# Benefits and Costs of a Higher Bank Leverage Ratio

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**Abstract**

This study reports estimates of the marginal benefits and costs of increasing the regulatory minimum bank equity-to-asset leverage ratio from 4 percent to 15 percent. Benefits arise from reducing the probability of a banking crisis. Costs arise from reduced lending, should banks pass higher equity costs on to borrowers. Net benefits increase with a higher discount rate, a smaller tax advantage of debt, a lower nonfinancial corporate debt-to-capital ratio, a higher cost of crises, a longer duration of crises, or permanent effects of crises. Baseline estimates indicate that the benefits equal costs at 19 percent.

*JEL* codes: D61, G28, K20, L51, N21, N22, N41, N42

Keywords: bank regulation, benefit-cost analysis, capital adequacy standards, US banking crises

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**Benefits and Costs of a Higher Bank Leverage Ratio**

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## 1. Introduction

Throughout US history, rather than rely on careful benefit-cost analyses carried out by state or federal legislators or others at their request, government officials have let the politics of banking interests drive banking legislation and regulation (see Calomiris and Haber 2014; Bordo, Rockoff, and Redish 2015). Quantifying the benefits and costs of banking regulation can prove challenging, given the variety of ways to estimate them (see Coates (2015)). Moreover, financial regulation can have general equilibrium effects, which render the measurement of benefits and costs even harder than measuring other forms of regulation (see Cochrane (2014)). Both the political legacy and the difficulties arising from the estimation of costs and benefits may help explain the persistent debate on the merits of raising capital requirements.

In spite of resistance from the banking industry, numerous justifications for increasing equity capital requirements exist (Admati and Hellwig 2013; Admati et al. 2013; Thakor 2014). These reasons include better monitoring and a higher probability of surviving distress (e.g., Holmstrom and Tirole 1997; Mehran and Thakor 2011) and curbing shifts toward riskier asset holdings (e.g., Acharya, Mehran, and Thakor 2016). Berger and Bouwman (2013) also show that more-capitalized small banks tend to have a greater likelihood of surviving in good times, market crashes, and banking crises, and more-capitalized large banks are more likely to survive a banking crisis.

Meanwhile, the 1988 Basel Accords offered a multilateral way to raise capital requirements but added layers of complexity that have fostered regulatory arbitrage (see Merton 1995; Jones 2000; Brealey 2006). Moreover, Flannery (2014) and Flannery and Giacomini (2015) show that even when banks satisfied regulatory capital requirements, regulatory capital offered banks little resistance to the last crisis. Furthermore, the regulatory complexity has continued to grow since the 2007–2008 financial crisis (see Haldane 2012; Barth and Miller 2017).[1]

Because the growing regulatory complexity has not eliminated crises, we assess the merits of a simple reform: raising the flat equity leverage ratio, defined as the ratio of equity capital to total assets, from the 2014 regulatory minimum of 4 percent to 15 percent. While an increase of 11 percentage points may seem high to some, most banks in recent times have operated with at least twice the 2014 regulatory minimum. Also, Begenau and Landvoigt (2017) use a dynamic equilibrium model and find that a leverage ratio of at least 15 percent may maximize welfare. Similarly, Karmakar (2016) finds that doubling equity capital requirements from 8 percent to 16 percent can maximize welfare, while Egan et al. (2017) find that substantial financial instability and loss of welfare can arise when the capital requirement falls below the 15–18 percent range. A 15 percent minimum also has recently been proposed in US policy circles—for example, the Terminating Bailouts for Taxpayer Fairness Act of 2013 and the Federal Reserve Bank of Minneapolis plan.[2]

To measure the costs and benefits of raising the leverage ratio using a framework more commonly familiar to regulators assessing the merits of regulation, we draw on the methodology developed by Miles, Yang, and Marcheggiano (2013) for banks in the United Kingdom. They assume for their framework that a higher bank capital ratio reduces the probability of a crisis, which in turn reduces the loss of GDP.

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[1] In a recent speech to the International Economic Association, Richard Herring offered similar conclusions (see Herring 2016).

[2] The Terminating Bailouts for Taxpayer Fairness Act of 2013, S. 798, 113th Cong. (2013–14), https://www.congress.gov/bill/113th-congress/senate-bill/798. The Minneapolis Fed plan features risk-weighted measures of capital, but step 1 of the plan translates the risk-weighted measure to a 15 percent leverage ratio (see Federal Reserve Bank of Minneapolis 2016).

In general, calculating the benefits requires estimates of the loss per crisis and the marginal impact of a higher capital ratio on the probability of a banking crisis. Estimates of the loss per crisis are relatively straightforward. For the marginal impact of a higher leverage ratio on the probability of a banking crisis, which is more challenging to estimate, we take a "top-down" aggregate approach for the United States alone. A key reason for doing so follows from Calomiris and Haber (2014) and Bordo, Rockoff, and Redish (2015), who highlight the unique institutional features of the US banking system that have contributed to the high frequency of crises in the United States. We use probit regressions, which yield results similar to other limited dependent variable methods we apply, to estimate the marginal impact of the one-year-lagged aggregate bank leverage ratio on the probability of a banking crisis.

On the cost side, we adopt the "bottom-up" approach taken by Miles, Yang, and Marcheggiano (2013), but instead of using data for only the six largest bank holding companies, we use data for all bank holding companies with at least $1 billion in total assets between 1996 and 2014. The assumption underlying this approach is that raising capital requirements may raise the cost of capital, which banks might pass on to firms, thereby lowering real capital formation and GDP.

If this assumption is accepted, a key input in the framework for calculating the costs of a higher leverage ratio turns out to be the fraction of corporate funding coming from bank loans. Miles, Yang, and Marcheggiano (2013) assume that input equals 33 percent for the United Kingdom and argue that it would be lower for the United States. Estimates from US flow-of-funds data suggest that the current value equals less than 6 percent. To avoid understating the possible effects that might arise if the higher equity funding costs spill over to other segments of the corporate debt market, we instead use the nonfinancial corporate debt-to-capital ratio estimates reported by Rajan and Zingales (1995). They report that the median market debt-to-capital ratio equals 23 percent, while the median book value debt-to-capital ratio equals 37 percent, which is consistent with more recent estimates reported by studies of the "low leverage" puzzle (see Strebulaev 2007).

Last, unlike Miles, Yang, and Marcheggiano (2013), we assume that the offset suggested by Modigliani and Miller (1958) does not exist in the sense that more-equity-financed banks, in spite of the lower leverage and likelihood of default, would not offer a lower return on equity. We make this assumption because we find that no relationship exists between estimated bank betas and book leverage. Assuming no offset has the effect of raising the costs of a higher leverage ratio relative to what they might be with an offset, and it generates more conservative estimates of the optimal level.

As in Miles, Yang, and Marcheggiano (2013), Cline (2016), Dagher et al. (2016), the Federal Reserve Bank of Minneapolis (2016), and Firestone, Lorenc, and Ranish (2017), we estimate optimal ratios under different assumptions. Given our focus on the leverage ratio, we find that the sample average and median leverage ratios that equate marginal benefits and costs each equal 21 percent. These estimates fall within the 20–30 percent range suggested by Admati and Hellwig (2013) and Admati et al. (2013), although we assume raising the leverage ratio might have nontrivial costs, whereas they do not. Under fairly conservative baseline assumptions about the benefits and high costs, the optimal leverage ratio that equates marginal benefits and costs equals 19 percent.

The remainder of the paper proceeds as follows. The next section offers historical perspectives on the enactment of several major banking laws in the United States and a fairly general discussion of the factors that have led to those laws. We then turn to our analysis of the costs and benefits of implementing a simple capital requirement—namely, the increase in the equity leverage ratio from 4 percent to 15 percent—before concluding.

## 2. US Bank Failures and Crises, Banking Laws, and Benefit-Cost Analyses

When banking crises have arisen, the government's response has often been to enact a new law with an official promise that "never again" will such problems disrupt financial markets and economic activity.[3] Yet crises have continued to happen despite many new laws and regulations.

Banking historians have pointed out that the frequency of banking crises follows from a political collusion that sought to define the range of activities in which banks could engage and the geographical areas in which they could operate. Calomiris and Haber (2014) argue that banking laws from roughly 1810 to the 1980s primarily reflected a collusion between small banking interests and agrarian populists acting to protect small banking interests—a collusion that dominated banking politics. Since 1980 that collusion has shifted toward one between larger bank interests and urban populists. Accordingly, while distress during the most recent crisis seemed concentrated among larger commercial and investment banks, past US banking crises resulted primarily from banks that were too small because of laws and regulations. We provide some empirical evidence that may lend support to this view in section 3.

To visualize the timing of crises, policy changes, and bank capital, figure 1 depicts the equity-to-asset leverage ratio (also known as the capital-to-asset ratio) for the entire banking system from 1861 to 2014. The figure also identifies crisis years using the gray vertical bars and lists major banking laws that altered the regulatory environment during the pre-1980s small-bank

[3] Indeed, the use of that phrase was illustrated most recently by President Barack Obama when he declared on January 21, 2010, while proposing banking reforms, that "Never again will the American taxpayer be held hostage by a bank that is 'too big to fail.'" See Jesse Lee, "President Obama: 'Never Again Will the American Taxpayer Be Held Hostage by a Bank That Is Too Big to Fail,'" White House blog, January 21, 2010.

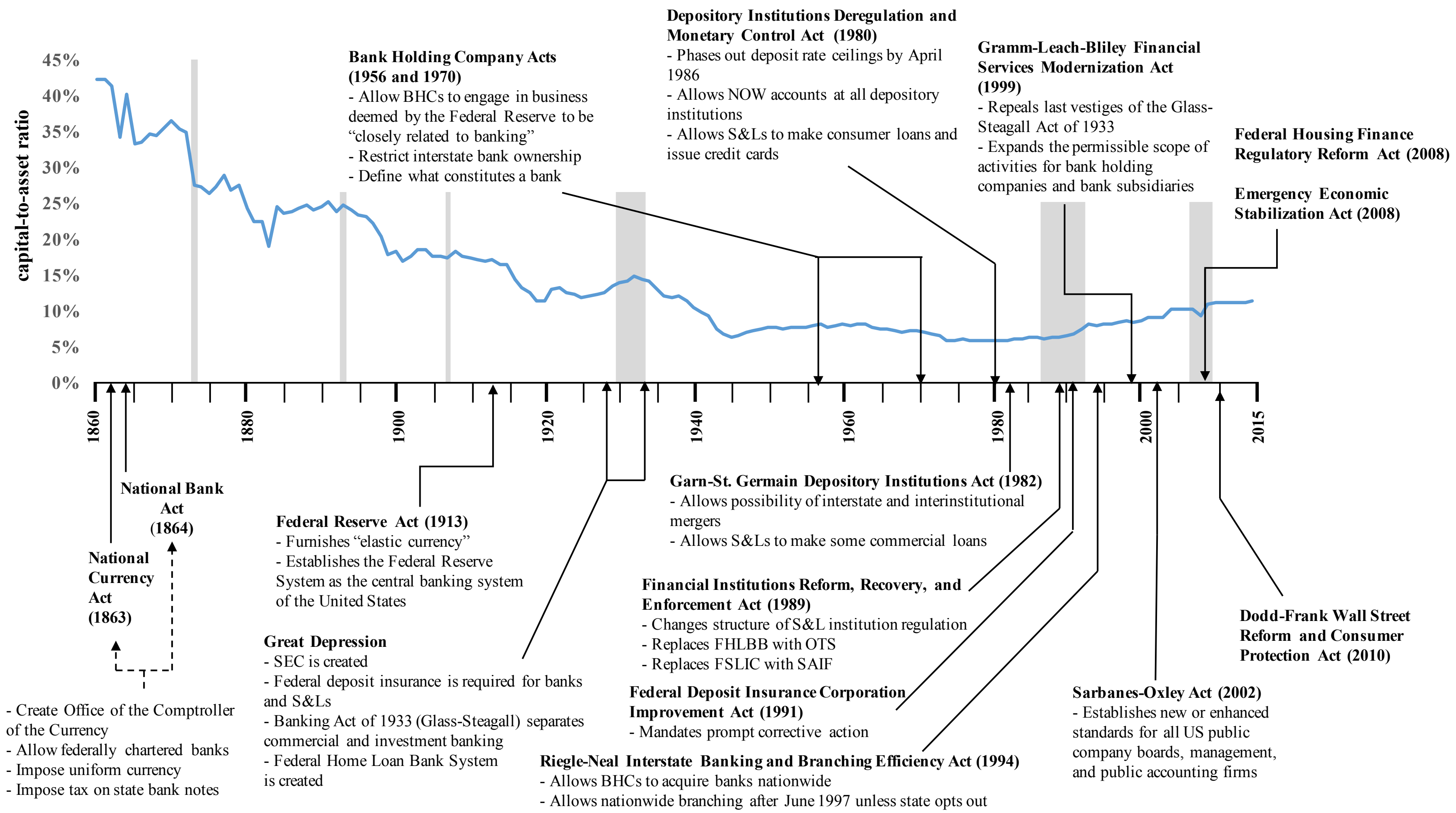
era .[4] Laws since the Depository Institutions Deregulation and Monetary Control Act of 1980 (Pub. L. No. 96-221, 94 Stat. 132), or DIDMCA, reflect the change in the political environment toward the large bank–urban populist political collusion.

Figure 1 shows that the leverage ratio of banks has steadily declined over time, from 42.3 percent in 1861 to a low of 5.7 percent in 1974, before it subsequently increased to 11.1 percent in 2014. Variations in the levels reflect significant changes in the regulatory views of the role of capital. "Prior to the 1980s, bank supervisors in the United States did not impose specific numerical capital adequacy standards. Instead, supervisors applied informal and subjective measures tailored to the circumstances of individual institutions" (FDIC 2003).

It was not until after the 1988 Basel Accords that regulatory capital requirements began rising again (see Barth and Miller 2017). The Dodd-Frank Wall Street Reform and Consumer Protection Act (Pub. L. No. 111-203, 124 Stat. 1376), enacted in July 2010, called for increasing capital requirements but also for employing more regulators with greater powers that aim to stop future crises. Yet the debate continues as to whether that policy offers a good substitute for simply maintaining a higher capital ratio. Having explained how capital, crises, and laws have evolved over time, we will briefly discuss how the business and politics of banking weakened banks.

[4] The Bank Holding Company Act of 1956 limited the definition of bank holding companies to those with an equity interest in two or more banks. This definition allowed single-bank holding companies to continue to own stakes in nonbank firms. The Banking Holding Company Act Amendments of 1970 closed this loophole.

**Figure 1. Timeline of US Major Banking Laws and Bank Capital-to-Asset (Equity-to-Asset) Leverage Ratio, 1861–2014**




Note: Shaded areas indicate crisis periods. BHC = bank holding company; SEC = Securities and Exchange Commission; S&L = savings and loan; NOW = negotiable order of withdrawal; FHLBB = Federal Home Loan Bank Board; OTS = Office of the Thrift Supervisor; FSLIC = Federal Savings and Loan Insurance Company; SAIF = Savings Association Insurance Fund.

Source: Adapted from figure 6.1 in James R. Barth, Gerard Caprio Jr., and Ross Levine, *Guardians of Finance: Making Regulators Work for Us* (Cambridge, MA: MIT Press, 2012), 148.

### *A. The Era of Small Banks*

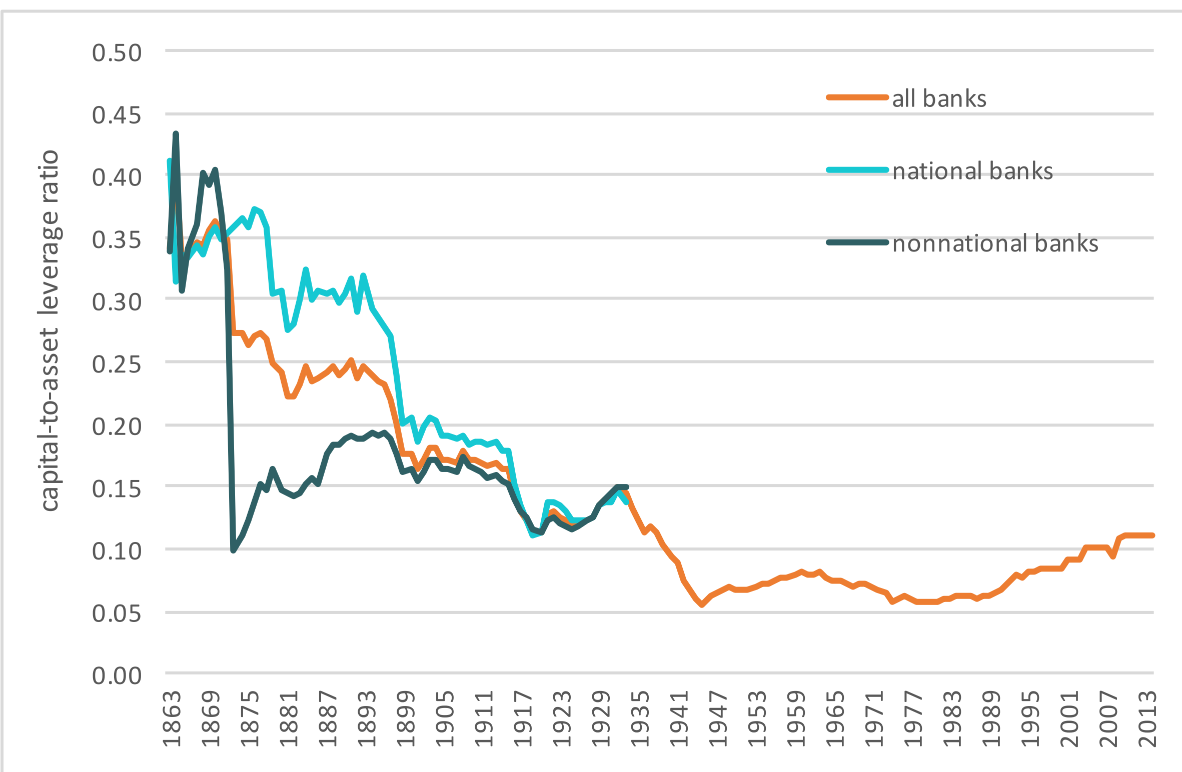
Until the early 1860s, states were the sole grantors of bank charters; the result was a patchwork of regulations recognized only within the jurisdictions of the issuers. It was in the interest of small banks to lobby their state legislatures to enact laws preventing banks chartered out of state from operating or acquiring banks in their jurisdictions. Branching was prohibited in some states, especially in the North and Midwest in the period after the Second Bank of the United States charter lapsed in 1836. In 1863, Congress established the Office of the Comptroller of the Currency (OCC) to issue national bank charters. The introduction of the OCC created a dual banking system, with national banks essentially limited for a long time to what state banks were allowed to do. The combination of interstate banking and branching restrictions meant that banks in the United States until recently have been poorly diversified across regions and thus prone to insolvency risks and bank runs.

An often overlooked aspect of regulatory capital requirements is that following the National Bank Acts and before the creation of the Federal Deposit Insurance Corporation (FDIC), capital requirements were specified not as ratios but as dollar-value entry requirements that increased with the size of the town in which banks were located. Thus, capital requirements served as barriers to entry.

White (1983) discusses capital requirements before the establishment of the Federal Reserve. National banks in towns with fewer than 6,000 inhabitants were required to have at least $50,000. Those in towns with populations between 6,000 and 50,000 had to have $100,000. Banks in larger towns had to have $200,000. New banks had to have a surplus fund that equaled 20 percent of required capital, which was built up from semiannual profits, and if the fund fell below that threshold, no dividends could be distributed. If a bank experienced losses greater than retained earnings plus the surplus, it was suspended. Capital requirements were usually weaker for state banks, although Louisiana and Massachusetts may have been exceptions.

Figure 2 depicts the capital-to-asset leverage ratios for all banks, national banks, and nonnational banks. The regulator of national banks, the OCC, gradually reduced capital requirements to enable them to compete with state banks, which federal authorities tried unsuccessfully to drive out of business by taxing the banknotes they issued. According to the Federal Reserve System's Board of Governors (1941, 45), "It was expected that the national banks would supersede the State banks and provision was made for the easy conversion of State banks into national banks without interruption to their business and without losing their corporate identities; but these expectations were not realized."

**Figure 2. Capital-to-Asset (Equity-to-Asset) Leverage Ratio: All Banks, National Banks, and Nonnational Banks, 1863–2014**

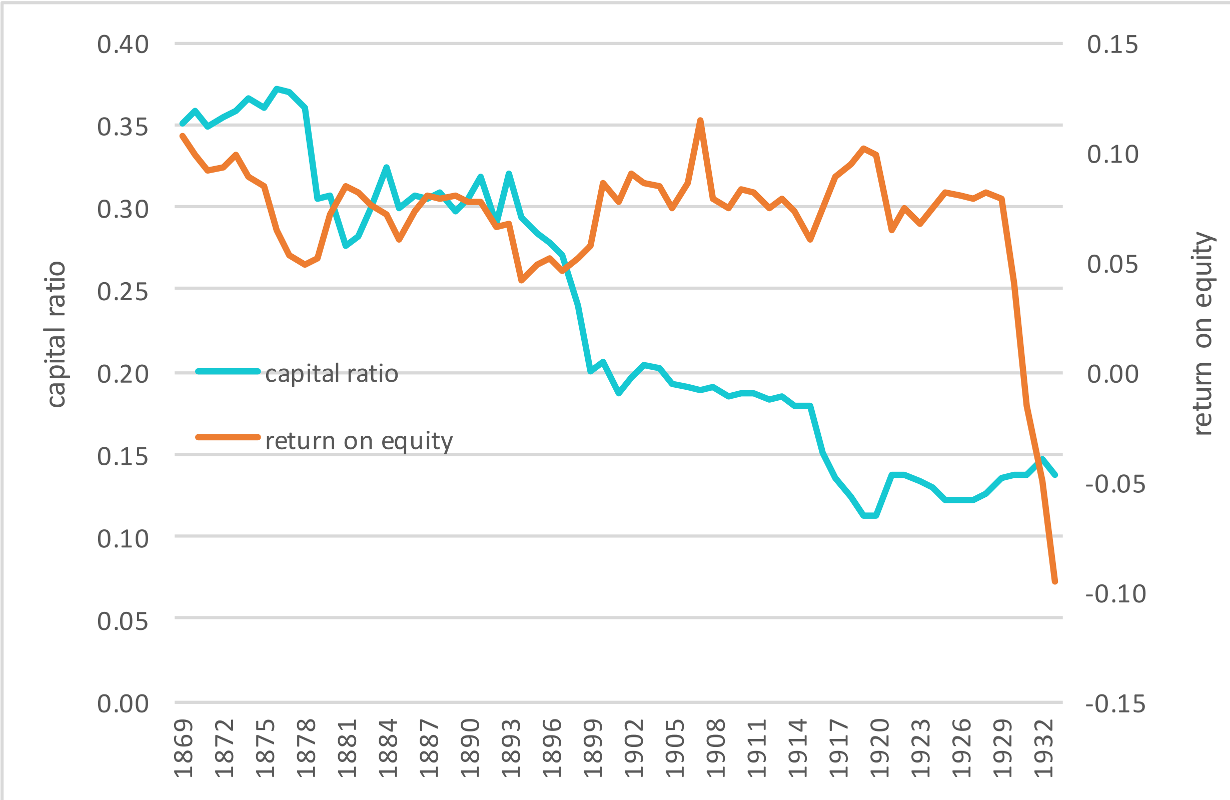



Source: See table A1.

Although national banks were outnumbered by nonnational banks in 1863 and 1864, over the next three decades they outnumbered nonnational banks until the 1890s, when the pattern again reversed. One reason for the growth of state banks could be their emergence in rural areas, where state capital requirements were generally lower than for national banks. Also, state regulation was generally laxer (White 1983). Capital requirements, and regulation generally, thus varied significantly across the two systems. By 1900 the gap between national and state bank capital ratios had narrowed significantly. White (1983) observes that the Gold Act of 1900 lowered capital requirements for national banks located in small towns, an action which may explain the subsequent decline in capital for all banks through 1920 as well as the increase in the number of banks.

Figure 3 depicts the capital-to-asset leverage ratio and the return on equity for national banks before the establishment of the FDIC. Further, it shows that as the ratio gradually fell, national banks were able to maintain a relatively stable return on equity over time. The exception is during the Great Depression. In spite of that, the average return on equity during the sample depicted in figure 3 equals about 7 percent.

**Figure 3. National Banks: Capital-to-Asset Ratio and Return on Equity, 1869–1933**




Source: See table A1.

### *B. The Era of Larger Banks*

The DIDMCA and the Riegle-Neal Interstate Branching and Banking Efficiency Act of 1994 (Pub. L. No. 103-328, 108 Stat. 2338) removed restrictions on interstate banking acquisitions and mergers as well as some of the restrictions on branching by banks. The number of banks began falling around 1980, while banks got larger in asset size mainly through mergers and acquisitions (see Janicki and Prescott 2006). In addition, the Financial Services Modernization Act of 1999, or Gramm-Leach-Bliley Act (Pub. L. No. 106-102, 113 Stat. 1338), repealed existing restrictions so that a financial services holding company could have banks, securities firms, and insurance companies as subsidiaries.

The US banking crisis that began in the spring of 2007 was followed by the Great Recession. Although bank size is often cited as a cause of the 2007–2009 crisis, Erel, Nadauld, and Stulz (2014) and Miller (2017) show that securitizing banks that had greater holdings of highly rated, private-label structured products performed worse during the crisis. These findings suggest that the banks' troubles related more to their activities than their size. Following the crisis, sections 606 and 607 of Dodd-Frank called for financial holding companies to be "well capitalized and well managed." The question still remains as to whether raising capital requirements has merit, and therefore we estimate and compare the benefits and costs of a higher leverage ratio.

## 3. On the Benefits and Costs of a Higher Leverage Ratio

We now turn to estimating the benefits of raising the flat equity leverage ratio from 4 percent to 15 percent against the costs for US banking organizations.[5] Our assessment of the benefits of a higher equity leverage ratio focuses on the relationship between the aggregate bank capital-to-asset (or equity-to-asset) ratio and major banking crises between 1892, when observations for all other variables included in our regression framework are first available, and 2014.

### *A. The Benefits of a Higher Capital Leverage Ratio: Reducing the Economic Effects of Crises*

Measuring the benefits by reducing the likelihood of a crisis year requires identifying when exactly crises occurred, which has proved challenging for the United States before the Great Depression. However, Jalil (2014) finds that between 1837 and 1929, major crises occurred in

[5] An issue that we do not address here is whether capital requirements should be implemented at the bank holding company level, at the bank subsidiary level, or both. See Black, Miller, and Posner (1978) and Kupiec (2015), who suggest that capital adequacy is better addressed at the subsidiary level than at the holding company level.

1837, 1839, 1857, 1873, 1893, and 1907.[6] The United States also experienced a banking crisis during the Great Depression (1930–1933), the Savings and Loan Crisis (1987–1992), and the recent crisis (2007–2009).[7] Using these years, we determine that the relative frequency of banking crisis years during the 1837–2014 period equals 10.7 percent and during the 1892–2014 period equals 12.2 percent.

López-Salido and Nelson (2010) also point out that crises in the United States occurred from 1973 to 1975 because bank capital levels had declined over the preceding decade, and from 1982 to 1984 in response to the Latin American debt crisis.[8] Adding the latter two events, the relative frequency of banking crisis years from 1837 to 2014 equals 14.0 percent, and from 1892 to 2014 it equals 17.1 percent. However, we exclude those events from our sample because those crises may have been relatively minor.

Table 1 reports data for crisis years since 1837 to provide a preliminary sense of the relationship between banking crises, real per capita GDP growth, and the aggregate bank capital-to-asset (equity-to-asset) ratio. Information about the construction of the bank capital ratio and

[6] Jalil (2014) covers the period from 1825 to 1929, which includes the banking crisis of 1833. However, this episode lies just outside our sample. Also, given that the Panic of 1907 began in mid-October, for the purpose of determining its effects on the real economy, Jalil suggests assigning the year 1907 to a prepanic period and 1908 to the crisis itself.

[7] For the Great Depression, we choose 1930–1933 because Friedman and Schwartz (1963) report that depositors experienced larger losses during those years (see table 16 on 438 of that volume). Also, annual percentage point declines in the number of banks equaled −5 percent, −8 percent, −13 percent, and −24 percent, respectively. The number of banks also declined throughout the 1920s, but Jalil (2014) identifies those declines as arising from minor crises. For the Savings and Loan Crisis, which took nearly a decade to resolve (from 1986 to 1995), we use Federal Deposit Insurance Corporation (FDIC) data on commercial bank failures to identify the S&L crisis years from 1987 to 1992. Almost 89 percent of the losses and 83 percent (949 out of 1145) of failed banks happened during those years. Reinhart and Rogoff (2009) identify the period 1984–1991 as a nonsystemic crisis period, and Chaudron and de Haan (2014) confirm the nonsystemic nature of the period. On the other hand, Laeven and Valencia (2012) and Dagher et al. (2016) identify 1988 as a systemic event in the United States, and Romer and Romer (2016) identify 1989–1992 as a period of financial distress. For the recent crisis, we use 2007–2009 because large financial institutions such as Citigroup and MetLife began to experience distress in 2007 and their stock prices rose after March 2009. Romer and Romer identify 2007–2011 as a period of financial distress.

[8] We thank Michael Bordo for bringing this study to our attention.

real per capita GDP growth variables, as well as the data sources we use, appears in table A1 of the appendix.

**Table 1. Real per Capita GDP Growth and Capital Ratios during Major Crisis Years, 1837–2014**

| Banking crisis year | Real per capita GDP growth (%) | Subsequent years with negative growth | Leverage ratio (%) |
|---|---|---|---|
| 1837 | −2 | | 41 |
| 1839 | 0 | 1840 (−2%), 1841 (−1%) | 47 |
| 1857 | −2 | | 39 |
| 1873 | 5 | 1874 (−1%), 1875 (−3%) | 28 |
| 1893 | −8 | 1894 (−1%) | 25 |
| 1907 | 1 | 1908 (−13%) | 17 |
| 1930 | −10 | | 14 |
| 1931 | −7 | | 14 |
| 1932 | −14 | | 15 |
| 1933 | −2 | | 15 |
| 1987 | 3 | | 6 |
| 1988 | 3 | | 6 |
| 1989 | 3 | | 6 |
| 1990 | 1 | | 6 |
| 1991 | −1 | | 7 |
| 1992 | 2 | | 8 |
| 2007 | 1 | | 10 |
| 2008 | −1 | | 10 |
| 2009 | −4 | | 11 |

Source: See table A1 in the appendix for details about variable construction and data sources.

Table 1 suggests that GDP has declined by small amounts during most banking crisis years and, in some cases, growth was still positive. Exceptions include the Panic of 1907 and the Great Depression, when the growth rate was negative and less than −10 percent. We discussed earlier how interstate banking restrictions factored into previous US banking crises, even when the aggregate capital ratio was high. The data in table 1 suggest that when the capital ratio was above 25 percent, banking crises were never associated with large negative real per capita GDP growth rates.

With this brief historical synopsis in mind, we follow the approach of Miles, Yang, and Marcheggiano (2013). They compute the benefits by multiplying estimates of the loss per crisis by a term that estimates the marginal impact on the probability of a banking crisis from increasing the capital ratio, but they work without historical data on bank capital or crises to estimate this impact. Instead, to quantify their assumption—that a higher capital ratio reduces the probability of a crisis, which in turn reduces the loss of GDP—they estimate the distribution of real per capita GDP shocks, using a panel of countries between 1821 and 2008. They show that GDP shocks relate to bank asset shocks, and then they examine the level of capital that would be large enough to absorb the GDP shock to the asset values.

Drawing from the approach of Miles, Yang, and Marcheggiano (2013), we compute the marginal benefit as the product of the loss per crisis and the term measuring the marginal impact of increasing the leverage ratio on the probability of a banking crisis:

$$\frac{\Delta Benefit}{\Delta LeverageRatio} = \underbrace{\left[ w_T \cdot \frac{1-\delta^T}{1-\delta} + \left(1 - w_T\right) \cdot \frac{1}{1-\delta} \right] \cdot Cost\ of\ Crisis}_{Loss\ Per\ Crisis} \cdot \frac{\Delta \Pr\left(Banking\ Crisis\right)}{\Delta LeverageRatio}, \quad (1)$$

where $w_T$ is the weight for the temporary component of the effects of a crisis on GDP, $\delta$ is the discount factor and $1-\delta$ is the discount rate, and $Cost\ of\ Crisis$ is measured as the one-year decline in real GDP per capita growth during a banking crisis. Before we discuss our approach to estimating the term $\frac{\Delta \Pr\left(Banking\ Crisis\right)}{\Delta LeverageRatio}$, which measures the marginal impact on the probability of a banking crisis of increasing the leverage ratio, we offer some additional intuition concerning equation (1).

In terms of the parameters used to compute the loss per crisis, Miles, Yang, and Marcheggiano (2013) assume that the temporary effects of a crisis last five years, but table 1 shows that the average length of a crisis in the United States is three years; as a more conservative benchmark, we assume that temporary effects last only two years.[9] At a 2.5 percent discount rate, the term in brackets in equation (1) would range from 40, if a crisis had only permanent effects, to 2.93 (1.975), if a crisis had only temporary effects that last three years (two years). At a discount rate of 5 percent, the term in brackets would range from 20, if a crisis had only permanent effects, to 2.85 (1.95), if a crisis had only temporary effects that lasted three years (two years).

Rather than assume crises have fully permanent effects, we assume crises have either 75 percent temporary effects ( $w_T$ = 0.75), as in Miles, Yang, and Marcheggiano (2013), or 90 percent temporary effects ( $w_T$ = 0.9). For these cases, at a 2.5 percent discount rate, the term in brackets equals 12.2 (6.6) with 75 percent (90 percent) temporary effects that last three years, and 11.5 (5.8) with 75 percent (90 percent) temporary effects that last two years. At a 5 percent discount rate, the term in brackets equals 7.1 (4.6) with 75 percent (90 percent) temporary effects that last three years and 6.5 (3.8) with 75 percent (90 percent) temporary effects that last two years.

We estimate that the cost of a crisis equals −10.3 percent of GDP, close to the −10 percent value that Miles, Yang, and Marcheggiano (2013) and Cline (2016) assume, or −4.4 percent.[10] The −10.3 percent value comes from either a second-stage ordinary least squares (OLS) or two-stage least squares estimation of the relationship between real per capita GDP growth and a banking crisis reported in appendix section A2, while the −4.4 percent estimate

[9] We also use a bivariate vector autoregression that includes real per capita GDP growth and a dummy variable that equals 1 for the start of a banking crisis (1893, 1907, 1930, 1987, and 2007). This autoregression is similar to that of Jalil (2014), whose results are based on an industrial production index rather than on GDP. Impulse response functions reveal that the effect of the start of a banking crisis dies out by the second year.

[10] In a previous draft, we estimated the same equations with the dummy variables reported in table 2, and the cost of a crisis was roughly −4.5 percent using the instrumental variable treatment regression method and −3.4 percent with the ordinary least squares regression that treats crises as exogenous.

comes from estimating an OLS regression that treats the banking crises as exogenous in that no first-stage probit regression gets estimated.

Using the −10.3 percent cost of a crisis, if we assume that crises have 25 percent permanent effects, that the temporary effects of a crisis last two years, and that the discount rate is 2.5 percent, the expected benefit of higher capital requirements per percentage-point reduction in the probability of crises equals 47.3 percent of one year's GDP. These assumptions provide a more conservative baseline than the 55 percent and 64 percent values used by Miles, Yang, and Marcheggiano (2013) and Cline (2016), respectively. Assuming instead, as in our benchmark case, that the discount rate equals 5 percent and that crises have 10 percent permanent effects, the expected benefit of higher capital requirements per percentage-point reduction in the probability of a crisis would fall to only 7.7 percent of one year's GDP.

To estimate the marginal impact of a higher leverage ratio on the probability of a crisis in equation (1), we deviate from the approach of Miles, Yang, and Marcheggiano (2013) for two reasons. First, they use a panel of countries to estimate the benefits of reducing the likelihood of a crisis and the associated decline in GDP growth, while the high frequency of banking crises in the United States suggests that its case merits study in isolation. Second, rather than data, they rely on well-reasoned assumptions about GDP shocks and bank balance sheets to reach conclusions about the link between the bank capital ratio, a banking crisis, and real per capita GDP growth between 1821 and 2008. We instead use data to directly estimate the association between the leverage ratio and the probability of a banking crisis.

One way to estimate the marginal impact on the probability of a banking crisis from increasing the leverage ratio in equation (1) is to use a limited dependent variable method and compute the marginal effects (on the probability of a banking crisis) at representative values of the leverage ratio. To see how, assume the crisis dummy variable, $I_t^{crisis}$, depends on an unobservable latent variable, $L_t^*$, which relates to other variables as follows:

$$I_t^{crisis} = \begin{cases} 1 \; if \; L_t^* > 0 \\ 0 \; otherwise \end{cases} , \qquad (2)$$
$$L_t^* = X_t'\gamma_X + \gamma_{LeverageRatio} LeverageRatio_{t-1} + e_t$$

where $LeverageRatio_{t-1}$ is the ratio of total banking sector capital (equity) to assets at the end of the previous year from 1891 to 2013, $X_t$ includes other continuous and dummy variables, and $e_t$ is an independently distributed error.[11]

Among the other variables, we include the one-year lag of the natural log of the cyclical component of the number of US banks extracted from Christiano and Fitzgerald's (2003) filter from 1891 to 2013, because bank entry following regulatory changes may have factored into past banking crises. As we discussed previously, White (1983), Mengle (1990), and Walter (2006) note that states historically used minimum-dollar capital requirements as a barrier to entry, and those barriers to entry were based on the size of the population in the locations where the banks operated. Thus, a correlation exists between the aggregate capital-to-asset (equity-to-asset) leverage ratio, the population, and the number of banks. However, Spearman correlation tests of independence indicate that the cyclical component of the number of banks is statistically independent of the leverage ratio and could be useful in examining the extent to which a sudden rise in bank entry might factor into banking crises.

[11] Jorda et al. (2017) use a specification similar to ours. However, they use the first year of a banking crisis, rather than any year during which a banking crisis occurred, as the dependent variable. When we use the first year of a banking crisis (1893, 1907, 1930, 1987, and 2007), the effect of lagged capital disappears. Our findings are therefore consistent with their conclusion that a higher capital ratio can speed up the recovery and therefore reduce the damage from a crisis, even if it does not eliminate crises.

We also include one-year-lagged inflation, one-year-lagged real per capita GDP growth, and changes in the natural log of one-year-lagged government size as a fraction of GDP.[12] Finally, we include Shiller's (2015) estimates of one-year-lagged returns on the S&P 500 and one-year-lagged real changes in the House Price Index to control for asset price shocks.

We also estimate some specifications that include dummy variables to capture the pre–Federal Reserve (Fed) period from 1892 to 1912, the pre-FDIC period from 1892 to 1933, the pre-Basel period from 1892 to 1987, and the pre–Riegle-Neal Act period from 1892 to 1994. The pre-Fed regime reflects the post–National Bank Act period. During this period, national banks were subject to double liability (see White 2011). Banks in some states were subject to double, triple, or even unlimited liability (see Esty 1998). White (2011) observes that bank failures were much less frequent during the period after the National Bank Act but before creation of the Fed, because double liability created incentives for bank shareholders to liquidate voluntarily before they became insolvent. The pre-FDIC period reflects the period after the creation of the Federal Reserve system, when discount window lending was introduced. The pre-Basel period may reflect what Gorton (2012) calls the "Quiet Period," when no major banking crises occurred. The pre–Riegle-Neal Act period may reflect the effects of interstate banking restrictions.

Assuming that a crisis is a normally distributed random variable, then the probability of a crisis or noncrisis, respectively, equals

$$I_t^{crisis} = \begin{cases} 1 \; with \; prob.: \Pr(L_t^* > 0) = \Phi\left( X_t' \gamma_X + \gamma_{LeverageRatio} LeverageRatio_{t-1} \right) \\ 0 \; with \; prob.: \Pr(L_t^* \leq 0) = 1 - \Phi\left( X_t' \gamma_X + \gamma_{LeverageRatio} LeverageRatio_{t-1} \right) \end{cases}, \qquad (3)$$

[12] We include this last variable because, as we mention in footnote 10, we also estimate instrumental variable treatment regressions to generate alternative estimates of the cost of a crisis in the United States, and the variable appears frequently in growth regressions.

which we estimate using the probit method.[13] Probit regressions assume the underlying latent variable follows a normal distribution, so we also repeat the exercise for logit and complementary log-log regressions, the latter being better suited for modeling rare events. In table 2, the first three columns report the results for specifications that only include continuous variables, and the last three columns report results using all variables.

**Table 2. Probit, Logit, and Complementary Log-Log Estimates of the Banking Crises, 1892–2014**

| 1. Variable | 2. Probit | 3. Logit | 4. Cloglog | 5. Probit | 6. Logit | 7. Cloglog |
|---|---|---|---|---|---|---|
| Lagged leverage ratio | −10.66** | −19.41** | −17.07** | −68.88** | −131.14** | −118.21** |
| | (4.99) | (9.61) | (8.27) | (29.33) | (56.23) | (49.46) |
| Lagged inflation | −9.52** | −17.74** | −15.05** | −17.29** | −29.66** | −23.87** |
| | (4.53) | (8.31) | (6.39) | (7.87) | (14.05) | (12.09) |
| Lagged cyclical component of banks | 10.07*** | 18.60*** | 16.50*** | 27.04*** | 51.06*** | 45.73*** |
| | (3.59) | (6.81) | (6.10) | (9.51) | (18.76) | (16.66) |
| Lagged real per capita GDP growth | −3.57 | −5.37 | −3.81 | −6.35 | −12.55 | −10.38 |
| | (3.79) | (6.85) | (6.17) | (5.85) | (11.15) | (10.12) |
| Lagged changes in size of government | 0.56 | 1.08 | 0.99 | 3.14* | 5.84* | 4.86* |
| | (0.98) | (1.80) | (1.57) | (1.65) | (3.07) | (2.77) |
| Lagged returns on S&P 500 | −2.76** | −5.11** | −4.44** | −4.70*** | −8.97** | −7.33** |
| | (1.08) | (2.07) | (1.81) | (1.81) | (3.50) | (2.98) |
| Lagged changes in real house prices | −1.77 | −3.02 | −2.33 | 2.60 | 4.45 | 3.71 |
| | (2.72) | (4.90) | (4.41) | (3.78) | (6.80) | (5.85) |
| Pre–Federal Reserve | — | — | — | 4.13** | 7.90** | 7.32** |
| | | | | (2.09) | (3.99) | (3.64) |
| Pre-FDIC | — | — | — | 3.66** | 7.45** | 6.81** |
| | | | | (1.71) | (3.34) | (2.85) |
| Pre-Basel | — | — | — | −4.36*** | −8.37*** | −7.25*** |
| | | | | (1.24) | (2.54) | (2.18) |
| Pre–Riegle-Neal | — | — | — | 1.56* | 2.64* | 1.93 |
| | | | | (0.88) | (1.56) | (1.25) |
| Constant | 0.02 | 0.09 | −0.29 | 5.25** | 10.13** | 8.84** |
| | (0.53) | (0.97) | (0.80) | (2.68) | (5.04) | (4.39) |
| N | 123 | 123 | 123 | 123 | 123 | 123 |

Note: Levels of statistical significance are represented as follows: 99 percent (***), 95 percent (**) and 90 percent (*).

[13] This approach implicitly assumes that each crisis year is statistically independent. Jalil's (2014) findings for the 1825–1929 period may well be consistent with this assumption, but since the Great Depression, crisis years may no longer be independent because crises tend to last longer than one year. In appendix table A4, we show that the results are qualitatively similar when we add a lagged dependent variable to the model in equation 2. Some have also suggested to us that an alternative approach might be to estimate the parameter using a survival analysis framework. This approach has merits in the sense that each crisis can be treated as a unique event that arises from idiosyncratic features. The downside to such an approach is that it would not address the duration of a crisis.

In appendix section A3, we report tests of nonstationarity and stationarity for each of the right-hand-side variables. With the exception of the lagged leverage ratio, we find the continuous variables are probably stationary. The apparent nonstationarity of the leverage ratio, which is bounded, may be owing to structural breaks. Tests of nonstationarity and stationarity indicate that the residuals of a regression of the lagged leverage ratio on the four dummy variables previously described may be stationary, which suggests that changes in the regulatory environment may explain the apparent nonstationarity.

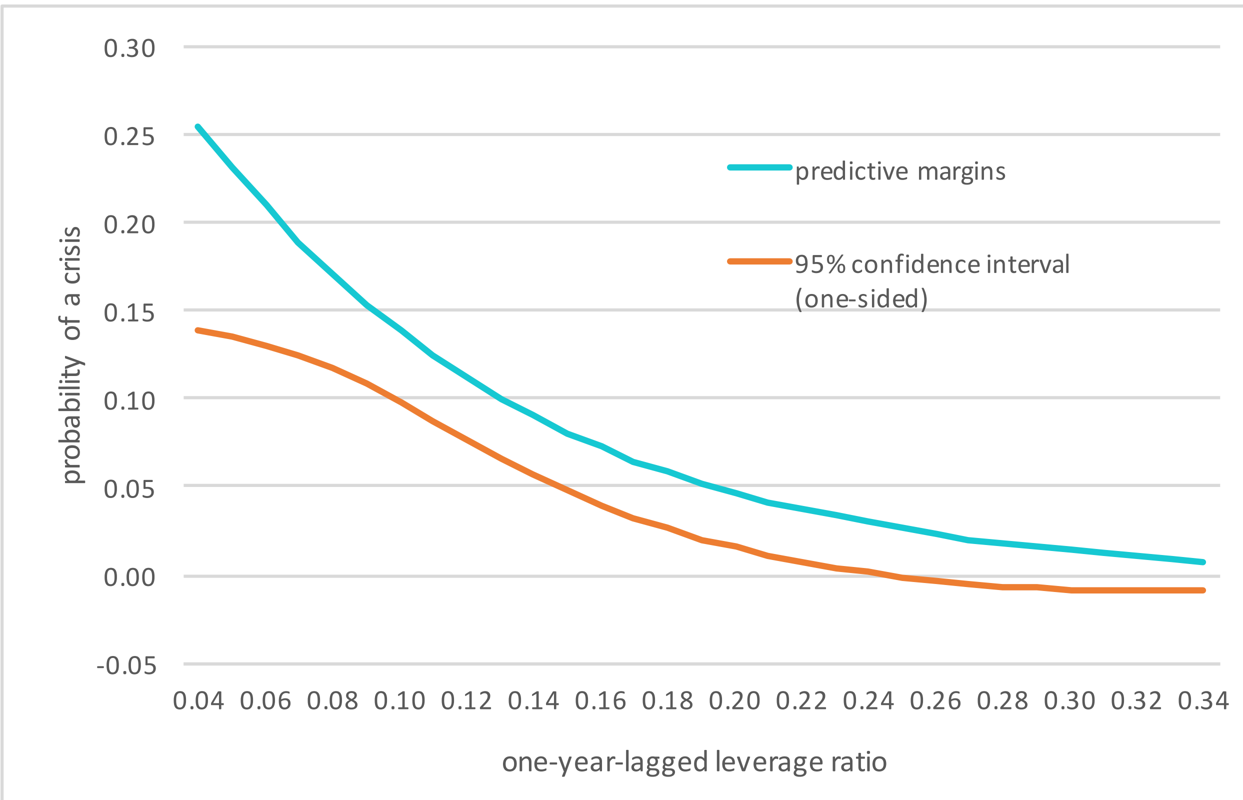
The regression results suggest that even though we use an aggregate banking statistic, because it reflects the level of capital across the industry, holding other factors constant, the lagged leverage ratio is negatively associated with banking crises.[14] In addition, we find that the cyclical component of the number of banks, lagged changes in the size of the government, and lagged changes in real house price are positively associated with a banking crisis, although for the changes in real house price, the results are not statistically significant at the 90 percent level or higher. We find that lagged real returns on the S&P 500 and lagged real per capita GDP growth are negatively associated with a banking crisis, although for the latter the results are not statistically significant at the 90 percent level or higher.

The negative and statistically significant coefficient for the pre-Basel FDIC dummy are consistent with the observation that there was a lower likelihood of a banking crisis during the "Quiet Period" after 1934. The positive and statistically significant coefficients for the pre–Riegle-Neal Act dummy are consistent with claims by Calomiris and Haber (2014) and Bordo,

[14] One concern about using the lagged leverage ratio as a right-hand-side variable is that it could be endogenous with respect to crises if crises last more than one year, which has been the case since the Great Depression. This endogeneity bias may not factor into the results, given that estimates of equation (2) after including a lagged endogenous variable that we report in table A4 are qualitatively similar. However, this is an issue that merits further study.

Rockoff, and Redish (2015) that banking crises were more likely before interstate banking; Chu (2015) also finds support for the concentration-stability hypothesis using data for Canadian banks during the 1867–1935 period.

**Figure 4. Predictive Margins of the One-Year-Lagged Leverage Ratio on Probability of a Banking Crisis**




Source: Authors' estimates.

Figure 4 presents the estimated predictive margins from the probit regression estimates, summarized in column 2 of table 2.[15] The figure shows that at low values of the leverage ratio,

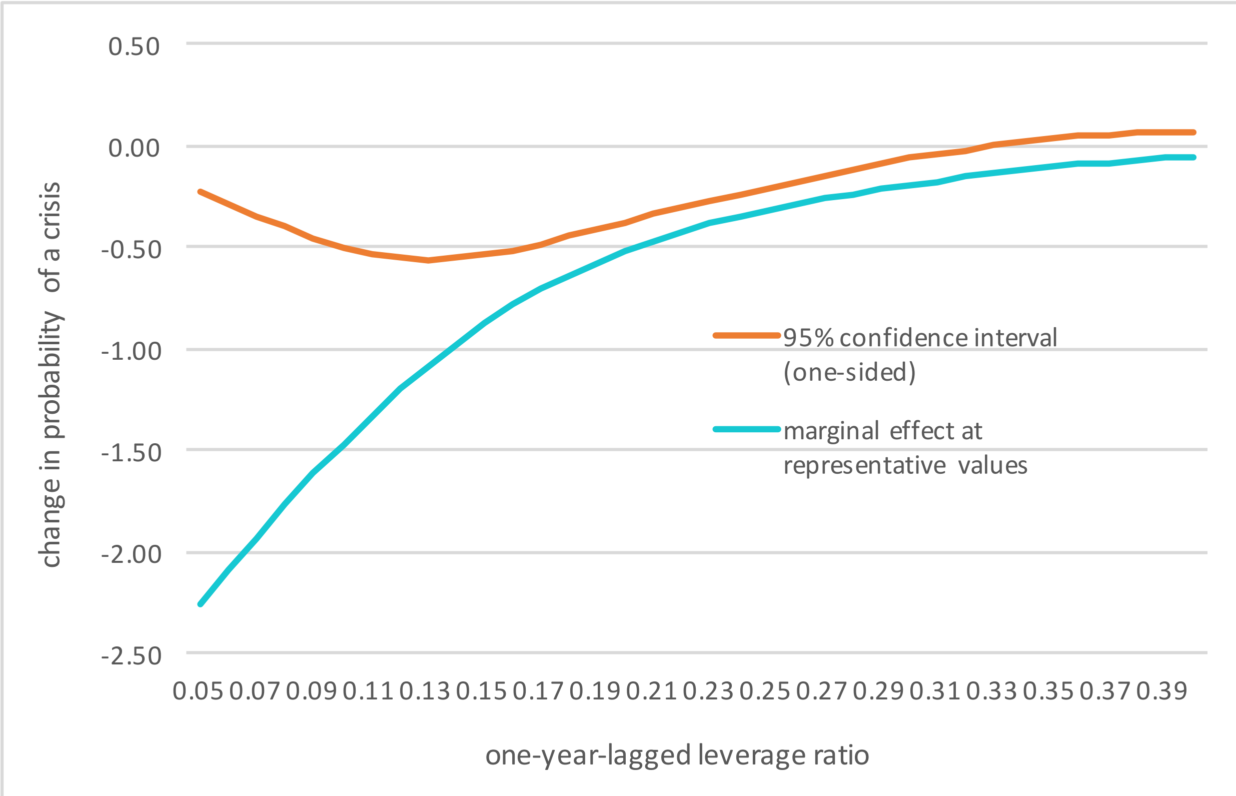
[15] In a previous draft, we calibrated our benefits to the results on the basis of the probit specification in table 2, column 5, which includes the dummy variables. However, the result of doing so is that the "predictive margins" schedule is much higher at low values of the leverage ratio but declines more sharply, and so the "marginal effect at representative values" schedule rises steeply and exhibits greater curvature. Using the predictive margins from the results in table 2, column 2 leads to the predictive margins schedule being lower and the schedule being flatter, and the corresponding marginal effects at representative values schedule likewise exhibits less curvature.

the probability of a banking crisis equals over 20 percent, but at higher values, the probability approaches zero. The standard error band is wider at lower levels of capital; this may reflect the fact that the capital levels reached low points in the late 1940s, when there were no banking crises, and again in the 1980s, when there were banking crises. The 1892–2014 sample average leverage ratio equals roughly 11 percent, which from the schedule in figure 4 implies that the relative frequency of a banking crisis is 12.4 percent, roughly equal to the relative frequency of banking crisis years during the sample.

Figure 5 depicts the key input we use in calculating the benefits, the marginal effects at representative values of the one-year-lagged leverage ratio on the probability of a banking crisis.[16] The figure shows that there are large marginal effects at low values of the leverage ratio, but the schedule tends to zero at higher values. We later use these marginal effects at representative values of the lagged leverage ratio to calculate the marginal benefits of increasing the simple equity leverage ratio, which we can compare against costs.

[16] In appendix section A5, figure A1, we show that the probit-based estimates of the schedules are similar to those for logit and complementary log-log regression estimates.

**Figure 5. Marginal Effects at Representative Values of the One-Year-Lagged Leverage Ratio on Probability of a Banking Crisis**




Source: Authors' estimates.

***B. Estimating the Costs of a Higher Leverage Ratio***

To estimate costs, Miles, Yang, and Marcheggiano (2013) examine the extent to which increasing bank capital requirements raises the cost of capital for banks. These added costs get passed on to borrowers in the form of higher interest rates, thereby reducing capital formation and GDP. While Miles, Yang, and Marcheggiano focus only on large banks, by using a $1 billion bank asset cutoff we can assess the impact of a rule change for much of US banking activity.

To translate changes in the weighted average cost of capital (WACC) into output losses, Miles, Yang, and Marcheggiano (2013) use an elasticity of output with respect to the cost of capital. To do this, the authors specify a production function, with capital and labor as inputs, from which they obtain the following elasticity of output with respect to the cost of capital:

$$\begin{aligned}\frac{dY}{dP_K}\frac{P_K}{Y} &= \frac{dY}{dK}\frac{K}{Y}\cdot\frac{dK}{dP}\frac{P}{K}\cdot\frac{dP}{dP_K}\frac{P_K}{P} \\ &= \alpha\cdot\sigma\cdot\frac{1}{\alpha-1}\end{aligned} \tag{3}$$

The first term measures the output elasticity with respect to the capital stock, which Miles, Yang, and Marcheggiano measure using capital's share of income, $\alpha$, assumed to equal 0.4. The second term measures the elasticity of substitution between capital and labor, $\sigma$, which as measured by Lawrence (2015) equals about 0.5. Cline (2016) applies the same parameter values for the United States to calculate the elasticity in equation (3) in his baseline case. The last term measures the elasticity of the price of capital relative to labor with respect to the cost of capital. Using the parameter values for $\alpha$ and $\sigma$ yields an elasticity of output equal to −0.33, slightly larger than Miles, Yang, and Marcheggiano's value of −0.25; this slightly higher elasticity of output has the effect of generating relatively higher costs.

Miles, Yang, and Marcheggiano (2013) assume that the cost of capital for firms equals the risk-free rate plus the market risk premium (multiplied by beta, measuring the market sensitivity of their equity returns to the market as a whole, set equal to one). Then, if banks pass on the costs of raising the leverage ratio to firms borrowing from the bank, the firm's cost of capital would rise in proportion to the fraction of all corporate funding coming from bank loans. However, rather than just bank loans, we use the debt-to-capital ratio, $\frac{Debt}{Debt + Equity}$, so that we do not understate the effects of higher capital requirements if the costs get passed on to other segments of the corporate debt market. Given our focus on the leverage ratio, the marginal cost equation that we use is this:

$$\frac{\Delta Cost}{\Delta LeverageRatio} = \frac{1}{1-\delta} \frac{\left[\alpha \cdot \sigma \cdot \frac{1}{\alpha - 1} \cdot \frac{Debt}{Debt + Equity}\right]}{Cost\ of\ Capital\ for\ Firm} \frac{\Delta WACC_{Bank}}{\Delta LeverageRatio} \tag{4}$$

Miles, Yang, and Marcheggiano use the fraction of all corporate funding coming from bank loans, which for their baseline case equals 33 percent, instead of a debt-to-capital ratio. They suggest that for the United States, this ratio might be lower. We use either the median market debt-to-capital ratio of 23 percent or the median book value debt-to-capital ratio of 37 percent, as reported by Rajan and Zingales (1995).[17]

We also assume the market risk premium equals 6 percent, as in Baker and Wurgler (2013).[18] Finally, we also analyze the effects of a 25 percent tax rate to reflect the tax advantage of debt.[19] Because we assume a constant elasticity of output with respect to capital, the marginal costs are horizontal and shift vertically as we vary the assumed parameter values.

Admati et al. (2013) argue that raising equity capital requirements has minimal, if not zero, social costs. Although the argument has appeal, some argue that there may be some output losses if it turns out that changing the mix of funding by banks has costs, which are then passed on to borrowers. We therefore attempt to address such concerns.

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[17] In an earlier draft, we used as parameter values the 1996–2014 average of bank lending as a fraction of all corporate funding from flow-of-funds data equal to 7 percent, the historical maximum of that series equal to 21 percent, as well as Miles, Yang, and Marcheggiano's (2013) 33 percent and Cline's (2016) 66 percent debt-to-asset ratio. However, Rajan and Zingales (1995) suggest that the debt-to-capital ratio is the most appropriate measure of firm leverage. From their table III panels A and B, as a lower bound on the range of values we use the median adjusted market value debt-to-capital ratio of 23 percent, while as an upper bound on the range of values we use the median unadjusted book value measure of debt-to-capital ratio of 37 percent. Strebulaev (2007) reports a median debt-to-capital ratio of 31.4 percent over the 1965–2000 period, which lies in the middle of the values we use and reflects the "low leverage puzzle," in that US firms tend to rely less on debt than theories of optimal capital might suggest.

[18] In an earlier draft, we assumed as in Miles, Yang, and Marcheggiano (2013) that the market risk premium equaled either 5 or 7.5 percent, but we found the results varied little based on this assumption. Therefore, we use a midrange value that Baker and Wurgler (2013) use.

[19] This figure is approximately equal to the values reported by Aswath Damodaran for "regional banks" and "money center" banks, available from http://people.stern.nyu.edu/adamodar/New_Home_Page/datafile/wacc.htm, as of the January 5, 2016, update.

For instance, the well-known "low-risk anomaly" reflects the fact that low-risk assets tend to outperform the market, whereas high-risk assets tend to underperform (see Baker and Wurgler 2013). Baker and Wurgler estimate the monthly effect of the low-risk anomaly at 68 to 75 basis points per month and suggest that, when annualized and multiplied by a 10 percentage point increase in the leverage ratio, the WACC would rise by 82 to 90 basis points. For an 11 percentage point increase in the leverage ratio that we use here, the WACC would rise by 90 to 99 basis points.

Miles, Yang, and Marcheggiano (2013) offer an alternative way to empirically estimate those costs by combining the capital asset pricing model and Modigliani and Miller's (1958) theorem insights (see Rubinstein 1973). We find that this approach generates increases in the cost of capital similar to what Kashyap, Stein, and Hanson (2010) estimate. For a 10 percentage point increase in capital requirements, Kashyap, Stein, and Hanson estimate that the WACC would increase between 25 and 45 basis points. While we focus on the effects of an 11 percentage point increase in the leverage ratio from 4 to 15 percent, a 10 percentage point increase in the leverage ratio using the approach we apply translates to a 31–60 basis point rise in the WACC.

To understand the Miles, Yang, and Marcheggiano (2013) approach, consider that a bank's measure of systematic equity risk should be proportional to a bank's asset risk multiplied by a bank's leverage, by which we mean the inverse of the leverage ratio. The dollar value of its assets multiplied by the beta for its assets equals the dollar value of its equity multiplied by the equity's beta, plus the dollar value of its debt multiplied by the debt's beta, or

$$\beta_{Asset} Assets = \beta_{Equity} Equity + \beta_{Debt} Debt \quad (5)$$

As the dollar value of the assets must equal the sum of debt plus equity, after dividing both sides by assets and substituting the sum of debt plus equity for assets, one obtains

$$\beta_{Asset} = \beta_{Equity}\frac{Equity}{Assets} + \beta_{Debt}\frac{Debt}{Assets} = \beta_{Equity}\frac{Equity}{Equity + Debt}. \tag{6}$$

The last equality arises because while debt as an obligation has only default risk—which is specific to the firm—and interest rate risk, the covariance between bond returns and the market portfolio equals zero, such that $\beta_{Debt} = 0$. Under these conditions, solving for the equity beta suggests that if a relationship exists between the asset beta and equity, it should be proportional to leverage:

$$\beta_{Equity} = \beta_{Asset}\frac{Equity + Debt}{Equity}. \tag{7}$$

This relationship is useful because while estimating the equity beta and measuring leverage is fairly straightforward, estimating the asset beta can prove challenging because assets may not trade, thereby making it difficult to quantify the market sensitivity. Miles, Yang, and Marcheggiano suggest estimating the asset betas from the coefficient of a regression of each bank's equity beta against the bank's leverage measured using the book value of its equity.

Because they have only semiannual data on bank leverage, to estimate equity betas Miles, Yang, and Marcheggiano (2013) apply the market model to daily closing stock prices for the six largest UK banks to estimate semiannual equity betas from 1996 to 2010. They then estimate the banks' asset betas by estimating pooled OLS, fixed effects, and random effects of the relationship between the banks' semiannual equity betas and measures of semiannual leverage. Larger US bank holding companies report leverage and other capital ratios at quarterly frequencies. Because our goal is to explore the implications of reducing bank leverage through a higher equity-to-asset leverage ratio, we estimate the relationship between bank equity betas and bank leverage, measured as total assets to book equity capital at quarterly frequencies.[20]

To estimate bank equity betas, we use a variant of Lewellen and Nagel's (2006) method of estimating quarterly betas from intraquarterly, daily data, which applies Dimson's (1979) correction for nonsynchronous trading arising from the use of daily data.[21] We compute 2,512,186 daily returns across all bank holding companies with at least $1 billion in assets that had between 59 and 64 observations per quarter computed from daily closing prices from January 2, 1996, to December 31, 2014.[22] As a benchmark portfolio, we use Datastream's Nonfinancial Index to eliminate any possible spurious correlations arising from the fact that we regress a bank's stock against an index that might otherwise include the stock.

As in Miles, Yang, and Marcheggiano (2013), we apply Fisher-type panel unit root tests with a drift term but no trend to both the equity betas and leverage for all banks with at least $1 billion in assets, or at least $50 billion in assets, and reject the null hypothesis that all series are nonstationary. In addition, we do not reject the null hypothesis of no serial correlation of the idiosyncratic errors based on Wooldridge's (2002) Wald test. In table 3, we report the estimated asset betas as suggested by equation (7) by regressing the equity betas against one-quarter-lagged bank leverage for banks with at least seven observations; we get similar results when we do not include this restriction.

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[20] We find similar results if we estimate the regressions replacing book leverage with the book asset-to-market equity ratio, total assets-to-Tier 1 capital or risk-weighted assets-to-Tier 1 capital.

[21] Dimson's (1979) method calls for correcting nonsynchronous trading bias by adding one-day leading and lagging returns to the standard bivariate market model and summing the three coefficients. The third quarter 1996–fourth quarter 2014 average Dimson beta equals 0.85, while the average ordinary market model beta equals 0.92.

[22] We lose 30,672 observations using this cutoff point.

**Table 3. Levels Estimates of Bank Asset Betas with Respect to Leverage across Methods Using Total Assets to Equity as an Estimate of Leverage, Third Quarter 1996–Fourth Quarter 2014**

| | Banks with total assets > $1 billion | | | Banks with total assets > $50 billion | | |
|---|---|---|---|---|---|---|
| | **Pooled OLS** | **Fixed effects** | **Random effects** | **Pooled OLS** | **Fixed effects** | **Random effects** |
| Assets to equity capital ratio | −0.002<br>(0.007) | −0.001<br>(0.008) | −0.002<br>(0.007) | 0.004<br>(0.011) | −0.008<br>(0.029) | −0.000<br>(0.014) |
| Intercept | 0.513***<br>(0.091) | 0.366***<br>(0.102) | 0.513***<br>(0.091) | 0.680***<br>(0.161) | 0.789**<br>(0.374) | 0.745***<br>(0.178) |
| *N* | 16,154 | 16,154 | 16,154 | 3,929 | 3,929 | 3,929 |
| *R*-squared overall | 0.008 | 0.008 | 0.008 | 0.086 | 0.083 | 0.085 |
| *R*-squared within | | 0.009 | 0.009 | | 0.092 | 0.091 |
| *R*-squared between | | 0.007 | 0.009 | | 0.026 | 0.044 |
| Hausman test (*p*-value chi-squared) | | 0.485 | | | 0.000*** | |
| Test for serial correlation (*p*-value *F*-test) | | 0.468 | | | 0.929 | |

Note: Standard errors clustered on the holding company are in parentheses. Levels of statistical significance are represented as follows: 99% (***), 95% (**), and 90% (*). OLS = ordinary least squares.

The estimated asset betas lie even closer to zero than those reported by Miles, Yang, and Marcheggiano (2013), whether we look at banks whose assets total at least $1 billion or those whose assets total at least $50 billion.[23] The Hausman test statistics in table 3 suggest that we cannot reject the hypothesis of no systematic differences between fixed- and random-effects specification for all banks, but we can reject this hypothesis for large banks. While Miles, Yang, and Marcheggiano use their fixed-effect estimates, we use the random-effects estimates of equation (6) for all banks and the fixed-effects estimate for large banks for the constant, $\hat{\beta}_0$, and estimated asset beta from the coefficient on the asset-to-equity capital ratio, $\hat{\beta}_{Asset}$, to compute the return on equity as

[23] Our pooled OLS estimates for all banks with at least $1 billion in total assets are similar to those reported by Baker and Wurgler (2013) for their 1996–2010 sample in table 4, panel A, column 2 of their study for the equity-to-assets ratio. Baker and Wurgler argue that the endogeneity of decisions about leverage as well as measurement error in the capital ratio would tend to bias the slope toward zero, while generating a positive intercept.

$$R_{Equity} = R_F + \left( \hat{\beta}_0 + \hat{\beta}_{Asset} \cdot \frac{Equity + Debt}{Equity} \right) R_M \quad (8)$$

Given that the asset betas reported in table 3 are small and statistically not different from zero, we assume no Modigliani-Miller offset exists, which raises the costs of capital above those which might occur if the Modigliani-Miller offset did exist. Using equation (8), at a market risk premium of 6 percent, the return on equity equals 8.08 percent for all banks and 9.73 percent for large banks. These figures lie below what Miles, Yang, and Marcheggiano (2013) assume but may be reasonable for the United States.[24]

The weighted average cost of capital adjusted for the tax advantage of debt equals

$$WACC = R_{Equity} \frac{Equity}{Equity + Debt} + R_F \cdot (1 - \tau) \cdot \left( 1 - \frac{Equity}{Equity + Debt} \right). \quad (9)$$

From equation (9), one obtains an average WACC equal to 5.1 percent at a bank leverage of 25, which rises to 5.5 percent for all banks and 5.7 percent for large banks when leverage falls to 6.67, assuming the risk-free rate equals 5 percent and the equity premium equals 6 percent. These average values lie close to the 5.33 percent that Miles, Yang, and Marcheggiano (2013) estimate for the six UK banks in their sample.

Miles, Yang, and Marcheggiano (2013) examine the effects of reducing leverage from 30 to 15. For the United States, total assets-to-book equity leverage averaged 9.4 by the fourth quarter 2014, the inverse of which implies a leverage ratio of 11.1 percent. Since in 2014 the leverage ratio under Basel III was 4 percent (see Barth and Miller 2017), we examine the effects of raising the leverage ratio from 4 percent to 15 percent, which implies reducing leverage from

[24] These figures are slightly higher than the 6.56 percent and 9.55 percent values reported by Damodaran for "regional banks" and "money center" banks, respectively, available from http://people.stern.nyu.edu/adamodar/New_Home_Page/datafile/wacc.htm, as of the January 5, 2016 update.

25 to 6.67. Keep in mind, however, that in the fourth quarter 2014, the 10th and 5th percentile leverage ratios equaled 8.6 percent and 7.8 percent, respectively. That means almost 95 percent of the bank holding companies in our sample operated with roughly twice the 4 percent threshold by the end of 2014, which is consistent with findings in Berger et al. (2008).

## 4. Comparing the Benefits and Costs of a Higher Leverage Ratio

### *A. Summary Statistics*

We begin by generating 288 optimal leverage ratios that arise from varying assumptions. We make 12 different assumptions about benefits, including (1) whether crises have 75 percent, 90 percent, or 100 percent temporary effects, (2) whether the temporary effects last two years versus three years, and (3) whether the loss per crisis is −4.4 percent or −10.3 percent. Our 12 different cost assumptions arise from assuming (1) four different cost assumptions using Miles, Yang, and Marcheggiano's (2013) approach, using a return on equity of 8.08 percent or 9.73 percent and assuming either a tax advantage of debt or no tax advantage of debt; (2) two different cost assumptions using Baker and Wurgler's (2013) approach, in which the WACC rises because the low-risk anomaly effect has a monthly estimate of 68 basis points or 75 basis points; and (3) the debt-to-capital ratio for nonfinancial corporations equals either 23 percent or 37 percent. From the 12 benefit and 12 cost assumptions, we get 144 cases at a discount rate of 2.5 percent and 144 cases at a discount rate of 5 percent, for a total of 288 cases.

Table 4 reports the mean, median, and 25th and 75th percentiles of the optimal leverage ratio across all cases and for subsets of the sample based on our assumptions. The results below the top line are sorted by the mean optimal leverage ratio. Across all cases, the mean and median optimal leverage ratio equal 21 percent.

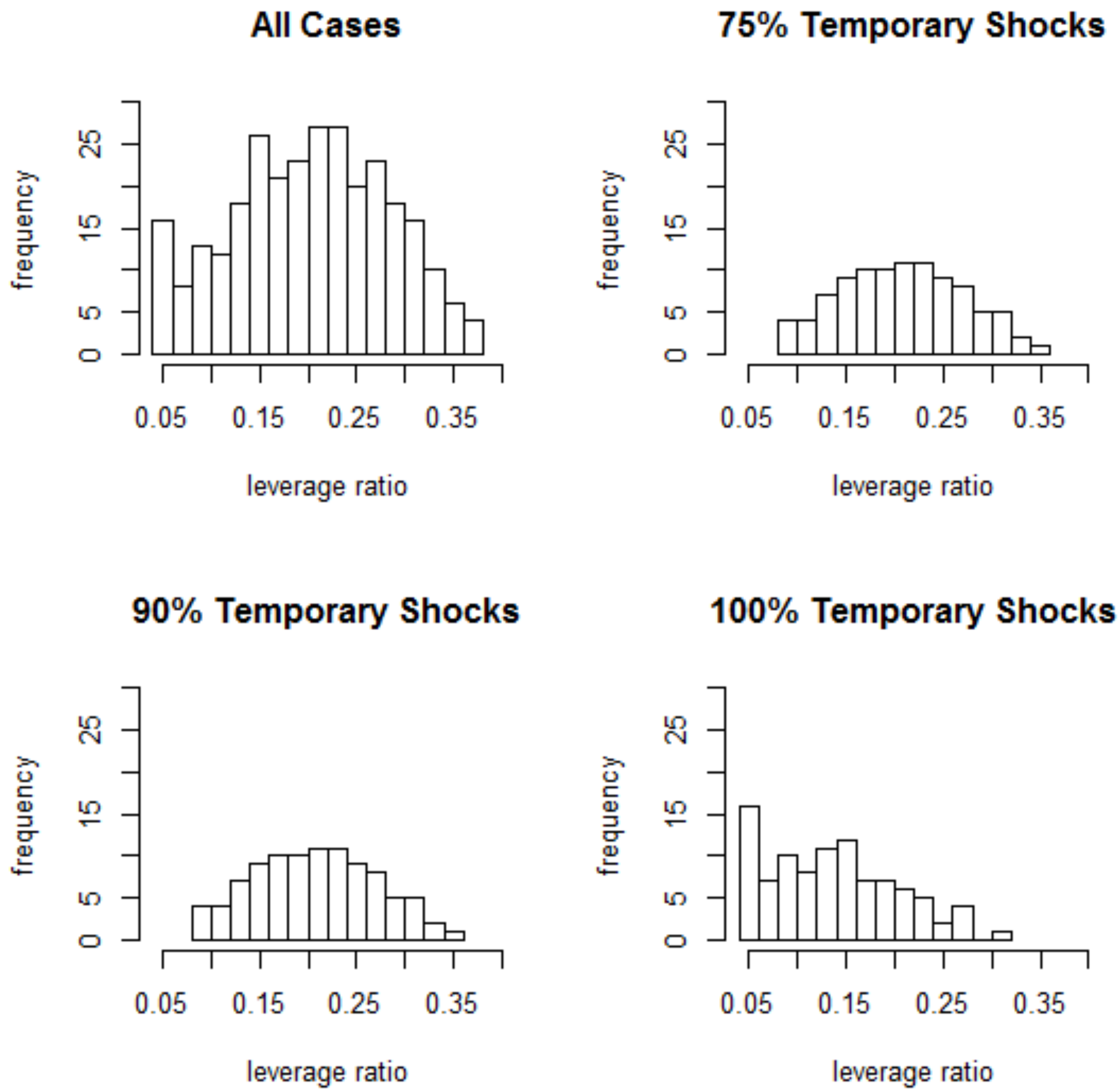
**Table 4. Summary Statistics of Optimal Leverage Ratios**

| | 25th percentile | Median | Mean | 75th percentile | Standard deviation | N |
|---|---|---|---|---|---|---|
| All cases | 0.15 | 0.21 | 0.21 | 0.27 | 0.08 | 288 |
| 25 percent permanent shocks | 0.22 | 0.27 | 0.27 | 0.31 | 0.06 | 96 |
| Miles et al. low ROE no tax advantage of debt | 0.21 | 0.27 | 0.26 | 0.32 | 0.07 | 48 |
| Growth −10.3 percent | 0.20 | 0.25 | 0.25 | 0.30 | 0.07 | 144 |
| 23 percent debt-to-capital ratio | 0.18 | 0.23 | 0.23 | 0.29 | 0.08 | 144 |
| Miles et al. low ROE tax advantage of debt | 0.17 | 0.23 | 0.23 | 0.29 | 0.08 | 48 |
| 5 percent discount rate | 0.17 | 0.23 | 0.22 | 0.28 | 0.07 | 144 |
| Miles et al. high ROE no tax advantage of debt | 0.17 | 0.22 | 0.22 | 0.28 | 0.08 | 48 |
| 3-year duration of shocks | 0.16 | 0.21 | 0.22 | 0.28 | 0.08 | 144 |
| 10 percent permanent shocks | 0.17 | 0.21 | 0.21 | 0.26 | 0.06 | 96 |
| Miles et al. high ROE tax advantage of debt | 0.14 | 0.20 | 0.20 | 0.25 | 0.08 | 48 |
| 2-year duration of shocks | 0.14 | 0.20 | 0.20 | 0.26 | 0.08 | 144 |
| 2.5 percent discount rate | 0.13 | 0.20 | 0.19 | 0.26 | 0.09 | 144 |
| 37 percent debt-to-capital ratio | 0.13 | 0.18 | 0.18 | 0.24 | 0.08 | 144 |
| Baker and Wurgler, alpha = 0.68 | 0.11 | 0.17 | 0.17 | 0.22 | 0.07 | 48 |
| Growth −4.4 percent | 0.12 | 0.17 | 0.17 | 0.22 | 0.07 | 144 |
| Baker and Wurgler, alpha = 0.75 | 0.11 | 0.16 | 0.16 | 0.21 | 0.07 | 48 |
| No permanent shocks | 0.09 | 0.14 | 0.14 | 0.19 | 0.07 | 96 |

Note: ROE = return on equity.

In 163 of the 288 cases, the optimal leverage ratios we compute fall within or exceed the 20 percent to 30 percent range that Admati and Hellwig (2013) and Admati et al. (2013) suggest. In 221 of the 288 cases, the optimal leverage ratio equals or exceeds 15 percent. Figure 6 depicts histograms of the distribution of the optimal leverage ratios and reveals that a key assumption in determining whether the benefits exceed costs is whether shocks have only temporary effects.

**Figure 6. Distribution of the Optimal Leverage Ratio**




### *B. Determinants of the Optimal Leverage Ratio*

Table 5 reports coefficient estimates of an OLS regression of the optimal leverage ratio against dummy variables that reflect the assumptions used to generate the optimal leverage ratios. The baseline case reflected by the constant assumes (1) that the cost of a crisis equals −10.3 percent; (2) that shocks are 90 percent temporary; (3) that the temporary component of shocks lasts two years, (4) that Baker and Wurgler's (2013) higher-cost assumption, that the slope of the low-risk anomaly equals 75 basis points per month, is true; (5) that the debt-to-capital ratio equals 37 percent; and (6) that the discount rate equals 5 percent.

**Table 5. Determinants of the Optimal Leverage Ratio**

| | OLS regression of OCR |
|---|---|
| −4.4 percent cost of a crisis (vs. −10.3 percent cost of a crisis) | −0.08*** |
| No permanent shocks (vs. 10 percent permanent shocks) | −0.07*** |
| 25 percent permanent shocks (vs. 10 percent permanent shocks) | 0.06*** |
| 3-year duration of shocks, (vs. 2-year duration of shocks) | 0.02*** |
| Miles et al. low ROE no tax advantage of debt (vs. Baker and Wurgler high-cost, low-risk anomaly slope 75 basis points) | 0.10*** |
| Miles et al. low ROE tax advantage of debt (vs. Baker and Wurgler high-cost, low-risk anomaly slope 75 basis points) | 0.07 |
| Miles et al. high ROE no tax advantage of debt (vs. Baker and Wurgler high-cost, low-risk anomaly slope 75 basis points) | 0.06*** |
| Miles et al. high ROE tax advantage of debt (vs. Baker and Wurgler high-cost, low-risk anomaly slope 75 basis points) | 0.04*** |
| Baker and Wurgler low-cost, low-risk anomaly slope 68 basis points (vs. Baker and Wurgler high-cost, low-risk anomaly slope 75 basis points) | 0.01*** |
| Debt-to-capital ratio, 23 percent (vs. 37 percent) | 0.05*** |
| 2.5 percent discount rate (vs. 5 percent discount rate) | −0.03*** |
| Constant | 0.19*** |
| $R$-squared | 0.97 |
| $N$ | 288 |

Note: Robust standard errors used to determine statistical significance. Levels of statistical significance are represented as follows: 99% (***), 95% (**) and 90% (*). OLS = ordinary least squares; OCR = optimal capital ratio.

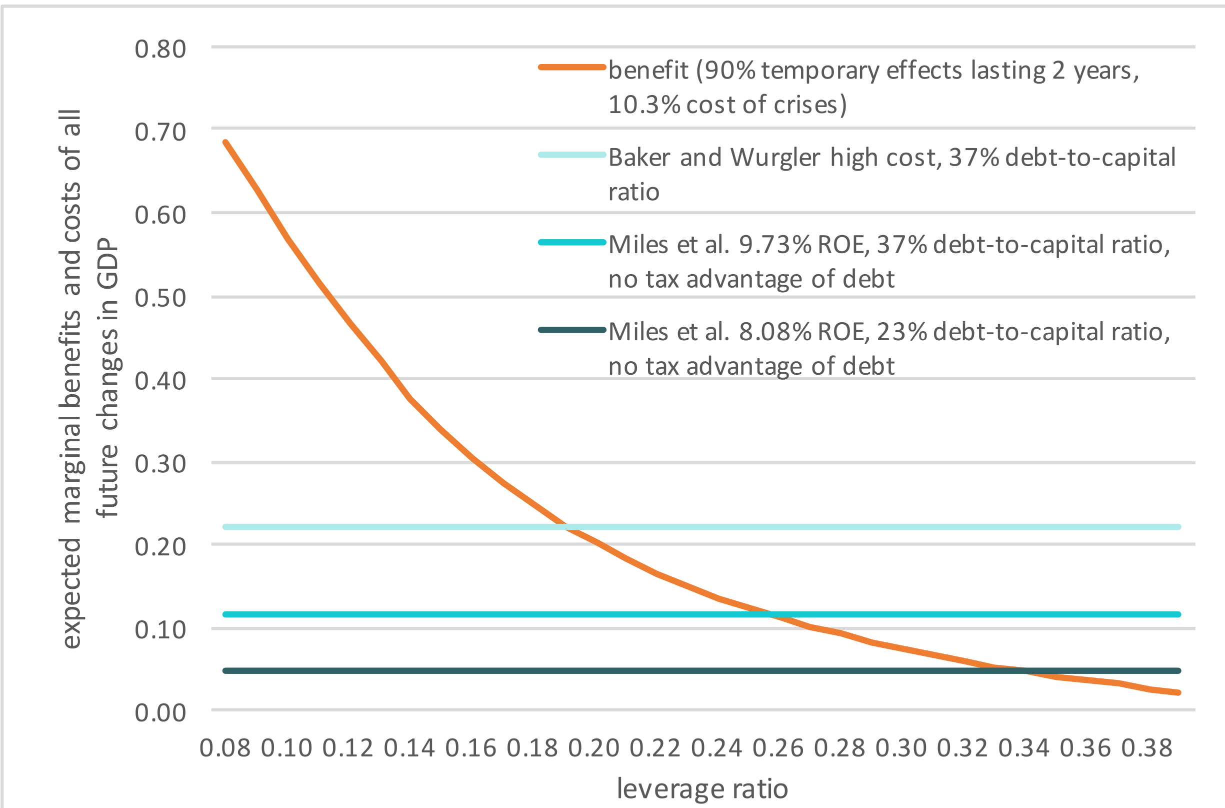
To show the *ceteris paribus* effects of changing the assumptions, we include as right-hand-side variables a dummy variable that equals

- one assuming shocks have 75 percent temporary effects, and zero otherwise;
- one assuming shocks have 100 percent temporary effects, and zero otherwise;
- one assuming the duration of the temporary effects of shocks equals 3 years, and zero assuming it equals 2 years;

- one assuming the cost of a crisis equals −4.4 percent, and zero assuming it equals −10.3 percent;
- one assuming the debt-to-capital ratio equals 23 percent, and zero assuming it equals 37 percent;
- one assuming the Baker and Wurgler (2013) lower-cost assumption, that the slope of the low-risk anomaly equals 68 basis points per month, and zero otherwise;
- one assuming the Miles, Yang, and Marcheggiano (2013) 8.08 percent return on equity case with no tax advantage of debt, and zero otherwise;
- one assuming the Miles, Yang, and Marcheggiano 8.08 percent return on equity case with a tax advantage of debt, and zero otherwise;
- one assuming the Miles, Yang, and Marcheggiano 9.73 return on equity case with no tax advantage of debt, and zero otherwise;
- one assuming the Miles, Yang, and Marcheggiano 9.73 return on equity case with a tax advantage of debt, and zero otherwise; and
- one assuming the discount rate equals 2.5 percent, and zero if it equals 5 percent.

The constant equals 19 percent, reflecting the optimal leverage ratio for the baseline assumptions previously mentioned. On the benefits side, *ceteris paribus*, lowering the cost of a crisis or increasing the temporary component of shocks to 100 percent tends to lower the optimal leverage ratio, whereas reducing the temporary component to 75 percent tends to increase the optimal leverage ratio. On the costs side, *ceteris paribus*, assumptions that generate smaller increases in the WACC result in a higher optimal leverage ratio, while accounting for the tax advantage generates a lower optimal leverage ratio. In addition, decreasing the debt-to-capital ratio for nonfinancial corporations from 37 percent to 23 percent, *ceteris paribus*, increases the optimal leverage ratio. Finally, *ceteris paribus*, lowering the discount rate to 2.5 percent tends to lower the optimal leverage ratio, because doing so shifts the benefits schedule upward and makes it steeper while also shifting up the cost schedule.

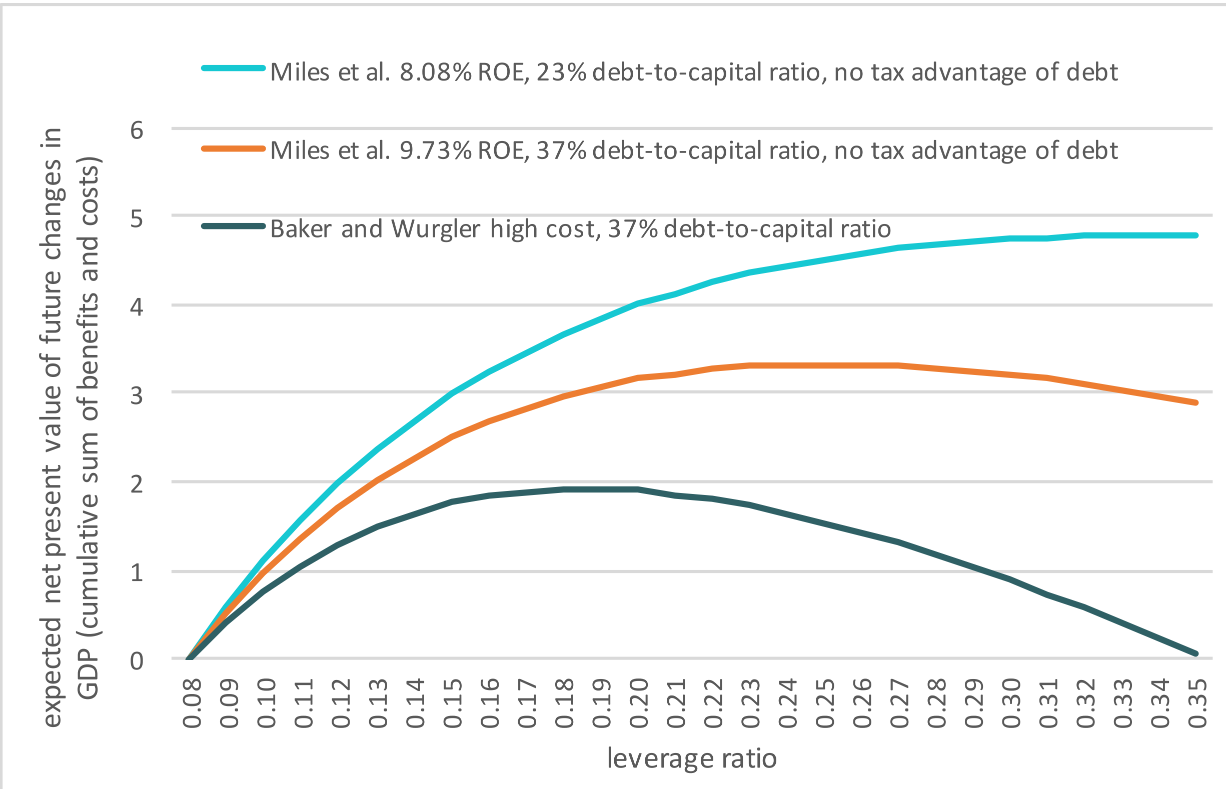
**Figure 7. Marginal Benefits and Costs across Various Cost Assumptions, Discount Rate Equal to 0.05**




Note: ROE = return on equity.

Figure 7 depicts the marginal benefit schedule for our baseline assumptions used to estimate the regression summarized in table 5, as well as three marginal cost curves reflecting the highest-cost, moderate, and lowest-cost assumptions, assuming a 5 percent discount rate. *Ceteris paribus*, for the highest-cost, moderate, and lowest-cost assumptions, the optimal leverage ratios equal 19 percent, 25 percent, and 34 percent, respectively. While the optimal criteria differ, this finding is consistent with Egan, Hortacsu, and Matvos's (2017) finding that the more damaging the instability, the greater will be the optimal capital requirement.

**Figure 8. Net Total Benefits across Various Cost Assumptions, Discount Rate Equal to 0.05**




Note: ROE = return on equity.

Figure 8 depicts the three corresponding net total benefit schedules, in which the peaks of the curves correspond with the optimal ratios implied by figure 7. We present results that increase the ratio starting at 8 percent because nearly 95 percent of all banks, which held more than 95 percent of all assets as of 2014 in our sample, had a ratio at least that large. While the net total benefits are smaller than those reported by Miles, Yang, and Marcheggiano (2013), this difference arises in part because we assume the temporary effects of crises last only two years rather than five years, we use a higher discount rate, and we start the schedule at an 8 percent leverage ratio because almost all banks were already operating at that level.

### *C. Comparing Optimal Capital Ratios across Benefit-Cost Studies for US Banks*

Table 6 summarizes key aspects of the optimal leverage ratios reported earlier, as well as those estimated by Cline (2016), step 1 of the Federal Reserve Bank of Minneapolis (2016), and Firestone, Lorenc, and Ranish (2017) for banks in the United States.[25] By combining our aggregate "top-down" approach to estimating the benefits with a bank-level "bottom-up" approach to estimate the costs, our baseline case assumptions generate an optimal book equity-to-asset leverage ratio equal to 19 percent, largely because we adopt the Baker and Wurgler high-cost assumption and assume that shocks have 10 percent permanent effects. The baseline case also assumes a 5 percent discount rate in order to compare with step 1 of the Federal Reserve Bank of Minneapolis plan and Firestone, Lorenc, and Ranish.

While our aim throughout has been to examine the merits of a simpler, higher capital requirement, to compare with other related studies of the United States we also transform that estimate into familiar regulatory capital measures. In our sample, the average ratio of Tier 1 capital to book equity equals 96 percent, which implies that the Tier 1 capital-to-total-asset ratio equals 18 percent. Given that the average ratio of total to risk-weighted assets for all bank holding companies with at least $1 billion in total assets equals 1.38, the implied optimal Tier 1 capital-to-risk-weighted-assets ratio equals 25 percent.

[25] For the sake of comparison, Miles, Yang, and Marcheggiano (2013) find that optimal Tier 1 capital-to-risk-weighted-assets ratios for UK banks in most cases range from 16 percent to 20 percent, which implies a range of Tier 1 capital leverage ratios of 7–9 percent. However, when they account for large GDP shocks, the optimal risk-weighted measure rises as high as 47 percent and implies a leverage ratio equal to 20 percent. Dagher et al. (2016) estimate optimal Tier 1 capital ratios for a sample of global banks equal to 15–23 percent of risk-weighted assets, which implies a leverage ratio of 8.5–13 percent.

## Table 6. A Comparison of US Optimal Capital Ratios

| | Cline (2016) | Minneapolis Fed (2016): Step 1 | Firestone et al. (2017) | This study |
|---|---|---|---|---|
| Approach to estimating probability of a crisis | Top-down | Bottom-up | Top-down and bottom-up | Top-down |
| Crises | BCBS (2010), Laeven and Valencia (2012) 1977–2015 | Laeven and Valencia (2012) 1970–2011, 162 countries, 147 crises | Laeven and Valencia (2012) 1988–2014 | Jalil (2014) for 1892–1929; Friedman and Schwartz (1963) for Great Depression; FDIC bank failure data for S&L crisis |
| Approach to estimating costs of higher capital requirements | Bottom-up | Bottom-up | Bottom-up | Bottom-up |
| Banks | 54 large US banks, 2001–2013 | All banks ≥ $250 billion, 2010–2015 | All banks ≥ $50 billion, 2001–2015 | All banks ≥ $1 billion, 1996–2014 |
| Discount rate | 2.5% | 5% | 2.7% (+ 5% rate of decay of the effects of crises) | 5% |
| Assumed Modigliani-Miller offset | 0.35–0.60 | 0.50 | 0.50 | 0 |
| Return on equity | 7%, 10%, 13% | 8.58% | 8.71% | 8.08%, 9.73% |
| Total assets/risk-weighted assets | 1.78 | 1.60 | 1.52 | 1.38 |
| Capital | Tangible common equity | Tier 1 | Tier1 | Common equity |
| Optimal leverage ratio | 7–8% | 15% | 8.6–16.5% | 19% |
| Optimal risk-weighted capital ratio | 12-14% (TCE/RWA) | 23.5% (Tier1/RWA) | 13-25% (Tier1/RWA) | 25% (Tier1/RWA) |

Note: FDIC = Federal Deposit Insurance Corporation; S&L = savings and loan; TCE = tangible common equity; RWA = risk-weighted assets.

Firestone, Lorenc, and Ranish (2017) apply both top-down and bottom-up approaches to estimating the benefits, together with a bottom-up approach to estimating the costs for banks with at least $50 billion in total assets. They generate a range of Tier 1 capital-to-risk-weighted-asset ratios from 13 to 25 percent, where the high-end estimate equals our implied optimal Tier 1 capital-to-risk-weighted-asset ratio. Although they do not compute an optimal leverage ratio, they report a risk-weighted-to-total-asset ratio equal to 0.66 (the inverse of which equals 1.52), which implies the optimal Tier 1 capital-to-total-asset ratio might range from 8.6 percent to 16.5 percent.

Step 1 of the Federal Reserve Bank of Minneapolis (2016) applies a bottom-up approach to estimate the benefits and costs of a higher capital leverage ratio for banks with at least $250 billion in total assets. The optimal Tier 1 capital-to-risk-weighted-asset ratio equals 23.5 percent. The authors report a 2015 ratio of total assets to risk-weighted assets equal to 1.6, which implies that the optimal Tier 1 leverage ratio equals 15 percent, close to the upper end of the range that Firestone, Lorenc, and Ranish (2017) report, and lower than our 19 percent value.

Lastly, Cline (2016) draws from the BCBS (2010) study to generate the top-down estimates of the benefits and, as here, takes a bottom-up approach to estimating the costs of a higher capital leverage ratio from a sample of large banks. Cline assumes a wider range of estimates of the return on equity and also assumes that bank loans make up one-third of corporate funding, while nonbank debt comprises an additional one-third of corporate funding. Therefore, the optimal capital ratios lie close to the bottom end of the range that Firestone, Lorenc, and Ranish (2017) report as being optimal.

## 5. Conclusion

The United States has experienced financial crises frequently. Because the US legislative and regulatory framework has often evolved to fix the last crisis but creates subsequent problems that feature in subsequent crises, we examine the feasibility, in terms of costs and benefits, of implementing a simpler, higher-equity leverage ratio.

While the debate continues over whether raising capital requirements such as the leverage ratio has social costs, a key benefit may be faster recovery from a crisis, if not a reduction in the likelihood of a banking crisis. In considering the effect of raising the leverage ratio from 4 percent to 15 percent, we find that the marginal benefits generally exceed the marginal costs, under a wide range of assumptions.

We find that the tax advantage of debt, or a larger fraction of corporate funding coming from debt, tends to drive up marginal costs relative to marginal benefits. Assuming that shocks have only temporary effects, that the temporary effects have a shorter duration, or that there is a smaller cost of a crisis tends to decrease the marginal benefits relative to the costs. Given the importance of higher capital requirements in bank regulation, more research is warranted on measuring the costs and benefits.

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# Appendix: Data Sources and Alternative Analyses

## A1. Data

### Table A1. Data

| Type of data | Table or figure | Variable construction and data source |
|---|---|---|
| Capital-to-asset (equity-to-asset) leverage ratio, all banks | Figure 1, figure 2, table 1, table 2 | For 1837–1933, divide series N-24, "Capital, surplus, and net undivided profits," by series N-20, "Total assets or liabilities (or total resources)," in Bureau of the Census, US Department of Commerce, *Historical Abstract of the United States: 1789–1945* (Washington, DC: US Government Printing Office, 1949), 262–63, http://www2.census.gov/prod2/statcomp/documents/HistoricalStatisticsoftheUnitedStates1789-1945.pdf. After 1933, divide "Total Equity Capital" by "Total Liabilities and Equity Capital," from Federal Deposit Insurance Corporation, "Liabilities and Equity Capital, FDIC-Insured Commercial Banks, US and Other Areas: Balances at Year End, 1934–2015," table CB14, accessed January 31, 2017, https://www5.fdic.gov/hsob/SelectRpt.asp?EntryTyp=10&Header=1. |
| Capital ratio, national banks | Figure 2, figure 3 | Divide series X-62, "Capital accounts," by series X-43, "Total assets or liabilities," in Bureau of the Census, US Department of Commerce, *Historical Abstract of the United States: Colonial Times to 1957* (Washington, DC: US Government Printing Office, 1960), 626–27, https://fraser.stlouisfed.org/files/docs/publications/histstatus/hstat_1957_cen_1957.pdf. |
| Capital ratio, state banks | Figure 2 | Divide series X-84, "Capital accounts," by series X-65, "Total assets or liabilities," in Bureau of the Census, US Department of Commerce, *Historical Abstract of the United States: Colonial Times to 1957* (Washington, DC: US Government Printing Office, 1960), 628–29, https://fraser.stlouisfed.org/files/docs/publications/histstatus/hstat_1957_cen_1957.pdf. |
| Return on equity, national banks | Figure 3 | Bureau of the Census, US Department of Commerce, "Net profits as percent of total capital accounts," *Historical Abstract of the United States: Colonial Times to 1957* (Washington, DC: US Government Printing Office, 1960), series X-199, 638, https://fraser.stlouisfed.org/files/docs/publications/histstatus/hstat_1957_cen_1957.pdf. |
| Real per capita GDP growth | Table 1, table 2 | Calculated as the annual change in the natural log transformation of real GDP per capita, available from Louis Johnston and Samuel H. Williamson, "What Was the U.S. GDP Then?," MeasuringWorth, accessed January 31, 2017, https://www.measuringworth.com/usgdp/. |
| Inflation (GDP deflator) | Table 2 | Calculated as the annual change in the natural log transformation of the GDP deflator, available from Louis Johnston and Samuel H. Williamson, "What Was the U.S. GDP Then?," MeasuringWorth, accessed January 31, 2017, https://www.measuringworth.com/usgdp. |
| One-year-lagged cyclical component of the number of banks | Table 2 | Lagged value of the cyclical component of the Christiano Fitzgerald filter applied to the number of banks. Data for the number of banks from 1891 to 1933 are from the Bureau of the Census, US Department of Commerce, "Number of Banks," *Historical Abstract of the United States: 1789–1945*, series N-19 (Washington, DC: US Government Printing Office, 1949). Data after 1933 are from Federal Deposit Insurance Corporation, "Number of Institutions, Branches and Total Offices, FDIC-Insured Commercial Banks, US and Other Areas: Balances at Year End, 1934–2015," table CB01, accessed January 31, 2017, https://www5.fdic.gov/hsob/SelectRpt.asp?EntryTyp=10&Header=1. |

| | | |
|---|---|---|
| One-year lagged growth in government size | Table 2 | Calculated as the annual change in the natural log transformation of the ratio of government outlays to nominal GDP. The nominal GDP data series comes from Louis Johnston and Samuel H. Williamson, "What Was the U.S. GDP Then?," MeasuringWorth, accessed January 31, 2017, https://www.measuringworth.com /usgdp/. The government outlays series from 1891 to 1901 comes from Office of Management and Budget, "Total Expenditures, Excluding Debt Retirements," *Fiscal Year 2017 Historical Tables: Budget of the U.S. Government* (Washington, DC: US Government Printing Office, 2016), series P-99 b. From 1902 to 2014, the series comes from Office of Management and Budget, "Total Outlays," *Fiscal Year 2017 Historical Tables: Budget of the U.S. Government* (Washington, DC: US Government Printing Office, 2016), table 1.1. |
| One-year lagged returns on the S&P 500 | Table 2 | Shiller's estimate of the natural log of the quantity one plus the real return on the S&P 500 index from 1891 to 2013 is available from the "Long Term Stock, Bond, Interest Rate and Consumption Data" hyperlink found at http://www.econ.yale.edu/~shiller/data.htm. |
| One-year lagged real house price index | Table 2 | Calculated as the annual change in the natural log transformation of the real housing price index from 1891 to 2013, available from the "US Home Prices 1890–Present" hyperlink found at http://www.econ.yale.edu/~shiller/data.htm. |
| Dimson beta | Table 3 | Estimate from intraquarterly regressions of daily bank stock returns is computed from closing stock price data, available from https://wrds-web.wharton.upenn.edu, against Datastream's daily nonfinancial index returns for the United States, available from Datastream. |
| Asset-to-equity leverage | Table 3 | Bank leverage is calculated from Call Report data series bhck2170 divided by bhck3210. |

## A2. Alternative Estimates of the Cost of a Crisis

In addition to using the probit method to estimate the marginal effects at representative values of the capital ratio, we estimate alternative values of the cost of a crisis using 2SLS-probit and OLS-probit results, where the probit regression is as described previously in equations (2) and (3).[26] The 2SLS-probit results are more robust to specification errors in the probit equation.

In the final 2SLS and OLS regression stage, we assume that the growth equation takes the following form:

$$d \ln GDP_t / Pop_t = X_t' \beta + \delta I_t^{crisis} + \varepsilon_t, \quad \text{(A1)}$$

[26] See Cerulli (2014) for a description.

where $d\ln GDP_t / Pop_t$ measures growth of real GDP per capita, and $I_t^{crisis}$ is an indicator variable that takes a value of 1 in 1893 and 1908 (as noted by Jalil 2014), as well as in 1930–1933, 1987–1992, and 2007–2009, and equals 0 otherwise. We get similar results if we replace the banking crisis dummy variable with the dummy variable indicating the start of a crisis (1893, 1907, 1930, 1987, and 2007), which suggests that including the subsequent years of a banking crisis has little effect on the estimates of the cost of a crisis. The other variables in $X_t$ include (1) one-year-lagged changes in the natural log of government size as a fraction of GDP, (2) one-year-lagged returns on the S&P 500, and (3) one-year-lagged inflation. Finally, $\varepsilon_t$ is an independently distributed error term. The construction of each variable and the data sources are reported in table A1 in the appendix. Table A2 indicates that the cost of a crisis may range from −4.4 percent to −10.3 percent.

**Table A2. Alternative Estimates of the Cost of a Crisis**

| | OLS | Probit-OLS | Probit-2SLS |
|---|---|---|---|
| Banking crisis | −0.044** | −0.105*** | −0.103*** |
| | (0.018) | (0.039) | (0.039) |
| Lagged changes in size of government | 0.031* | 0.035* | 0.036* |
| | (0.016) | (0.020) | (0.020) |
| Lagged returns on S&P 500 | 0.107*** | 0.074* | 0.075* |
| | (0.032) | (0.041) | (0.039) |
| Lagged inflation | 0.075 | −0.041 | −0.042 |
| | (0.096) | (0.125) | (0.122) |
| Constant | 0.014** | 0.027** | 0.026*** |
| | (0.007) | (0.011) | (0.010) |
| *R*-squared | 0.29 | 0.28 | 0.16 |
| *N* | 123 | 123 | 123 |

Note: Robust standard errors are in parentheses. Levels of statistical significance are represented as follows: 99% (***), 95% (**) and 90% (*). OLS = ordinary least squares; 2SLS = two-stage least squares.

## A3. Tests of Nonstationarity and Stationarity

Table A3 reports feasible generalized least-squares augmented Dickey-Fuller (ADF) nonstationarity tests proposed by Elliott, Rothenberg, and Stock (1996) and stationarity tests proposed by Kwiatkowski, Phillips, Schmidt, and Shin (KPSS tests; see Kwiatkowski et al. 1992) for each of the continuous variables used to estimate equation (3). Unless otherwise specified, the tests assume that a trend exists. We use the Akaike information criterion to determine the number of lags to include in computing the ADF test statistics, which is reported in parentheses next to the test statistic. We use the Newey-West automatic bandwidth selection procedure to determine the number of lags to include in computing the KPSS test statistics, which is reported in parentheses next to the test statistic. For the ADF tests, if the test statistic is larger in magnitude than the 1 percent critical value, we can reject the null hypothesis that the series is nonstationary. For the KPSS test, if the test statistic lies below the 10 percent critical value, we cannot reject the null hypothesis that the series is stationary.

The results suggest that with the exception of the one-year lagged leverage ratio, the series are likely stationary. The capital ratio is in principle bounded between 0 and 1. However, in principle, a bounded series can still be found nonstationary in a finite sample. We find that we cannot reject the ADF test, and we do reject the KPSS test for the lagged leverage ratio. However, this could be owing to structural breaks that may reflect changes in regulations. The ADF and KPSS tests, when applied to the residuals of a regression of the lagged leverage ratio against the pre-Fed, pre-FDIC, pre-Basel, and pre–Riegle-Neal-Act dummy variables, suggest the residuals may be stationary.

## Table A3. Tests of Nonstationarity and Stationarity

| | ADF test null (alternative) hypothesis I(0) (I(1)) | KPSS test null (alternative) I(1) (I(0)) |
|---|---|---|
| Lagged leverage ratio | | |
| Test stat | −2.46 (2) | 0.36 (7) |
| Critical value | −4.03 | 0.12 |
| Residuals of regression of leverage ratio against dummy variables (no trend) | | |
| Test stat | −4.31 (2) | 0.13 (7) |
| Critical value | −2.60 | 0.35 |
| Lagged inflation | | |
| Test stat | −5.39(1) | 0.07 (6) |
| Critical value | −4.03 | 0.12 |
| Lagged cyclical component of banks (no trend) | | |
| Test stat | −8.23 (7) | 0.04 (7) |
| Critical value | −2.60 | 0.35 |
| Lagged real per capita GDP growth | | |
| Test stat | −6.67 (1) | 0.07 (6) |
| Critical value | −3.50 | 0.12 |
| Lagged changes in size of government | | |
| Test stat | −5.85 (5) | 0.03 (5) |
| Critical value | −3.50 | 0.12 |
| Lagged returns on S&P 500 | | |
| Test stat | −6.18 (2) | 0.04 (2) |
| Critical value | −3.50 | 0.12 |
| Lagged changes in real house prices | | |
| Test stat | −6.14 (3) | 0.05 (7) |
| Critical value | −3.50 | 0.12 |

## A4. Including Lagged Endogenous Variables

Table A4 compares estimates of the probit, logit, and complementary log-log model estimates of the equations reported in table 2, with an added lagged dependent variable. The coefficient estimates for the lagged leverage ratio are similar to those reported in table 2.

**Table A4. Probit, Logit and Complementary Log-Log Estimates of the Banking Crises, 1892–2014**

| | Probit | Probit | Logit | Logit | Cloglog | Cloglog |
|---|---|---|---|---|---|---|
| Lagged crisis year | 2.60***<br>(0.64) | 1.67<br>(1.17) | 4.68***<br>(1.21) | 2.91<br>(2.23) | 3.80***<br>(0.92) | 2.43<br>(2.03) |
| Lagged leverage ratio | −8.27<br>(6.02) | −70.83**<br>(34.63) | −16.77<br>(12.88) | −132.71**<br>(64.22) | −18.59<br>(11.77) | −118.33**<br>(53.35) |
| Lagged inflation | −8.53**<br>(6.50) | −16.29*<br>(8.94) | −18.07<br>(12.20) | −29.12*<br>(15.62) | −18.84*<br>(10.77) | −24.44*<br>(13.28) |
| Lagged cyclical component of banks | 9.69**<br>(4.18) | 25.82**<br>(10.95) | 18.55**<br>(8.72) | 47.47**<br>(20.60) | 15.54*<br>(7.96) | 41.21**<br>(17.39) |
| Lagged real per capita GDP growth | −5.52<br>(4.87) | 0.19<br>(6.91) | 10.44<br>(9.30) | -0.48<br>(13.26) | 9.55<br>(8.60) | −1.14<br>(11.84) |
| Lagged changes in size of government | −0.17<br>(1.35) | 2.65<br>(1.90) | -0.29<br>(2.50) | 5.14<br>(3.49) | −0.16<br>(2.17) | 4.47<br>(3.03) |
| Lagged returns on S&P 500 | −2.91**<br>(1.43) | −4.57**<br>(2.02) | −5.51*<br>(2.85) | −8.76**<br>(3.76) | −4.62*<br>(2.70) | −7.33**<br>(3.12) |
| Lagged changes in real house prices | 3.73<br>(3.47) | 5.96<br>(5.10) | 6.80<br>(6.47) | 11.20<br>(9.55) | 6.97<br>(5.75) | 10.00<br>(8.52) |
| Pre-Federal Reserve | — | 3.98*<br>(2.26) | — | 7.44*<br>(4.19) | — | 6.71*<br>(3.70) |
| Pre-FDIC | — | 4.02**<br>(2.05) | — | 7.90**<br>(3.81) | — | 7.18**<br>(3.10) |
| Pre-Basel | — | −3.07**<br>(1.55) | — | −5.88**<br>(3.00) | — | −4.90*<br>(2.67) |
| Pre–Riegle-Neal | — | 0.44<br>(1.29) | — | 0.81<br>(2.30) | — | 0.28<br>(1.85) |
| Constant | −1.02<br>(0.69) | 4.95<br>(3.07) | −1.62<br>(1.38) | 9.36<br>(5.60) | −1.33<br>(1.21) | 8.07*<br>(4.61) |
| *N* | 123 | 123 | 123 | 123 | 123 | 123 |

Note: Levels of statistical significance are represented as follows: 99% (***), 95% (**), and 90% (*).

## A5. Comparing Estimates of the Marginal Effects at Representative Values of the Leverage Ratio across Methods

Figure A1 depicts the marginal effects at representative values of the leverage ratio for the probit, logit, and complementary log-log regressions. The result suggests that the methods generate broadly similar marginal effects at representative values schedules, which implies that the assumed distribution of dependent variables has little effect on the results.

**Figure A1. Comparing Estimates of the Marginal Effects at Representative Values of the Leverage Ratio across Methods**