this reduction with estimates of the economic cost of banking crises provides a basis for calculating the "benefit" of higher capital requirements. This benefit is the expected damage avoided by reducing the risk of occurrence of a banking crisis. This paper first quantifies expected costs and frequency of banking crises, paying special attention to avoiding overstatement of recession losses if the economy has an unsustainable positive output gap prior to the crisis, as well as to finite life of losses considered to persist after the first few years of a crisis. The "benefits" section of the paper then continues with calibration of a "benefits curve" relating damages avoided to the level of bank capital, based on the most important official survey of the influence of bank capital on the likelihood of banking crises (BCBS 2010a).

The analysis then turns to the cost curve relating economic costs to the level of the capital requirement. This relationship turns out to be an upward-sloping straight line. The cost line is steeper if the Modigliani-Miller offset is lower, the excess unit cost of equity versus debt is higher, there is spillover to nonbank finance, the capital share in output is higher, and the elasticity of substitution between capital and labor is higher. The optimal level of capital will then be the amount at which the slope of the benefits curve equals the slope of the (straight-line) cost curve. Requiring still higher amounts of capital will not provide sufficient further reduction in expected damages from banking crises to warrant the additional loss of output caused by less capital formation. The calibrations explore a range of alternative parameter estimates to obtain a sense of the sensitivity of this optimal capital ratio, in addition to arriving at a central estimate.

BENEFITS

Actual GDP losses in past episodes of banking crises provide the point of departure for estimating the benefits of higher capital requirements. This section first sets forth a method for calculating losses from banking crises. These losses are then translated into a "curve" relating benefits of higher capital requirements to the level of these requirements.

Trend Output and Cumulative Initial-Years Loss

The first step in calculating losses is to identify a benchmark baseline for GDP that could have been expected in the absence of the banking crisis, for comparison against actual GDP realized. Defining year T as the year the crisis begins, crisis losses over an initial five-year period can be estimated as:

$$1) L_{cum5} = \sum_{t=T}^{t=T+4} \hat{Q}_t - Q_t$$

where $\hat{Q}_t$ is expected GDP and Q_t is actual GDP in year T and the four subsequent years. Expected output is calculated by applying a trend growth rate for output relative to working-age population to the annual growth in working-age population, with the base set as potential GDP in the year before the crisis. The use of working-age population is important because of the sharp demographic changes in the period after the Great Recession. Adjusting the base output level to potential addresses the problem of otherwise overstating the level of output that might have been expected by failing to recognize an unsustainable boom prior to the crisis.

For its part, expected output is calculated as:

$$2) \hat{Q}_t = \frac{Q_{T-1}}{(1+\Omega_{T-1})} \prod\nolimits_t (1+g) \times (1+n_t)$$

where Ω_{T-1} is the output gap in the year before the crisis, g is the long-term rate of growth of output per working-age population, and n_t is the rate of growth of working-age population in year t. The multiplication operator Π_t refers to the cumulative product from period 1 to period t.

Long-Term Losses

In most of the banking crises, output does not fully return to its trendline by the end of the fifth year.[1] A crucial question is then how to treat ongoing losses in later years. The approach here is to apply a finite life-span of the "missing" capital stock and worker skills caused by the crisis, rather than interpreting the loss as persisting over an infinite horizon. In contrast, simply capitalizing the gap between output and trend still present in year 5 (or another year chosen as marking the end of the crisis) by dividing by the discount rate would implicitly assume that the extra capital equipment that would have been created during the crisis under normal circumstances would have had an infinite life. The approach here is to identify a lifetime "M" of the relevant productive capacity, and to apply straight-line depreciation. The

1. This outcome is consistent with the finding by Blanchard, Cerutti, and Summers (2015) that in two-thirds of recessions in advanced economies in the past 50 years, output after the recession is below the prerecession trend.

present value of losses subsequent to year 5 ("LT" for long-term), discounted back to values of the base year preceding the crisis, is calculated as:

$$3) L_{LT} = L_5 \sum_{t=6}^{t=M+5} \{1 - \frac{1}{M}(t-5)\}/(1+\rho)^{t-5}$$

where $L_5 = \hat{Q}_5 - Q_5$, and ρ is the discount rate. I set this rate at 2.5 percent, based on US experience in 1962–2008.[2] For productive capacity lifetime I use 15 years.

The damage of the banking crisis is then expressed as a proportion of precrisis potential output, in two components: the initial cumulative five-year loss, d_{cum5} , and the longer-term loss over the subsequent 15-year horizon, d_{LT}. The first is the value in equation (1) divided by potential output in the base year prior to the crisis; the second is the value in equation (3) divided by the same base potential output.[3] Total damage is the sum of the two measures: $d_{tot} = d_{cum5} + d_{LT}$.

Figure 1 illustrates the losses from a banking crisis. The solid line in the figure is the path of actual output. It initially peaks in the year before the crisis, t_{-1}, falls in the year of the crisis, t_0, and rises thereafter to the fifth year of observed data, t_1. Potential output at the outset of the crisis is Q*, but actual output is higher at Q_{t-1}, reflecting a positive output gap. Output then falls well below potential in the crisis, to Q_{t0}. The approach here calculates potential output rising at trend rates (the middle of the three upward sloping dashed lines). The period t_2 is set here at 15 years after the fifth year. The approach here calculates output loss as the sum of areas A and B. If areas C and G were also included in the loss estimate, the implicit assumption would be that capital equipment that was not created because of the crisis would have had an infinite life.

In an upper-bound estimate of output loss, there would be no reduction from the initial positive output gap, and losses would be assumed to last forever. In that case the loss would add not only areas C+G but also D+E+F (presumably with some time discounting to address the infinite horizon). Such an estimate, however, would be seriously exaggerated.

Estimates of Losses from Banking Crises

By now a relatively standard set of episodes is recognized as banking crises (see BCBS 2010a, 39; Reinhart and Rogoff 2008; Laeven and Valencia 2012). For several decades after the Great Depression, banking

2. The 10-year Treasury bond rate after deflation for the consumer price inflation rate in the same year showed an average of 2.45 percent in 1962–2008. The inflation-adjusted 10-year Treasury bond had an average rate of 2.25 percent in 2003–08 (earlier periods are not available). Calculated from Federal Reserve (2016); IMF (2015a); and BLS (2016).

3. Note that the first five years involve no discounting, in part because with typically falling per capita income the usual intertemporal consumption basis for discounting is not present but also because the period is short enough for discounting to have limited influence.

crises were essentially absent in industrial countries. Even so, US and other industrial-country banks barely avoided a crisis from large exposure to Latin America in the region's sovereign debt crisis of the early 1980s, in part thanks to concerted lending and official sector support of adjustment programs (Cline 1984, chapter 2). Failure of one large US bank (Continental Illinois) in 1984 did not metastasize into a banking sector crisis, as the Federal Deposit Insurance Corporation guaranteed all depositors and creditors and the failure stemmed from bank-specific rather than systemic shocks. Then by the late 1980s crises began to arise, notably in the savings and loan banks in the United States. The early 1990s witnessed banking crises in Nordic economies (Finland, Norway, and Sweden), and by 1997 Japan experienced a crisis that had built up in the aftermath of the collapse of the bubble economy in the late 1980s. The "mother of all postwar banking crises," however, has turned out to be that associated with the Great Recession. In 2007–08, 16 industrial countries experienced banking crises, accounting for about two-thirds of all the banking crisis episodes among industrial countries in the past three decades.[4]

Table 1 reports estimates for equations (1) through (3) for 22 banking crises in 1977–2008 in advanced industrial countries.[5] It also reports corresponding estimates for six advanced economies that escaped a banking crisis in the 2007–08 period. The first column indicates the year the crisis began. The second column reports the average growth rate of real GDP per working-age population from 1980 through 2014, for crisis episodes in 2007 or 2008. For earlier crises, the column shows the corresponding growth rate during the two decades prior to the crisis through year 5 after the crisis.[6] The third column reports the International Monetary Fund's estimate of the output gap in the year prior to the crisis, in percentage terms (IMF 2015a).[7] There is a positive output gap in all but two of the 22 episodes, suggesting the importance of adjusting the trend GDP estimates downward by the amount of the positive output gap (equation 2). In both Greece and Ireland, actual output was about 10 percent above potential in 2007, making the adjustment particularly important in these cases.

The fourth column reports average annual growth of working-age population in the five years beginning the year of the crisis. This potential labor force was shrinking relatively rapidly in Germany, Greece, and Ireland after 2008, and also in Portugal and Spain. The steepest decline, at about 0.8 percent per year, was in noncrisis Japan.

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4. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Netherlands, Portugal, Spain, Sweden, Switzerland, United Kingdom, and the United States (Laeven and Valencia 2012, 24–26).

5. The crises are as identified in Laeven and Valencia (2012).

6. These rates are from log-linear regressions of real GDP per working-age population on time. Real GDP is from IMF (2015a, 2015b). Population of age 16–64 is from OECD (2015a, 2015b). For Germany, growth is postunification, with data beginning in 1991.

7. No estimate is available for Spain in 1976. The output gap used here is estimated from applying a Hodrick-Prescott filter to output for 1957–82.

The fifth column indicates the cumulative five-year loss of output against the benchmark potential GDP path, as a percent of potential GDP in the year before the crisis. The median five-year loss amounted to about 23 percent of base-year potential GDP. The final column of the table reports a similar estimate for four-year loss of output as calculated by Laeven and Valencia (2012). Those estimates are broadly similar, albeit somewhat larger—with a median of about 32 percent. The higher estimates reflect the absence of an adjustment for above-potential GDP in the base year in the Laeven-Valencia estimates, as well as their use of trend GDP growth (rather than actual working-age population growth). These differences make the estimates much more modest here for Ireland (31 percent, instead of 106 percent of GDP in the Laeven-Valencia estimates) and Greece (22 percent instead of 43 percent). There is also a sizable difference for the United States (19 percent of base GDP instead of 31 percent).

The sixth column indicates the shortfall of output in year 5 from the benchmark baseline for potential GDP, expressed as a percent of the base year potential GDP (in the year prior to the crisis). The seventh column of table 1 indicates the long-term loss subsequent to year 5 (equation 3), as a percent of the base year potential GDP.[8] With a median of 43 percent of GDP, this cost is relatively large. The eighth column is the sum of the five-year cumulative loss and long-term cost, again as a percent of base year potential GDP. The median total loss is 64 percent of GDP.

The bottom panel of table 1 carries out the same calculations for what may be seen as a "control" group of advanced economies that did not experience banking crisis in the Great Recession. Three of these economies (Finland, Japan, and Norway) experienced banking crises in the 1990s but escaped the banking crises of 2007–08.[9] It turns out that the "losses" that would have been attributed for this period are also relatively high for these economies. The median five-year cumulative loss is about 21 percent of base year potential GDP, surprisingly close to the 23 percent median for the crisis cases. The median total cost (including long-term) is about 54 percent of GDP, compared with 64 percent for the banking crisis cases. At the extreme, then, it could be posited that the contribution of the banking crisis to losses should be calculated as the excess of the estimates for the crisis group over the control group. If this approach were adopted, the marginal contribution of the banking crisis would be small—only 10 percent of base year potential GDP even for the total cost including long-term.

It might be argued that the losses in such economies as Canada and Japan were driven by external diseconomies of the banking crises in the United States and the euro area, and thus that the problem is

8. With $\rho = 0.025$ and $M = 15$, the value of the summation on the right-hand-side of equation (3) is 5.44. The long-term cost d_{LT} in the third-from-last column in table 1 equals this constant times the previous column, "gap5," which in turn equals $L_5 / \hat{Q}_0$ in equations (1) and (2).

9. For purposes of comparability to the main advanced industrial economies, this set of control countries excludes several economies also designated as "advanced" by the IMF (2015a): Eastern European, newly industrialized East Asian, and small economies.

underestimation of the banking crisis costs (rather than overestimation) for lack of including externalities. On the other hand, much of the loss of output in the euro area reflected a sovereign debt crisis, and with the exception of Ireland and to a considerably lesser extent Spain, this crisis did not stem primarily from banking crises (Cline 2014, chapter 3). Essentially the worst global recession in 80 years imposed severe losses, and attributing the entirety of these losses to banking crises may overstate the cost of a typical banking crisis and thus the welfare gains from reducing the probability of such a crisis.

Another complication is that the IMF's calculations of the output gap might be seen as endogenous to hindsight reflecting actual history rather than what might have been. For example, in October 2007 the IMF's estimate of the US output gap for 2007 was –0.5 percent of potential GDP, whereas in October 2015 its estimate of the 2007 output gap was +2.66 percent of potential GDP (IMF 2007b, 2015a). Similarly, whereas the median value of the initial output gap in table 1 is +2.5 percent, the corresponding median value for contemporary estimates by the IMF in 2008 (or, for the United States and United Kingdom, 2007) was –0.4 percent (IMF 2007a, 2008c). Yet it would seem inappropriate to completely ignore the benefit of hindsight. In the US economy, for example, the jeopardy that arose from the housing market bubble is now evident but was much less recognized in 2007.

The analytical challenge is that an extremely wide range can arguably be asserted for the magnitude of banking crisis damages. As noted, the estimate could be as low as 10 percent of the base year's GDP, using the control group approach. At the opposite extreme, if it is assumed that there was no positive output gap before the crisis, and that the entire gap from the no-crisis baseline by year 5 should be seen as permanent, then the median damage from a banking crisis could be estimated as high as 450 percent of GDP![10]

In the empirical estimates developed below, the central estimate of damage is placed at the 64 percent benchmark reported in table 1. The main calculations include alternatives at 30 percent and 100 percent of base-year GDP as what might be considered plausible-low and plausible-high estimates, respectively. However, in the discussion of the final results, the outcomes are also reported for two extremes: damage of 10 percent and 450 percent of base-year GDP. As will be shown, the resulting optimal ratio of capital to assets turns out to be considerably narrower than might have been thought for this 45-fold variation in the damage parameter. That outcome essentially reflects the sharp curvature of the function relating the probability of a banking crisis to the capital ratio, as developed below.

Finally, it warrants mentioning that the damage estimates here are formulated in a binary nature: either zero, for no crisis, or a fixed estimate (64 percent of base-year GDP in the central estimate), if a

10. With no initial output gap, the median output loss is larger by 2.5 percent of initial GDP, boosting the median five-year loss to 35.4 percent. The median gap in year 5 becomes 10.3 percent of initial year GDP. Assuming this gap persists forever, and discounting at 2.5 percent, the "permanent" portion of the loss becomes 10.3/0.025 = 412 percent of base-year GDP. Adding the loss in the first five years boosts the total to 447 percent.

banking crisis occurs. It would be useful to provide a graduated estimate of output loss that relates the depth of the loss, given a banking crisis, to the amount of bank capitalization. However, the various studies that provide empirical information on banking crises typically focus on the probability of a crisis in relation to bank capitalization, rather than additionally calculating a relationship between the severity of the crisis (if one does occur) to the depth of bank capitalization.

Comparison with Basel Committee Estimates

In its 2010 survey of damages from banking crises, the Macroeconomic Assessment Group of the Basel Committee on Banking Supervision (BCBS) assessed the long-term economic impact (LEI) at 19 percent of GDP with no permanent effects; 158 percent of GDP with permanent effects and an infinite horizon; and 63 percent for the "median cumulative effect across all studies," which it also characterized as the case in which "crises have a long-lasting or small permanent effect on output" (BCBS 2010a, 10, 13). On the basis of the existing studies, the BCBS argued that a 1 percentage point reduction in the annual probability of a banking crisis would thus generate gross benefits corresponding to 0.19 percent, 0.63 percent, or 1.58 percent of GDP, depending on the degree of permanency of the losses. The study also noted that the estimates were from before the Great Recession, and cited Haldane (2010) as arguing that the current crisis would impose much higher losses, ranging from 90 to 350 percent of (one-year's) world GDP (BCBS 2010a, 11).

It turns out that the estimates in table 1 are extremely close to the middle case of the BCBS. Namely, the median total loss of 64 percent of base GDP is almost the same as the survey median of 63 percent found by the BCBS for the middle (as opposed to high permanent) estimate, even though in contrast the present study is heavily dominated by actual experience from the 2007–08 crisis rather than for earlier periods (and a wider range of countries, including emerging-market economies). Similarly, the cumulative initial effect during the crisis years, 19 percent in the BCBS estimates, is fairly close to the median five-year cumulative effect estimated here (22.9 percent). The key difference in the damage estimates, then, is in the long-term "permanent" effects, as table 1 shows no estimates anywhere near 158 percent. The central reason again is the judgment that nothing lasts forever and that some form of productive resource lifespan must be taken into account in arriving at a meaningful "permanent" effect.

There is another key contrast, however. It concerns the baseline frequency assumed for the incidence of banking crises. This incidence is crucial, because the product of the annual probability of a crisis and the damage cost of a crisis determines the expected damage from a banking crisis, and thus the amount of benefit that can be achieved by reducing the likelihood of a crisis.

The BCBS (2010a, 39) places the annual probability of a banking crisis at 3.6 to 5.2 percent for "all BCBS countries" and 4.1 to 5.2 percent for G-10 countries. The slightly lower range for both concepts is from the compilation of crises by Laeven and Valencia (2008) and the higher range from Reinhart and Rogoff (2008). The frequency estimates are for the period 1985–2009.[11]

It is by no means clear, however, why the starting point should be 1985. In table 1, there is a banking crisis recorded for Spain in 1977. If we begin the period at 1977 and bring it up the present, 2015, then there is a span of 38 years to consider. If we consider all the industrial countries listed in table 1 (including the "control" group with no crisis in 2008), there are 22 countries. So the number of country-years in this full span is 836. The number of banking crises in table 1 is 22. On this basis, the annual frequency of a (new) banking crisis is 2.6 percent.

At the upper end of the BCBS range for both frequency of and damage from banking crisis, the expected annual loss from a banking crisis under conditions of 1985–2009 was 5.2% x 158% = 8.2 percent of one year's GDP. By this reckoning, if it were possible to purchase an insurance policy that would completely eliminate the risk of a banking crisis, it would be worth devoting 8.2 percent of GDP every year to pay the premium on this policy. This amount would be several times what most countries pay for national defense.

If instead the estimates of table 1 are adopted and the time span is set at 1977–2015, then the expected annual loss from banking crises amounts to 2.6% x 64% = 1.7 percent of GDP. Although still high, this estimate (which includes long-term effects) would seem more plausible than the 8.2 percent of GDP expected loss in the high end of the BCBS estimates. Even this lower figure could be exaggerated, however, to the extent that it mainly captures the extreme outcomes of the Great Recession, something broadly comparable to a 100-year flood that included losses from uncertainty associated with sovereign debt distress not necessarily triggered by banking crises.

The Capital Requirements Benefits Curve

Let the probability of a banking crisis when the capital requirement is at its base level k_0 be P_{cr0}. Let the total (including long-term) output loss from a banking crisis be L_{cr}. Defining the crisis loss as the fraction λ of one year's base GDP (Y_0), where $\lambda_0 = L_{cr} / Y_0$, the annualized expected loss from a banking crisis expressed as a fraction of base year GDP will be:

$$4) D_0 = P_{cr0} \lambda_0$$

11. With 25 years and 10 countries, there are 250 country-years. In this period, there was at least one crisis in all G-10 countries except Canada. The frequency measure represents dividing the total of 9 (Laeven-Valencia) to 13 (Reinhart-Rogoff) crises by 250 country-years. All G-10 countries experienced crisis in 2007 or 2008 except Canada and Sweden (BCBS 2010a, 39). Seven of the crises in Laeven-Valencia and Reinhart-Rogoff were from 2007 or 2008, constituting 54 percent of the G-10 banking crises in the period according to the first study and 78 percent according to the second.

Now suppose that increasing bank capital requirements from their base level k_0 to a higher level k reduces the annual probability of occurrence of a banking crisis to P_{crk}. Suppose that the relationship between the probability of a crisis and the ratio of capital to (total) assets is of the form:

$$5) P_{crk} = Ak^{\gamma};$$
$$\ln P_{crk} = \ln A + \gamma \ln\ k$$

where $\gamma < 0$.

The gross benefits of increasing the capital ratio from its base value of k_0 to level k, expressed as the reduction in expected annualized crisis losses, will then be:

$$6) B = -(P_{crk} - P_{cr0})\lambda_0$$
$$= -\left(Ak^{\gamma} - Ak_0^{\gamma}\right)\lambda_0$$
$$= -A\lambda_0(k^{\gamma} - k_0^{\gamma})$$

Because $\gamma < 0$ (that is, the probability of crisis declines as k rises), the final expression within parentheses is negative (considering that $k > k_0$), yielding a positive benefit in equation (6). The derivative of the benefit equation is:

$$7) \frac{dB}{dk} = -A\lambda_0 \gamma k^{\gamma - 1}$$

Again with $\gamma < 0$, this derivative is positive, so the benefit is a rising function of the capital ratio. The final exponent of k is a strictly negative number, such that increasing k reduces the overall value of the right-hand side. The benefit function is thus concave with respect to the capital ratio; there are diminishing returns to increases in the capital ratio.

Calibrating the Benefits Curve

Arguably the most crucial and also the most uncertain building block in implementing the benefits model set forth in equations (4) through (7) is the curve describing the response of the probability of a banking crisis to the level of the bank capital requirement (equation 5). The most authoritative estimates on this question still seem to be those compiled in a survey by the BCBS in 2010 (BCBS 2010a). It is worth quoting from the study on its method:

> Mapping tighter capital and liquidity requirements into reductions in the probability of crises is particularly difficult. This study relies mainly on two types of methodology. The first involves reduced-form econometric studies. These estimate the historical link between the capital and

liquidity ratios of banking systems and subsequent banking crises, controlling for the influence of other factors. The second involves treating the banking system as a portfolio of securities. Based on estimates of the volatility in the value of bank assets, of the probabilities and of correlations of default and on assumptions about the link between capital and default, it is then possible to derive the probability of a banking crisis for different levels of capital ratios. (BCBS 2010a, 3).

Key studies of the first type include Barrell et al. (2010) and Kato, Kobayashi, and Saita (2010). An example of the second category is Elsinger, Lehar, and Summer (2006). Table 2 shows the resulting synthesis of the BCBS mapping of capital ratios to banking crisis probability.

The third and fourth columns of table 2 provide a basis for estimating the probability function in equation (5). If the logarithm of the crisis probability (column 3 or 4) is regressed on the logarithm of the ratio of capital to total assets (column 2), the resulting constant and coefficient estimates provide an estimate of A and γ.[12]

The point of departure for increasing capital ratios is a base of 7 percent tangible common equity relative to risk-weighted assets (3.9 percent of total assets), near the lower bound of the range considered in BCBS (2010a), as shown in table 2. At this level of capital, the probability of banking crisis is 4.6 percent in the all-models estimate and 3.3 percent in models considering liquidity and assuming meeting the net stable funding ratio (NSFR) liquidity targets. However, both these estimates are higher than the 2.6 percent benchmark identified above, based on 1977–2015 experience. As a result, in the main estimate here, the constant A is adjusted downward by the ratio 2.6/4.6.[13]

Figure 2 shows the benefits curve relating the main estimate of losses avoided annually as a percent of total GDP in response to alternative ratios of capital to total assets. The zero point in these benefits is set at a starting point of 3.9 percent capital relative to total assets. The damages use the all-models estimates in table 2 (after the shrinkage from base crisis frequency of 4.6 to 2.6 percent). As can be seen, after the ratio of capital to total assets exceeds about 7 percent, the curve levels off, reaching a plateau of 1.67 percent of output. Thus, whereas the benefits of reducing the incidence of banking crises would amount to about 1 percent of GDP annually at a capital ratio of 5 percent, about 1.3 percent of GDP at a capital ratio of 6 percent, and about 1.5 percent at a capital ratio of 7 percent, boosting the capital ratio

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12. With $\ln(P_{cr}) = a + b \ln k$, in equation (5) the constant $A = \exp(a)$, and the coefficient $\gamma = b$. The estimations yield: for column 3, and using pure numbers rather than percentages, $\ln(P_{cr}) = -14.41\ (-85) -3.50\ (-60) \ln(TCE/TA)$; adj. $R^2 = 0.997$, with t-statistics in parentheses. For column 4: $\ln(P_{cr}) = -13.16\ (-63) -3.016\ (-42) \ln(TCE/TA)$; adj. $R^2 = 0.995$. The extremely high R^2 and t-statistics likely reflect the fact that the BCBS numbers are already syntheses in stylized form rather than underlying empirical observations. Note that these log-log regressions achieve a higher explanation than either quadratic or cubic specifications.

13. As discussed below, an optimistic alternative uses the adjustment factor 2.6/3.3 applied to the constant A in the curve for the NSFR models. A pessimistic alternative uses no downward adjustment in the constant and applies the curve for the all-models with no change in liquid assets.

far higher to 25 percent would boost the benefits only marginally higher to 1.67 percent of GDP. This concave nonlinearity stems directly from the survey findings in BCBS (2010a).

It is important to recognize that the 1.67 percent potential upper-bound benefit refers to the level of GDP, not the annual growth rate. Thus, if extremely high capital requirements were set (say 20 to 25 percent of total assets), and there were no costs, the long-term path of GDP would be expected to lie 1.7 percent higher than if there had been no change from the pre-Basel III requirements. The corresponding increase in the growth rate—again if there were no costs at all from higher requirements because of complete M&M offset—would amount to 0.055 percent annually over a 30-year period.[14]

COSTS OF HIGHER CAPITAL REQUIREMENTS

If the Modigliani-Miller offset is incomplete, however, higher capital requirements for banks will increase their costs. As they pass along these extra costs to borrowers, lending rates will rise. Firms borrowing capital will find it is no longer profitable to borrow as much and make plant and equipment investments as large as before. With less capital formation, total output will reach levels lower than otherwise. As will be shown, the output cost of higher capital requirements turns out to be a linear function of the level of the requirement, expressed as the ratio of equity capital to total (not risk-weighted) assets.

Average Cost of Capital

The initial and driving force in the output cost is the increase in the interest rate banks must charge on loans as a consequence of shifting from cheaper debt finance to more expensive equity finance (under incomplete M&M effects). Thus, defining z as the average cost of capital to banks, one has:

$$8) z = z_0 + (k - k_0)(\rho_B - r_d)(1 - \mu)$$

where k is the ratio of equity capital to total assets, ρ_B is the unit cost of equity capital for banks, r_d is the real interest rate on debt financing of the banks, and μ is an M&M offset factor.[15] Subscript *0* refers to the base period prior to the regime shift raising capital requirements.

The analysis here refers to the ratio of equity capital to total assets, not risk-weighted assets. This ratio is sometimes called the "leverage ratio," although it is actually a close transform of the *inverse* of the leverage ratio of debt to equity.[16] Note further that regulatory requirements refer to capital required

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14. That is: $1.00055^{30} = 1.0166$.

15. It is the real interest rate that is comparable to the cost of equity as measured, for example, by the inverse of the price-earnings ratio. The reason is that nominal earnings will tend to rise with inflation so the equity cost is already stated in real terms.

16. If L = D/E, where L is the debt-equity leverage ratio, D is debt, and E is equity; and k = E/A, where A is assets, then considering that debt plus equity equals assets, L = (A–E)/E = A/E –1, so L = 1/k –1.

relative to "risk-weighted" assets. Low risk weights for some assets (especially for highly rated sovereign obligations but also for home mortgages) result in values of risk-weighted assets (RWA) that are considerably smaller than unweighted assets.

In equation (8), if the capital ratio is increased from a modest base (say 5 percent) to a high level (say 25 percent), there will be a corresponding increase in the weighted average cost of capital reflecting the excess of the equity cost rate (ρ_B) over the borrowing rate facing the banks (r_d). The final term in the equation shrinks this increase in average cost of capital by the factor μ. If offset is complete (μ =1), the average cost of capital to banks remains unchanged at z_0 regardless of how high the capital requirement k is raised.

The real interest rate paid by banks on debt is the risk-free rate i plus the spread facing banks, S_B.

$$9) r_d = i + S_B$$

For nonfinancial firms, the average cost of capital is a weighted average of the interest rate charged by banks, the interest rate charged by nonbank financial entities and on corporate bonds, and the firm's equity cost:

$$10) w = \phi_B(z + S_f) + \phi_{NB} r_{NB} + \phi_f \rho_f$$

The interest rate charged by banks is their average cost of capital (z) plus the risk spread applicable to the firms (S_f).

Some spillover effect is likely to occur to lending rates by nonbanks when banks must charge more. If nonbanks raise their rates by the fraction θ of the increase in bank lending rates, and assuming that banks increase their lending rates by the same amount that their average cost of capital increases as a consequence of higher capital requirements, then:

$$11) r_{NB} = r_{NB,0} + \theta \times (z - z_0)$$

where $r_{NB,0}$ is the nonbank lending rate in the base period prior to regulatory reform.

With the elements for calculating average cost of capital to firms in hand, the proportionate increase in the cost of capital to the economy (v) resulting from a bank capital ratio of k rather than the base period level k_0 will be:

$$12) v = \left(\frac{w_k}{w_0} - 1\right)$$

Impact on the Economy

As suggested by Miles, Yang, and Marcheggiano (2012) and followed in Cline (2015), the proportionate output cost to the economy from placing the bank capital requirement at k rather than at the prereform level of k_0 will then be:

$$13) C = \frac{v \times \alpha \times \sigma}{(1 - \alpha)}$$

where α is the elasticity of output with respect to capital (capital's factor share) and σ is the elasticity of substitution between capital and labor.

The derivative of this output cost with respect to the required capital ratio is then:

$$14) \frac{dC}{dk} = \frac{dC}{dv} \times \frac{dv}{dw} \times \frac{d_w}{d_z} \times \frac{d_z}{d_k}$$

$$= \frac{\alpha\sigma}{1-\alpha} \frac{1}{w_0} \left(\phi_B + \theta\phi_{NB}\right)\left\{\left(\rho_B - r_d\right)(1 - \mu)\right\} \equiv \psi$$

All the terms in the final right-hand side of equation (14) are constants, so the derivative of the proportionate output loss with respect to the capital requirement is a constant (set equal to ψ in the final right-hand-side expression). The two expressions containing differences are both greater than zero, so this constant is positive. A graph representing the proportionate output cost on the vertical axis and the capital requirement on the horizontal axis will thus be a straight line sloping upward.

In the base case for the calculations developed below, the parameters and base values of variables in equation (14) are as follows: $\alpha = 0.4$; $\sigma = 0.5$; $w_0 = 0.046$; $\phi_B = 0.333$; $\theta = 0.5$; $\phi_{NB} = 0.333$; $\rho_B = 0.10$, $r_d = 0.025$; and $\mu = 0.45$. The resulting value of ψ, the constant derivative of output with respect to the capital ratio, is 0.15. Thus, for example, if the capital requirement is increased by 10 percent of total assets, the level of output will decline by 1.5 percent from the path it otherwise would have followed. Over 30 years, cumulative output loss would amount to 45 percent of the initial base-year output level, ignoring time discounting as well as the baseline growth rate.[17] This illustration makes it evident that the economic cost of a large increase in capital requirements would be substantial. Identifying the optimal level of capital thus requires a close examination of the marginal cost in comparison to the marginal benefit.

17. If the baseline growth rate is approximately equal to the social discount rate, the two influences cancel each other out.

OPTIMAL CAPITAL REQUIREMENTS

With the marginal social cost of additional capital given by equation (14) and the marginal social benefit given by equation (7), the optimal capital ratio k^* will occur where these two marginal effects are equal, at:

$$15) -A\lambda_0\gamma k^{*\,\gamma-1} = \psi$$

Solving for the optimal capital ratio k^* yields:

$$16) k^* = \left[\frac{\psi}{-A\lambda_0\gamma}\right]^{\frac{1}{\gamma-1}}$$

In graphical terms, this optimal capital ratio will occur where the slope of the convex benefit function equals the slope of the linear cost function.

Tables 3 and 4 report parameter values applied in implementation of the model using equations (4) to (16). For seven key influences shown in table 3, three alternative parameter values are considered: a base case using the central estimates; a "low" case in which the parameters will generate a lower optimal capital ratio (with other parameters unchanged); and a "high" case in which the parameters will generate a higher optimal capital ratio (OCR).

The first parameter, λ_0, is the expected present value of damage from a banking crisis, as a fraction of one year's base GDP. The estimates in table 1 provide the central value of 0.64 for this parameter. The low OCR variant is set at 0.30 (effectively treating most of the damages as those occurring within the first five years); the high OCR variant, at 1.0, represents much longer persistence of damages.

For the second parameter, ρ_B , the unit cost of equity capital, the base case uses 10 percent. This is the rate indicated in IIF (2011). For the two alternative rates, 13 and 7 percent, the source is Cline (2015, 21). These were the rates identified for 54 large US banks in 2001–13 for the earnings yield (inverse of price/earnings ratio) and the ratio of net income to equity, respectively. The 13 percent equity cost variant will impose greater costs from forcing a shift away from debt to equity, so it represents a low-OCR case; conversely, a 7 percent equity cost represents a high-OCR case.

The base case places the M&M offset, μ, at 0.45, again based on the estimates in Cline (2015). The low-OCR alternative posits a smaller offset of 0.35; the high-OCR alternative sets the offset at 0.6. For the spillover effect, θ, the base estimate assumes that nonbank lending rates rise by one-half of the increase in bank lending rates. The low-OCR variant sets this spillover effect at 0.7, raising the economic cost of higher capital requirements for banks; the high-OCR variant assumes a spillover coefficient of only 0.2, making higher capital requirements less costly. The base elasticity of output with respect to capital, α, is set at 0.4, reflecting the high share of capital in GDP in recent years. As can be seen in equation (13), the economic cost of higher capital requirements is positively associated with α. Higher cost translates to a lower optimal capital ratio. The low-OCR variant of α is set at 0.43. Conversely, the high-OCR variant is set at the more traditional notional value of $\alpha = 0.33$.[18] The elasticity of substitution, σ, is set at 0.5 in the base case (following Miles, Yang, and Marcheggiano 2012). Again equation (13) reveals the direction of influence of this parameter on economic cost of higher capital requirements as being positive. The low-OCR variant is thus set at 0.8 (higher cost will lead to a lower optimal capital ratio), and the high-OCR variant, at 0.4.[19]

The final two rows of table 3 show alternative sets of parameters for the crisis probability curve. The base case applies the "all models" column of table 2, but imposes the base crisis probability estimate of 2.6 percent developed in the initial section above. The high-OCR alternative instead accepts the BCBS (2010a) base crisis probability of 4.6 percent and applies the curvature of the all-models estimates (table 2). That is, with higher crisis damages and hence benefits or curbing the probability of crisis, there will be a higher return to additional bank capital. The low-OCR variant imposes the lower 2.6 percent base probability of crisis, and applies the somewhat more favorable curvature of the net stable funding ratio estimates in the BCBS (2010a) study.

For the other parameters and base values in the model, single estimates are applied, as shown in table 4.

Equity cost to firms is based on a typical price-earnings ratio of 15. A real risk-free interest rate of 1.5 percent is meant to represent medium- to long-term rates under conditions more normal than those following the Great Recession. The risk spread for banks is based on observed credit default swap rates.[20] Financing shares of corporations from banks, nonbank lending (including bonds), and equity (including retained earnings) are set at one-third each, based on Rajan and Zingales (1995).

The base value of the capital/assets ratio is set at 3.93 percent, based on the base value of 7 percent for tangible common equity relative to risk-weighted assets and a ratio of 1.78 for total assets to risk-weighted assets for US and euro area banks (BCBS 2010a, 57). The two final entries in table 4 are the estimated base values of average cost of capital to banks and average cost of capital to nonfinancial firms, obtained by applying equations (8) and (10) to the parameters and base values in tables 3 and 4.

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18. In 2013–14, compensation of employees accounted for 61.3 percent of national income in the United States; in 1990, this share was 66.4 percent (BEA 2016).

19. The intuition regarding this influence is that if the elasticity of substitution is higher, raising the cost of capital will have a greater impact in reducing the amount of capital applied in production, which in turn will drive lower output.

20. For the six largest US banks, credit default swap rates in 2015 averaged 76 basis points (Bloomberg). The rate of 100 basis points makes allowance for higher rates at other banks.

RESULTS

Application of the base case values for the parameters in tables 3 and 4 yields an optimal capital/assets ratio of $k^* = 0.0656$. Figure 3 shows the paths of benefits (equation 6) and costs (equation 13), using the base case. As noted, in this case the total potential benefit of higher capital ratios plateaus at about 1.7 percent of annual GDP. If the capital/assets ratio were raised all the way to 25 percent, the cost would reach 3 percent of annual GDP. The two curves intersect at a capital/assets ratio of about 15 percent. But the optimal capital ratio, the point at which the slopes of the two curves are parallel, occurs at a capital/assets ratio less than half as high, at 6.56 percent. This optimal ratio would correspond to a ratio of capital to risk-weighted assets of 11.7 percent.

Figure 4 provides a histogram of the estimates of the optimal capital/assets ratio across all 2,187 possible combinations of parameters in table 3 (again calculated using equation 16). The lowest optimal ratio is 0.0411. The highest estimate finds $k^* = 0.1164$. At about 12 percent, even the highest case is slightly less than half of the midpoint of the 20 to 30 percent range recommended by Admati and Hellwig (2013, 179).

The median estimate of the optimal capital ratio is $k^* = 0.0694$ percent, slightly higher than the base case estimate ($k^* = 0.0656$). When arrayed from lowest to highest, the 25th percentile shows a value of $k^* = 0.0611$, and the 75th percentile places k^* at 0.0787. On this basis, it seems reasonable to place the *central estimate of the optimal capital ratio at about 7 percent of total assets, and a more risk-averse main estimate at about 8 percent*.

Returning to the issue of potentially wide variation in the estimated damage from a banking crisis, it is useful to consider the optimal capital ratios implied by the extreme ends of the spectrum discussed above. If a banking crisis causes output loss of only 10 percent of base year GDP ($\lambda_0 = 0.1$), and if all other parameters in tables 3 and 4 are set at their base values, then the optimum capital ratio reaches only 4.3 percent of total assets ($k^* = 0.043$). If instead banking crisis damage is set at 450 percent of GDP ($\lambda_0 = 4.5$), the optimal capital ratio rises to 10.1 percent of total assets ($k^* = 0.101$), higher than the 75th percentile in the main estimates but lower than the very highest estimate (11.6 percent) identified from the most extreme combination among the alternative parameters already considered.

COMPARISON WITH OTHER ESTIMATES

Alternative estimates in four other studies warrant special discussion. The first two are important in their own right but also provide key inputs for the estimates here. The third is a benchmark academic study, and the fourth, a recent empirical study conducted at the IMF.

First, in its summary assessment, the 2010 Basel Committee study that provides the basis for the crisis probability estimates here identified an optimal ratio of capital to risk-weighted assets (TCE/RWA) of 10 percent if there are no permanent effects of banking crises, and 12.5 percent if there are "moderate" permanent effects (BCBS 2010a, 2). The moderate permanent effects case is close to the 11.7 percent identified here (6.56 percent of total assets). There is, nonetheless, an important difference. As shown in figure 3, net benefits—the vertical distance between the benefits curve and the cost line—show a steady and sizable decline after capital exceeds the optimal ratio. In contrast, in the BCBS study the net benefits remain almost flat at about 1.7 percent of GDP even as the ratio of capital to risk-weighted assets reaches 16 percent. This level corresponds to a ratio of about 9 percent for capital relative to total assets. At this level, net benefits (the distance between the upward sloping line for cost and the convex curve for benefits) would be significantly smaller than at the optimal ratio.[21] The reason for the seeming flatness of the net benefits curve in the BCBS study is not clear. This pattern appears to reflect a nonlinear cost curve that allows for costs to plateau almost as fully as benefits. The study's cost estimates are opaque, however, as they are based mainly on several dynamic stochastic general equilibrium (DSGE) models without details reported.

Second, Miles, Yang, and Marcheggiano (2012) use a framework similar to that applied here. Although specific components and calibrations differ, their overall results are similar to those obtained here. On the side of economic costs of additional capital, their cost curve is only about half as steep as that developed here, largely because they set their base value for the average cost of capital to firms at about twice the level assumed here.[22] Their benefits curve is quite different in concept, and is premised on the proposition that a given decline in GDP causes an equal proportionate decline in risk-weighted assets. The distribution of asset reductions is then compared with capital to estimate the implied incidence of banking crises. They obtain a distribution of GDP declines based on 200 years' data for 31 countries. The authors set the present value of a banking crisis at a loss of 55 percent of one year's GDP–a benchmark similar to the 64 percent base estimate here. If they exclude the most extreme cases (where GDP falls by 35 percent), it turns out that their optimal capital ratio lies in the range of 7 to 9 percent of total assets.[23]

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21. In the base case here, at the optimal capital ratio of k^*= 0.0656, B-C = 1.0 percent of GDP; at k = 0.09, B-C = 0.82 percent of GDP.

22. Miles, Yang, and Marcheggiano posit a shift from bank leverage of 30 to 15, meaning k rises from 0.033 to 0.066. They calculate the resulting rise in average cost of capital to banks at 18 basis points, and a resulting increase in average cost of capital to firms of 6 basis points. They place base capital cost to firms at 10 percent, so 6 basis points is an increase of 0.63 percent in the cost of capital. Their calculation of the resulting output loss is the same as in equation (13) here. They use α = 0.33 and σ = 0.5, so C = 0.148 percent. The corresponding change here from base to optimal is as follows. The capital ratio k rises from 0.0393 to 0.0656; average bank capital cost z rises by 11 basis points; average cost of capital to firms rises by 5 basis points, after taking account of spillover to nonbanks (θ = 0.5). But because average capital cost to firms begins at 4.6 percent (real) rather than 10 percent, the proportionate increase of capital cost to firms is 1.1 percent. Applying equation (13) (and using α = 0.4 instead of 0.33) yields a decrease in output by 0.37 percent, more than twice the Miles, Yang, and Marcheggiano estimate.

23. The authors state this range as 16 to 20 percent of risk-weighted assets. They use a ratio of 0.45 for RWA/TA, or 2.22 for TA/RWA, implying an optimal range of 7 to 9 percent of total assets.

That range is surprisingly close to the range identified here: 6.56 percent of total assets (base case) to 7.9 percent (conservative 75th percentile).

Third, the prominent analysis of Admati and Hellwig (2013) calls for far higher capital requirements than identified in the present study as optimal. They do not attempt to calculate an optimal capital ratio. They rely heavily on the Modigliani-Miller theorem to argue that higher equity capital would not increase costs. They state that the minimum equity capital for banks should be 20 to 30 percent of total assets (p. 179), which would correspond to 36 to 53 percent of risk-weighted assets. This range is based not on a comparison of marginal benefits against marginal costs, but on a general appeal to typical equity ratios in the nonbank corporate sector and evidence on historical capital ratios for banks (pp. 30–31). The authors argue that nonbank firms maintain a minimum equity of 30 percent of assets, and that banks are no different from other corporations. However, because banks are in the business of taking deposits, inherently their main business line involves much more debt (i.e., to depositors) than is typical of other sectors. As for their observation that US banks had equity ratios of 25 percent of assets in the early 20th century, Calomiris (2013, 19) replies that this evidence is misleading because after the 1930s asset risk substantially declined as a consequence of a very large increase in bank holdings of cash assets.

Fourth, a recent study by researchers at the IMF (Dagher et al. 2016) arrives at results broadly similar to those of the present study. The authors use the same banking crisis database used in the present study and focus on the observed levels of nonperforming loans (NPLs) recorded in that database. They then calculate what percent of loan losses bank capital would have covered if it had been at alternative levels relative to risk-weighted assets. They assume either a central estimate of 50 percent loss given default on NPLs or a conservative estimate of 75 percent. They show a sharply nonlinear curve indicating that initially additional capital covers large portions of losses but as capital is raised still higher additional loss coverage turns modest—similar to the benefits curve in figure 2. They find that for advanced economies, to cover 85 percent of bank losses in banking crisis episodes would have required broadly defined capital ratios of 15 percent of risk-weighted assets in the main case of 50 percent loss given default, or 23 percent in the conservative 75 percent loss-given-default case. Stripping out intangible equity, subordinated debt, and cyclical-peak additional capital, this range would correspond to 9 to 17 percent of risk-weighted assets, or 5 to 10 percent of total assets.[24]

The authors note that the top of the Basel III capital requirements schedule (for global systemically important banks [G-SIBs], and including a countercyclical buffer) reaches 15.5 percent broadly defined

24. The deductions are 1.5 percent for intangible equity, 2 percent for subordinated debt, and 2.5 percent for the buffer imposed only at cyclical peaks.

capital relative to risk-weighted assets.[25] Considering further that banks tend to hold more than the legally required minimum capital, they interpret their findings as being consistent with Basel III requirements for G-SIBs, as well as Financial Stability Board recommendations for total loss absorbing capacity (TLAC). After adjusting for the different capital concepts, their 15 to 23 percent range is relatively close to the 12 to 14 percent range for tangible common equity relative to risk-weighted assets identified in the present study.

IMPLICATIONS FOR REGULATORY CAPITAL

The Basel III regulatory reform requires that by 2019 banks hold a minimum of 4.5 percent of risk-weighted assets (RWA) in common equity, plus another 2.5 percent as a capital buffer (BCBS 2010b, 69). The total requirement of 7 percent of RWA in common equity corresponds to 3.9 percent of total assets.[26] G-SIBs are to hold additional capital of up to 2.5 percent of RWA, bringing the ratio to 9.5 percent of RWA (BCBS 2014).[27]

A capital ratio of 9.5 percent against risk-weighted assets corresponds to a ratio of 5.3 percent against total assets. Against the optimal ratio estimated here—6.56 percent central estimate and 7.9 percent for the conservative 75th percentile estimate—the Basel III capital requirements are too low. They would need to rise by about one-fourth to reach the central estimate, and by about one-half to reach the more risk-averse 75th percentile estimate. Even so, the increases needed to reach the optimal capital ratios are far less than the five-fold multiple called for by Admati and Hellwig (2013).

In the United States, the additional amount for G-SIBs is to range up to 4.5 percent, bringing the ratio to as high as 11.5 percent of RWA (Federal Reserve 2015a). This level would correspond to 6.5 percent of total assets. That level would be almost exactly the same as the base case optimal capital ratio identified in the present study. However, in practice the highest G-SIB increment by early 2016 was 3.5 percent (for JP Morgan), and the amount for the US G-SIBs was centered at about 3 percent.[28] So the principal G-SIB rate stood at about 10 percent of RWA, or 5.6 percent of total assets. On this basis, even for US G-SIBs the capital requirement would need to increase capital by about one-sixth to reach the

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25. This amount corresponds to 9.5 percent of RWA for tangible common equity for G-SIBs, excluding the cyclical peak amount.

26. As noted above, this study uses the BCBS (2010a, 57) estimate that for US and European banks the ratio of total assets to risk-weighted assets is an average of 1.78.

27. The top "bucket" in the 2014 survey of 75 large banks was set at 2.5 percent, though a higher bracket at 3.5 percent was identified for larger banks in the future BCBS (2014, 4).

28. Hugh Son, "JP Morgan Shares Rise on Surprise Drop in Capital Surcharge," Bloomberg, January 14, 2016; Ian Katz and Jesse Hamilton, "JP Morgan $12.5 billion Short in Fed Systemic-Risk Charges," Bloomberg, July 20, 2015.

central-estimate optimal capital ratio and by about two-fifths to reach the more conservative benchmark (6.56 and 7.9 percent, respectively).

The G-SIBs account for a large portion of assets in the international banking system. The broad implication is thus that capital requirements on track under Basel III are below optimal levels, but not nearly as far below as some past studies have suggested.

Table 5 summarizes Basel III requirements for G-SIBs, and in addition reports the TLAC requirements recommended by the Financial Stability Board in response to the St. Petersburg Summit of the Group of Twenty (G-20) in 2013 (FSB 2015). The Basel III requirements are to be met by 2019; the TLAC target is to be met by 2022. The table shows the requirements in the usual form, against risk-weighted assets, and also the corresponding central estimate of the implied ratios against total assets.[29]

The analysis in this study is based on the tangible common equity concept of capital. This metric is used to calibrate the relationship between the probability of banking crisis and the level of capital (table 2). The proper comparison thus contrasts a Basel III target of 9.5 percent of RWA against an optimal range of about 12 to 14 percent identified in the present study.

As shown in table 5, however, the further requirement for TLAC pursued by the G-20 and Financial Stability Board would bring TLAC up to 18 percent of RWA. A key question is thus whether this additional layer would constitute an effective achievement of the optimal 12 to 14 percent range.

It is beyond the scope of this study to provide an in-depth analysis of the merits of the contingent convertible (CoCo) debt and subordinated debt that would constitute the increment that would approximately double TCE to reach the TLAC level. A preliminary view, however, is that TLAC does not adequately address the basic purpose of capital, which is to ensure that the bank remains solvent. Instead, it is designed to ensure that a large bank can indeed go bankrupt without requiring a call on taxpayer funds. Subordinated debt could be subtracted from the bank's debt liabilities only upon bankruptcy. Bankruptcy of large banks is precisely what capital requirements should be designed to avoid, considering that episodes of failure of large banks would be difficult to envision without an associated banking crisis. As for CoCo debt, in a panic the collapse of market values of this debt would hardly contribute to an atmosphere favorable to avoiding broader crisis (Persaud 2014).[30] Moreover, US banks have not used CoCo debt because its interest does not qualify as a tax-deductible expense.

29. Based on TA/RWA = 1.78. Note that Dagher et al. (2016) use a corresponding estimate of 1.75.

30. In early 2016 there was a sharp sell-off in CoCo debt of European banks in an environment of heightened uncertainty and falling bank equity prices. Thomas Hale, Joel Lewin, and Katie Martin, "Eurozone bank coco bonds extend slide," *Financial Times*, February 8, 2016.

FURTHER CONSIDERATIONS

Two major additional issues warrant reflection in interpreting the results of the estimates here. The first concerns the relationship between capital actually held by banks and the amount required by financial regulations. The second concerns the possibility that decisions in monetary policy could change the regulatory policy calculus.

Behavioral Cushions. In practice, in the United States (at least) the large banks have already reached capital ratios that not only exceed the Basel III requirements but also are close to the optimal levels identified in this study. In the fourth quarter of 2014, 31 large bank holding companies (representing more than 80 percent of total bank assets) held Tier 1 common equity amounting to 11.9 percent of risk-weighted assets (Federal Reserve 2015b, 3). The Basel III requirement, including the G-SIB surcharge as applied in the United States (an average of 3 percent), is 10 percent of RWA.[31] So these banks held one-fifth more capital than the regulatory requirement (and well before the 2019 deadline). For these large banks, the ratio of total assets to RWA was an average of 1.53 (ibid). So their common equity was 7.8 percent of total assets—effectively at the conservative (75th percentile) side of the optimal level estimated here. The question thus arises as to whether the Basel regulatory requirement should be raised to the optimal level or instead placed significantly below the optimal level because of the banking practice of maintaining a cushion.

In the estimates above, the central result for optimal capital is 6.6 percent of total assets. If banks maintained a cushion of an additional one-fifth, their capital would stand at 7.9 percent of total assets. As it turns out, this is the same as the conservative alternative (75th percentile) estimated here for the optimal ratio. The reasonable policy approach, then, would seem to be to set the regulatory requirement at the central estimate of the optimal level, in the expectation that in practice the banks would add a cushion that places their actual capital levels at the conservative (75th percentile) optimal target.

Monetary Policy Offset? Another key consideration is whether the costs of additional capital could easily be offset by more expansionary monetary policy, essentially achieving greater bank capitalization at no cost to the economy. The problem with this line of thinking is that monetary policy should stick to its central mandate—maintaining price stability along with high employment—and not be burdened with extraneous obligations. Superficially the numbers do look congenial to the monetary offset argument. Specifically, increasing the capital requirement by as much as 10 percent of total assets would raise the cost of capital to the economy by "only" about 20 basis points.[32] This amount is substantial relative to the

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31. That is: 4.5 percent plus 2.5 percent capital conservation buffer plus 3 percent G-SIB surcharge (table 5).

32. Using the base values of the parameters above, shifting the financing of 10 percent of total assets from debt (paying 2.5 percent) to equity (paying 10 percent) would boost average cost of capital to banks by 75 basis points (0.1 x [0.1 – 0.025]) with

average cost of capital to the economy (4.6 percent in the base case, with the increment representing a proportionate increase of 4.3 percent in the unit cost of capital). However, it would be equivalent to only a modest loosening of monetary policy (e.g., reducing the policy interest rate from 3 to 2.8 percent). But an environment of reduced capital formation and consequently lower output would tend to be one of supply scarcity rather than demand deficiency, and long-term regulatory structure should not be premised on the pursuit of monetary policy more expansionary than otherwise advisable.

CONCLUSION

This study finds that long-term damage of a banking crisis amounts to 64 percent of base-year potential GDP and that in the past three decades the annual probability of such a crisis was about 2½ percent. The probability of a banking crisis can be reduced by requiring banks to hold more capital. The response of crisis probability is highly nonlinear, such that the most impact in reducing chances of a crisis comes from the initial increases in capital above pre-Basel III levels. After taking account of the additional cost to the economy from imposing higher capital requirements (thereby raising lending rates and curbing new investment and future output levels), it is found that the optimal ratio for tangible common equity is about 6.6 percent of total assets and a conservative estimate at the 75th percentile is about 7.9 percent. These benchmarks would correspond to 11.7 and 14.1 percent of risk-weighted assets, respectively. On this basis, the Basel III benchmarks are below optimal capital requirements, at only 7 percent of RWA (9.5 percent for G-SIBs). Further international banking reform could usefully consider phasing in capital requirements on the order of one-fourth to one-half higher than the Basel III requirements.

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no M&M offset, and by 41 basis points applying the base case offset of 45 percent. Including the 50 percent spillover to nonbank financial intermediaries, and applying the weights of alternative finance to the economy, the overall effect would be an increase of 20.5 basis points (0.333 x 41 + 0.333 x 20.5).

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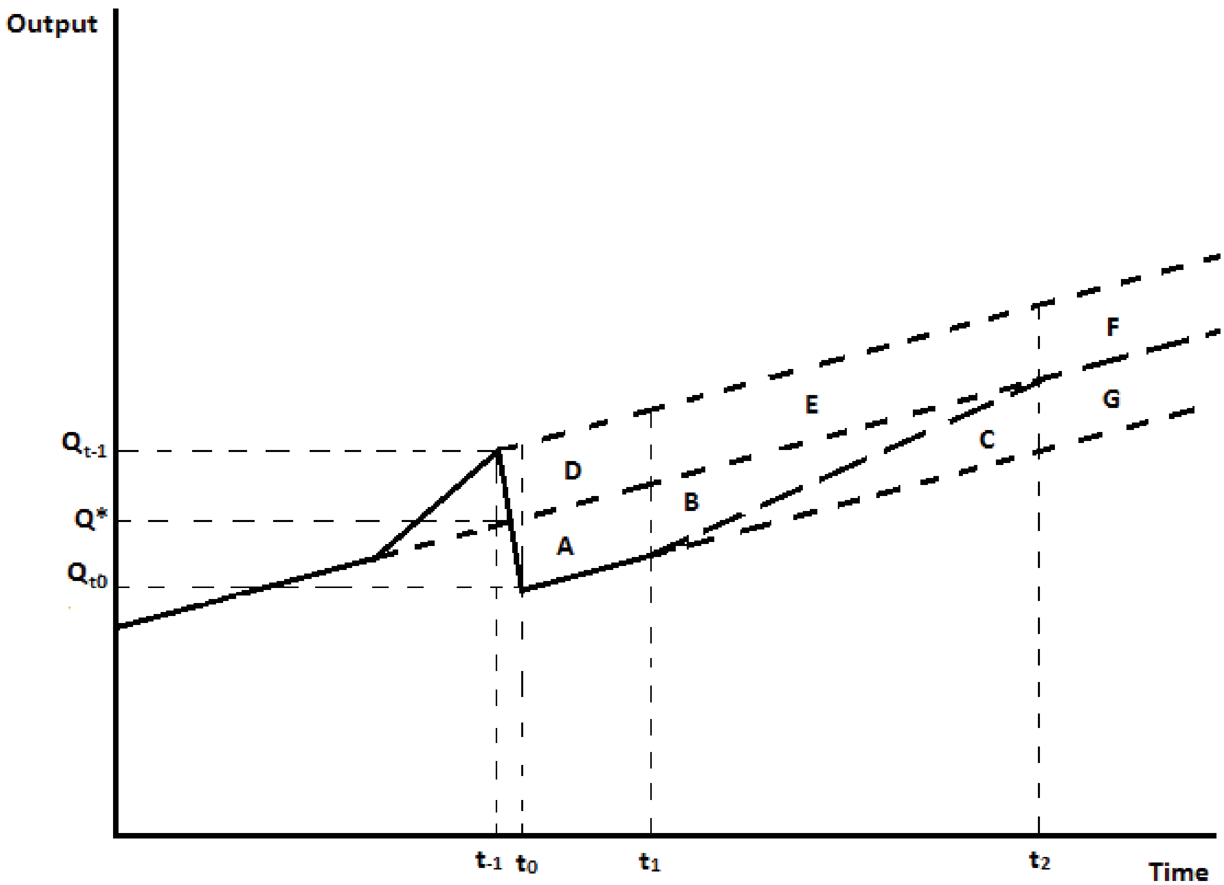
Figure 1 Losses from a banking crisis



Source: Author's illustration.

Table 1 Calculations of output losses from banking crises, advanced industrial countries, 1977–2015

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Country	**Crisis year**	***g***	Ω_{T-1}	***n***	d_{cum5}	***gap5***	d_{LT}	d_{tot}	**LV:** d_{cum4}
Austria	2008	1.76	3.2	0.32	11.5	4.4	23.9	35.5	14
Belgium	2008	1.72	2.99	0.64	18.4	6.8	36.9	55.3	19
Denmark	2008	1.6	3.94	0.05	24.3	8.5	46.0	70.3	36
Finland	1991	1.97	2.34	0.28	57.6	11.7	63.7	121.2	69.6
France	2008	1.53	1.99	0.03	16.1	4.6	25.0	41.1	23
Germany	2008	1.52	2.25	–0.57	0.2	0	0	0.2	11
Greece	2008	1.46	10.62	–0.77	21.5	18.7	101.8	123.3	43
Iceland	2008	1.51	4.3	–0.16	13.1	6.6	35.7	48.7	43
Ireland	2008	3.5	9.69	–0.46	31.1	11.7	63.5	94.6	106
Italy	2008	1.27	2.7	0.24	34.8	12.2	66.4	101.2	32
Japan	1997	2.5	0.98	–0.31	25.6	8.5	46.1	71.7	45
Netherlands	2008	2.04	1	–0.01	28.6	9.8	53.1	81.7	23
Norway	1991	2.76	–1.99	0.51	7.1	0	0	7.1	5.1
Portugal	2008	2.1	1.46	–0.48	32.9	13.7	74.5	107.4	37
Spain	1977	3.25	2.57	1.24	35.9	16.5	90.0	125.8	58.5
Spain	2008	1.86	2.88	–0.3	25.1	10.4	56.8	81.8	39
Sweden	1991	1.75	1.63	0.39	27.8	5.4	29.6	57.4	32.9
Sweden	2008	1.79	4.9	0.21	9.3	3.1	16.9	26.2	25
Switzerland	2008	1.03	1	1.08	10.8	3.9	21.1	31.9	0
United Kingdom	2007	2.05	2.51	0.76	25.9	10.9	59.5	85.4	25
United States	1988	1.76	–0.32	0.97	0	0.8	4.5	4.5	0
United States	2007	1.74	2.66	0.69	19.1	7.2	39.4	58.5	31
Median		1.76	2.54	0.23	22.9	7.8	42.7	64.4	31.5
Control (2008):									
Australia		1.91	1.08	1.46	12.0	3.3	17.8	29.7	n.a.
Canada		1.42	1.75	0.81	14.7	3.0	16.2	30.9	n.a.
Finland		2.04	6.09	–0.16	19.5	7.6	41.6	61.1	n.a.
Japan		1.85	0.43	–0.81	29.5	5.7	31.2	60.7	n.a.
New Zealand		1.47	0.08	0.55	23.1	4.5	24.3	47.4	n.a.
Norway		1.88	2.3	1.18	34.8	10.8	58.9	93.7	n.a.
Median		1.87	1.42	0.68	21.3	5.1	27.7	54.0	

n.a. = not applicable

g = long-term growth of output relative to working-age population (1980–2014; or for crises before 2007, 20 years before to 5 years after crisis) (percent per year). Ω_{T-1} = output gap in year before crisis (percent). *n* = average growth of working-age population (16–64) in 5 years beginning in crisis year. d_{cum5} = cumulative damage over 5 years as percent of potential GDP in year prior to crisis (Q^*). *gap5* = shortfall of output in year 5 of crisis from benchmark baseline, as percent of Q^*. d_{LT} = long-term damage after year 5, as percent of Q^*. d_{tot} = total damage as percent of Q^*. LV: d_{cum4} = Laeven-Valencia: cumulative damage over 4 years as percent of trend output in year 4.

Sources: Author's calculations; IMF (2008a, 2008b, 2015a); OECD (2015a, 2015b); Laeven and Valencia (2012).

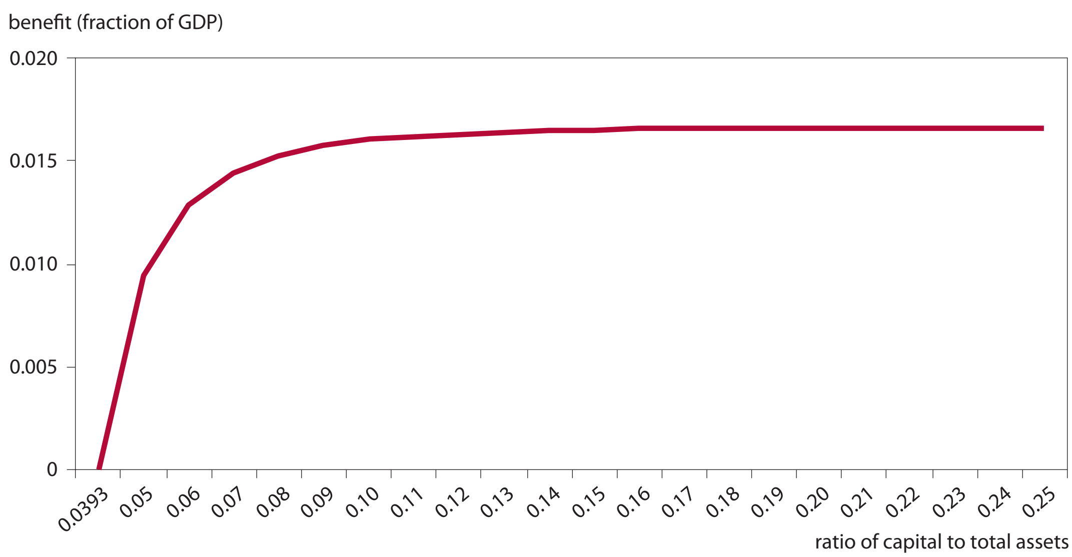
Table 2 BCBS synthesis of impact of capital on the probability of systemic banking crises (percent)

TCE/RWA	TCE/TA	P_{cr}: all models, NCLA	P_{cr}: NSFR
6	3.37	7.2	4.8
7	3.93	4.6	3.3
8	4.49	3	2.3
9	5.06	1.9	1.6
10	5.62	1.4	1.2
11	6.18	1	0.9
12	6.74	0.7	0.7
13	7.3	0.5	0.5
14	7.87	0.4	0.4
15	8.43	0.3	0.3

BCBS = Basel Committee on Banking Supervision; TCE: tangible common equity; RWA: risk-weighted assets; TA: total assets; P_{cr}: probability of crisis; NCLA = no change in liquid assets. The NCLA variant reflects model results when liquid assets are not changed; NSFR = meeting net stable funding ratio. The NSFR variant is for results modeling an increase in the ratio of liquid assets to total assets by 12.5 percent; TCE/TA = based on TA/RWA = 1.78 for US and euro area banks

Source: BCBS (2010a, 15, 57).

Figure 2 Benefits of additional bank capital



Source: Author's calculations.

Table 3 Alternative parameter values for simulations

Parameter	Concept	Low OCR	Base	High OCR
λ_0	Total loss (including long-term) from banking crisis as fraction of one year's base GDP	0.30	0.64	1.0
ρ_B	Cost of equity capital to banks	0.13	0.10	0.07
μ	Modigliani-Miller offset factor	0.35	0.45	0.60
θ	Spillover coefficient, banks to nonbanks	0.7	0.5	0.2
α	Elasticity of output with respect to capital	0.43	0.40	0.33
σ	Elasticity of substitution, capital and labor	0.8	0.5	0.4
	Crisis probability curve (jointly):			
A	Constant	1.50E–06	3.14E–07	5.52E–07
γ	Exponent	–3.016	–3.500	–3.500

OCR = optimal capital ratio

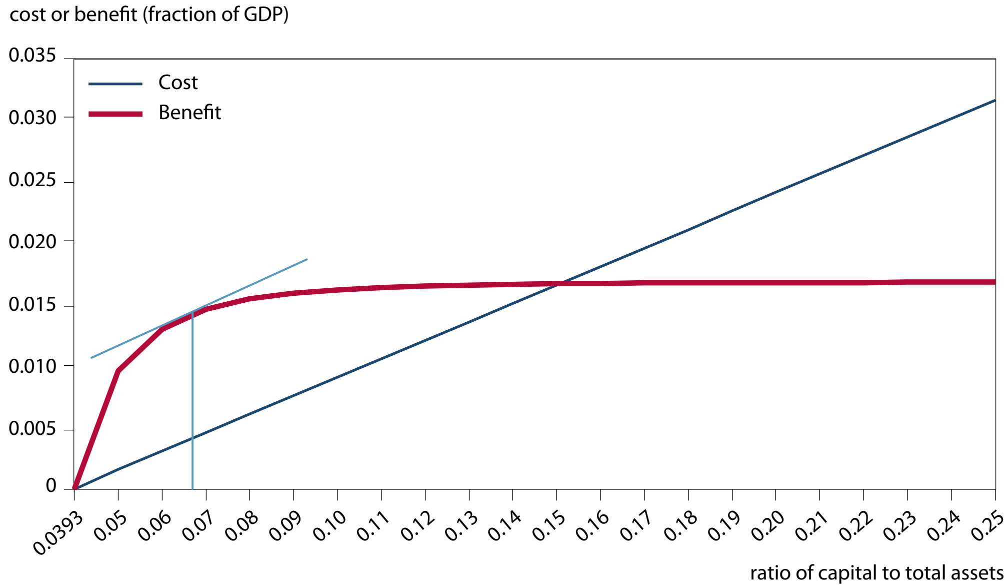
Source: Author's calculations.

Table 4 Other parameters and base values

Parameter	Concept	Value
ρ_f	Unit cost of equity capital for nonfinancial firms	0.066
i	Real risk-free interest rate	0.015
S_B	Risk spread in banks' borrowing rate	0.01
S_f	Risk spread in nonfinancial firms' borrowing rate	0.015
ϕ_B	Share of firms' financing provided by banks	0.333
ϕ_{NB}	Share of firms' financing provided by nonbanks	0.333
ϕ_f	Share of firms' financing provided by firms' equity	0.333
k_0	Base level of bank capital relative to total assets	0.0393
z_0	Base average cost of capital to banks	0.0286
w_0	Base average cost of capital to nonfinancial firms	0.046

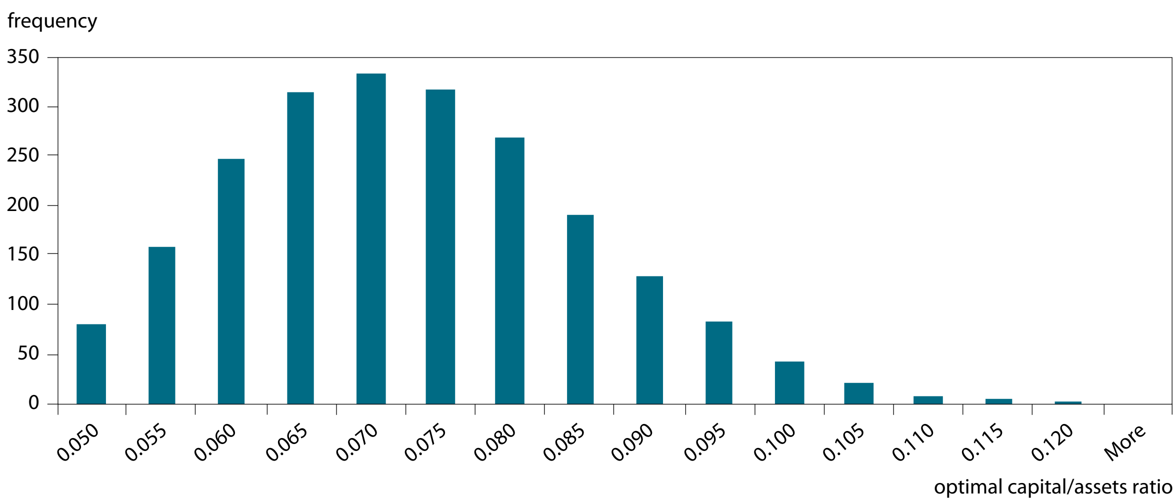
Source: Author's calculations.

Figure 3 Benefits and costs of additional bank capital



Source: Author's calculations.

Figure 4 Frequency of estimates for optimal capital/assets ratio



Source: Author's calculations.

Table 5 Basel III and FSB capital requirements for G-SIBs

Capital requirement	Percent of risk-weighted assets	Percent of total assets
Tangible common equity (TCE):		
Minimum	4.5	2.5
Capital conservation buffer	2.5	1.4
G-SIB surcharge	2.5	1.4
Total	9.5	5.3
Other Tier 1 capital[a]	1.5	0.84
Tier 2 capital[b]	2.0	1.12
Total Basel III capital (G-SIBs)	13.0	7.3
Other TLAC[b]	5.0	2.8
Total TLAC (FSB)	18.0	10.1

FSB = Financial Stability Board; G-SIBs = global systemically important banks; TLAC = total loss-absorbing capacity

a. Includes goodwill, deferred tax assets, some contingent convertible debt.
b. Other contingent convertible debt, subordinated debt.

Sources: BCBS (2010b, 2014); FSB (2015).