Optimal Capital Structure and Hedging Policies for Banks: The End of Bailouts[1]

Robert S. Goldstein[2]   Fan Yang[3]

February 16, 2021

[1]We thank Anat Admati, Lorenzo Garlappi, Adriano Rampini, Anjan Thakor, Chao Ying and Hongda Zhong for thoughtful feedback. Any remaining errors are our own.

[2]Piper Jaffray Endowed Chair in Finance, University of Minnesota and NBER, golds144@umn.edu.

[3]Associate Professor of Finance, University of Connecticut, fan.yang@uconn.edu.

ABSTRACT

We find that the volatility of bank equity returns can be reduced by 34% if banks hedge their exposure to bank-index risk. We then investigate the joint optimal hedging and capital structure decisions of banks when bank-industry risk is hedged using a convertible forward contract. Compared to the no-hedge benchmark, optimally hedged banks increase equity valuations, lower default probabilities (in spite of choosing higher leverage), and mostly eliminate systemic risk. That banks choose not to hedge bank index risk is consistent with managers internalizing bank bailouts. Governments can eliminate bailouts by forcing firms to insure against industry-risk.

I Introduction

The financial crisis of 2007-2009, and the government bailouts that followed, generated significant discussion regarding the optimal regulation of financial institutions. At the micro-prudential level, Admati et al (2013) and others have argued that banks should be forced to hold significantly more equity capital (especially during economic booms) in order to both reduce the likelihood of bank defaults during a crisis, and facilitate recovery after a crisis.[1] In contrast, DeAngelo and Stulz (2015) and others[2] argue that high bank leverage is socially optimal because high leverage allows banks to create large supplies of liquid assets, which are in great demand by society.[3] Importantly, because only safe debt commands a liquidity premium, DeAngelo and Stulz (2015) predict that banks will use all available risk management tools in order to hedge as much risk as possible from their asset structure. Their prediction, however, is based on a model that abstracts from both deposit insurance and government bailouts to banks.

As such, this paper begins by investigating whether banks do in fact use all readily available risk management tools to minimize their asset risk. Specifically, we first run 36-month rolling-window regressions of bank equity excess returns on a host of available hedging instruments in order to identify regression coefficients. We then use these regression coefficients out-of-sample in order to create hedged portfolios at each date using only information available at that date. For the case in which the hedging instrument is the bank index, we find that hedged portfolios are associated with an average reduction in volatility of 34% (from $\sigma_{unhedged} = 0.342$ to $\sigma_{hedged} = 0.226$), with an even larger reduction (39%) for the 7 largest banks. Moreover, these hedged returns exhibit *positive* skewness, in sharp contrast to the *negative* skewness exhibited by unhedged bank equity returns. Skewness is an important characteristic when investigating optimal capital

[1]See, for example, Holmstrom and Tirole (1997), Calomiris and Mason (2003), Coval and Thakor (2005), Hanson, Kashyap and Stein (2011), Mehran and Thakor (2011), Berger and Bouwman (2013), Thakor (2014).

[2]See, for example, Gorton and Winton (1998, 2003), Diamond and Rajan (2000, 2001), Krishnamurthy and Vissing-Jorgensen (2012), Gorton (2010), Gorton and Metrick (2010), Stein (2010), Holmstrom and Tirole (2011), Merton and Thakor (2019).

[3]That much of a bank's value stems from its ability to create liquidity via deposit productivity is consistent with the empirical findings of Egan, Lewellen and Sunderam (2018).

structure because, holding volatility constant, skewness has significant impact on bank default probabilities (see, for example, Nagel and Purnanandam (2020)).

We then investigate the joint optimal hedging and capital structure policies of banks based on a model calibrated to these empirical findings. Consistent with the prediction of DeAngelo and Stulz (2015) (albeit due to a different mechanism), but in strong conflict with our empirical findings, our model predicts that shareholder value is maximized when the firm chooses to minimize its exposure to bank-index risk, as this allows banks to simultaneously increase its leverage and reduce its probability of default, leading to significant increases in tax benefits to debt net of bankruptcy costs.

Our model can be seen as an extension of the "financing as a supply-chain" framework of Gornall and Strebulaev (GS, 2018) in which both optimal capital structure and optimal risk management policies are investigated. Importantly, the GS framework focuses only on *microprudential* policy implications in that it restricts its attention to optimal bank capital structure policy, which is intimately linked to bank default probabilities. In contrast, our generalized framework also has important implications for *macroprudential* policy. Indeed, if all banks follow a policy of hedging bank-index risk, then bank defaults become largely idiosyncratic, with bank default correlations dropping from 0.13 for the unhedged case to nearly zero for the optimally hedged case. Hence, under our assumption of no government bailouts, systemic risk is almost completely eliminated without any need for regulation.[4]

Our findings are reminiscent of the literature that recommends that regulators should force banks to purchase insurance against large negative shocks to the banking industry (see, for example, Kashyap, Rajan and Stein (2008), Acharya et al (2017)). However, there are important differences between this literature and our findings. First, our optimal policy of shorting the bank index is much more stringent than just having banks purchase an insurance policy that pays off only in sufficiently poor aggregate

[4]Schinasi (2005) argues that idiosyncratic bank defaults provide the financial system with a healthy level of "creative destruction," and thus should not be prevented. Separately, although we do not model it, accounting for asymmetric information might provide additional incentive for hedging index risk, as bank managers with superior skills may wish to hedge market-risk in order to signal their skills to investors more quickly (DeMarzo and Duffie (1995); Breeden and Viswanathan (2016)).

states of nature. In addition, rather than following this literature's suggestion of having banks pay for an expensive put option on the index to protect against downside index risk (which increases default probabilities), under our optimal policy, banks pay zero up front to hedge their downside exposure to bank-index risk, which they accomplish by sacrificing their upside exposure. That is, banks suffer losses on their short position only in those states of nature they can (typically) most afford to do so, which in turn leads to bank default probabilities that are extremely low regardless of the aggregate state of nature.[5,6] Moreover, we propose and investigate the use of *convertible* forward contracts that provide firms the option to pay off any losses on the forward contract via equity issuance rather than cash outflow. This option reduces default probabilities and measures of systemic risk even further.

A second distinction is that, whereas in this other literature banks must be forced by regulators to purchase insurance, in our model, banks *choose* to hedge bank index-risk because that is the policy that maximizes shareholder wealth. Importantly, note that in the equilibrium model of Acharya et al (2017), banks are precluded from hedging bank-index risk. If instead banks were permitted to hedge index-risk in their model, they would choose do so to in order to avoid paying a systemic-risk tax imposed by government. Moreover, some have voiced concern that regulation that imposes additional costs on banks (such as the insurance policies suggested by this literature) would drive a larger share of intermediation into the less-regulated shadow banking system. In contrast, our analysis shows that banks become *more* competitive (i.e., more valuable) by hedging bank-index risk.[7]

[5]Rampini, Sufi and Viswanathan (2013) emphasize a tradeoff between financing and risk management because both require collateral. Given that banks would pay out only in "good states of nature," collateral requirements may be low, especially if the government provides insurance to their counterparties. Using convertible forwards to hedge industry-risk, which gives banks the option to pay out in equity rather than in cash, further reduces default concerns.

[6]Fahlenbrach, Prilmeier and Stulz (2018) provide evidence suggesting that banks may be overoptimistic about the risk of loans during periods of high loan growth. Having banks pay out on their short position on the bank index when the index does well may curtail such behavior.

[7]Moreover, governments can use some of the savings associated with eliminating future bailouts to facilitate this market. Indeed, having those governments who control their own currency (and therefore have the ability to create cash) be the main provider of disaster risk, and in turn support the prices of these convertible forward contracts, may be part of an optimal regulatory framework.

Our benchmark model's counterfactual prediction that banks will choose to hedge bank-index risk brings to light an important puzzle: why don't value-maximizing banks hedge bank-index risk?[8] Note that, in practice, the largest banks are very active in risk management, especially towards hedging exposure to interest rate and foreign exchange rate risk.[9,10] We believe the most likely resolution to this puzzle is that our model is incomplete in that it does not account for government bailouts to banks[11] that are perceived as too systemic to fail.[12] That is, banks don't need to pay to hedge their exposure to downside index risk, because expected government bailouts offer this insurance for free. If bank bailouts are indeed the explanation for banks' decisions not to hedge bank-index risk, then banks are acting rather iniquitously in our model, as they are colluding to remain systematically important, and rent-seeking by forcing taxpayers to bail out the system during financial crises.[13] In contrast, in Kashyap, Rajan and Stein (2008) and Acharya et al (2017), banks are guilty only of not internalizing negative externalities associated with credit crunches and fire sales.[14]

[8]Hanson, Kashyap and Stein (2011) argue that large banks feel compelled to operate with extremely high leverage because of the extreme competition (i.e., thin margins) in the financial sector. However, this interpretation does not explain why banks do not hedge industry-risk, because, in the absence of bailouts, bank margins would be *widened* by banks managing index-risk. In contrast, note that both banks' choices of high leverage and lack of hedging index-risk are consistent with banks internalizing bailouts.

[9]According to the BIS Derivative Statistics (2020), financial institutions account for the lion's share of the gross exposures on interest rate derivatives. Moreover, Ellul and Yerramilli (2013) provide empirical evidence that banks with better risk management have lower tail risk.

[10]See, for example, Purnanandam (2007), Gomez, Landier, Sraer, and Thesmar (2020), Drechsler, Savov, and Schnabl (2017). Haddad and Sraer (2020), Hoffmann, Langfield, Pierobon, and Vuillemey (2019), Rampini, Viswanathan and Vuillemey (2019).

[11]We emphasize that these bailouts do not have to be paid directly to shareholders in order for shareholders to benefit. For example, anticipated bailouts to bank bondholders increase the equilibrium price that banks can sell their debt issuances for. Related, Veronesi and Zingales (2010) estimate the 2008 government bailout increased bank asset values by $130 billion (mostly benefitting bondholders), paid for by taxpayers.

[12]See, for example, Kelly, Lustig and van Nieuwerburgh (2016); Bai, Goldstein and Yang (2019).

[13]Similar conclusions have been reached by Acharya and Yorulmazer (2007), Farhi and Tirole (2009, 2012), Acharya (2009), Chan-Lau (2010), Acharya and Thakor (2016).

[14]See also Bernanke and Gertler (1989), Shleifer and Vishny (1992, 2011), Holmström and Tirole (1997), Peek and Rosengren (1997, 2000), Diamond and Rajan (2009), Stein (2010), Gertler and Kiyotaki (2010), Ivashina and Scharfstein (2010), Brunnermeier and Sannikov (2014, 2016), and Rampini and Viswanathan (2019), and Chodorow-Reich (2014).

Our paper contributes to several strands of the banking literature. First, we build on the literature that investigates optimal capital structure for banks.[15] Importantly, our paper emphasizes that optimal capital structure policy cannot be decoupled from optimal risk management policy, as most of the literature assumes. Moreover, our findings suggest that optimal capital structure models that do not account for government bailouts are misspecified across a dimension that is crucial for the problem under investigation. Second, our paper is related to the literature that investigates social benefits associated with reductions in bank default risk via channels such as increased incentives for monitoring effort, and decreased incentives for asset substitution and regulatory arbitrage.[16] However, this literature typically touts these benefits to justify regulations to force banks to hold more capital, whereas our paper emphasizes that bank default risk drops automatically when banks choose an optimal risk management policy by hedging index-risk, in spite of the fact that their optimal leverage ratios increase. Third, our paper builds on the literature which argues that risk management can increase shareholder value.[17] Our paper also relates to the large literature that argues for regulation focusing more on macroprudential rather than microprudentical policies.[18] There is a significant literature that attempts to identify statistics that measure a bank's impact on systemic risk, such as the "distress insurance premium" (DIP), proposed by Huang, Zhou, and Zhu (2012), and CoVaR, proposed by Adrian and Brunnermeier (2016). Note that banks that follow our proposed optimal policy would see their systemic risk measures drop to near zero. Interestingly, whereas Crockett (2000) and Acharya (2009) argue that there may be an inherent tension between micro-prudential and macro-prudential regulation of the financial sector, our channel in which banks optimally choose to hedge bank-index

[15] See, for example, Diamond and Rajan (2000), Coval and Thakor (2005), Shleifer and Vishny (2010), Mehran and Thakor (2011), Acharya, Mehran, Schuermann, and Thakor (2012), Harding, Liang, and Ross (2012), Sundaresan and Wang (2014), Thakor (2014), Allen, Carletti, and Marquez (2015), DeAngelo and Stulz (2015), Acharya, Mehran, and Thakor (2016), and Gornall (2018).

[16] See, for example, Holmstrom and Tirole (1997), Biais and Casamatta (1999), Hellwig (2009), Edmans and Liu (2011), Allen, Carletti and Marquez (2011), Mehran and Thakor (2011), Boyson, Fahlenbrach and Stulz (2016).

[17] See, for example, Smith and Stulz (1985), Froot Scharfstein and Stein (1993).

[18] See, for example, Crockett (2000); Borio, Furfine, and Lowe (2001); Borio (2003), Kashyap and Stein (2004), Kashyap, Rajan, and Stein (2008), Brunnermeier, Crockett, Goodhart, Persaud, and Shin, (2009), French et al. (2010), Acharya, Engle and Richardson (2012).

risk does not seem to suffer from this concern.[19] Finally, whereas Chowdry and Schwartz (2016) show that the fraction of market risk that a firm can hedge is limited due to the presence of idiosyncratic shocks when the hedging instrument used is a *standard* forward contract, we show that the use of *convertible* forward contracts overcomes this limitation.

Although our paper mostly focuses on banks, its implications are easily extended to all firms. In particular, our paper offers a simple policy for the elimination of government bailouts: governments should require all firms to hedge their industry-risk, as this would guarantee that any defaults within an industry would be mostly idiosyncratic. Under this policy, rather than counting on bailouts, which "privatize profits and socialize losses," firms effectively pay for insurance against adverse industry movements. By using convertible forward contracts rather than put options, firms pay for this insurance not through up-front payments, but rather by forgoing profits when the industry performs well (and thus, in states of nature that the firm can typically most afford to pay). Moreover, the convertible feature reduces default risk even further. Such a policy reduces financial distress costs by reducing asset volatility, and also reduces the costs of moral hazard associated with firms choosing policies based upon the expectation of receiving bailouts. Moreover, such a policy would greatly reduce the negative externalities associated with fire sales when an entire industry suffers financial distress. Given the current criticism regarding how corporate bailouts have been implemented during the pandemic, with many arguing that firms with political connections have fared much better than firms without, such a simple policy would eliminate any government favoritism.

The rest of the paper is as follows. In Section 2 we empirically investigate how much bank risk can be hedged using readily available financial instruments, and specifically show that a significant fraction of bank volatility can be eliminated by banks shorting the bank index. In Section 3, we generalize the "financing as a supply-chain" model of Gornall and Strebulaev (2018) by investigating the joint optimal capital structure and risk-management policies of banks. We show that by shorting the bank index, banks can simultaneously increase their optimal leverage ratio and decrease their default risk,

[19]Managerial contracts for those banks that follow our proposed optimal strategy would need to be updated to reflect relative performance. See, for example, Bertrand and Mullainathan (2001), Garvey and Milbourn (2006).

which in turn increases shareholder wealth due to increased tax benefits. We demonstrate the benefits of using a convertible forward contract as the hedging instrument, as it significantly decreases default probabilities when the bank industry performs poorly, while not increasing default probabilities when the bank industry performs well. Moreover, we show that shorting the index mostly eliminates systemic risk. We conclude in Section 4. In the Appendix, we demonstrate how the optimal hedge ratio for one bank is impacted by the hedging decisions of other banks. In addition, we investigate the impact that hedging industry-risk would have had on the hotel and airline industries during the Covid pandemic.

II Empirical Analysis

Here we investigate the exposure of large banks to risks that are hedgeable using readily available financial instruments. Specifically, we estimate volatility and skewness of hedged and unhedged equity returns, using out-of-sample regression coefficients to identify hedge ratios.

Our sample consists of data at the monthly frequency from January 2000 to March 2020. We obtain bank stock returns from CRSP and Yahoo finance. We focus on twelve banks that the Federal Reserve has identified as systemically important financial institutions: Bank of America Corporation (Ticker: BAC); The Bank of New York Mellon Corporation (BK); Barclays PLC (BCS); Citigroup Inc. (C); Credit Suisse Group AG (CS); Deutsche Bank AG (DB); The Goldman Sachs Group, Inc. (GS); JP Morgan Chase & Co. (JPM); Morgan Stanley (MS); State Street Corporation (STT); UBS AG (UBS); Wells Fargo & Company (WFC).

We also construct a comprehensive data set of instruments that provide a measure of aggregate risks that bank assets may be exposed to. These instruments include: the market return (MKT); a financial sector ETF (Ticker: XLF); average mortgage rates with maturities 15 and 30 years; the VIX index; 5, 10, and 30-year Treasury rates; the

Seasonally Adjusted Case Shiller Home Price Index; and the BBB-AAA credit spread.[20] We also investigate a strategy in which banks hedge by taking a short position in a portfolio of other bank stocks.

Most of our analysis focuses on one-factor regressions. Specifically, we use rolling regressions with 36-month windows to estimate regression coefficients $\{\beta_{j,\tau}\}$ in the equation:

$$r_{j,t} = a_j + \beta_{j,\tau}\ x_t, \tag{1}$$

where $r_{j,t}$ is the excess return of bank-j from dates t to $(t+1)$, x_t is either an excess return, or the change of some market variable (such as an interest rate, or the VIX), and $t \in (\tau-36, \tau-35, ..., \tau-1)$. We then use the regression coefficient estimate $\hat{\beta}_{j,\tau}$ as a hedge ratio in order to compute out-of-sample hedged bank excess stock returns over the following month τ as

$$r^H_{j,\tau} = r_{j,\tau} - \hat{\beta}_{j,\tau} x_\tau. \tag{2}$$

We update $\hat{\beta}_{j,\tau}$, and hence rebalance, the hedged portfolio each month.

For the case of multiple regressors $(K > 1)$, we specify:

$$r_{j,t} = a_j + \sum_{k=1}^{K} \beta_{j,k,\tau}\ x_{k,t}, \tag{3}$$

where j is an index for banks, $\{r_{j,t}\}$ are excess returns of bank-j at date-t, k is an index for regressors, and $t \in (\tau-36, \tau-35, ..., \tau-1)$. We then use the vector of factor loadings $\{\hat{\beta}_{j,k,\tau}\}$ as hedge ratios in order to compute out-of-sample hedged bank excess stock returns over the next month τ as

$$r^H_{j,\tau} = r_{j,\tau} - \sum_{k \neq j} \hat{\beta}_{j,k,\tau} x_{k,\tau}. \tag{4}$$

Table I compares the performance across different hedging variables. We use the out-of-sample volatility (in Panel A) and skewness (in Panel B) of the hedged stock

[20] We use the S&P 500 excess return as the market. XLF and the S&P 500 return data are obtained from CRSP. Mortgage rates, Treasury rates, the VIX index, the Case Shiller Home Price index and the BBB-AAA spreads are obtained from the St. Louis Fed. The risk-free rate is obtained from Kenneth French's website.

returns as measures of hedging performance. The last column reports the simple average volatility or skewness across all banks. Among all these variables, shorting the financial sector index (XLF) generates the lowest average volatilities. Indeed, averaging across the twelve banks, shorting the financial sector index lowers bank excess return volatility by 34% (from $\sigma_{unhedged} = 0.342$ to $\sigma_{hedged} = 0.226$), with an even larger reduction (39%) for the 7 largest banks. It also significantly increases the skewness of the hedged returns for all the banks. Specifically, whereas unhedged bank returns are negatively skewed for each of the twelve banks (ranging from -1.68 to -0.11, with an average skewness equal to -0.76), average hedged returns (XLF) have a skewness equal to +0.31. Thus, shorting the financial sector index not only reduces bank equity volatility, but also bank downside risk measured by skewness, which is an important statistic for estimating bank default probabilities.

In contrast, using instruments that are sensitive to changes in interest rates, mortgage rates, credit spreads, home prices, and a volatility index have little impact on reducing average bank return volatilities out-of-sample. This observation is consistent with the hypothesis that banks are doing a good job hedging most other risks.

In Panel C of Table I, we report the hedged and unhedged stock excess returns during the month of March 2020, which is a month that saw the S&P 500 lose 12.5% and the financial sector index (XLF) lose 21.7% due to the Covid-19 pandemic. Once again, hedged returns are based on a hedge ratio using 36 months of returns prior to March 2020. That is, all hedge ratios are estimated out-of-sample. As is clear from this table, our simple hedging strategy using the financial sector index (XLF) performed extremely well during this month. Indeed, whereas the average unhedged stock return across banks was -25.47%, hedged bank stock returns would have experienced a return of +0.28%. Moreover, whereas the worst performing stock suffered a 39% loss in equity that month, its loss would have only been 18% had it hedged bank-industry risk. In contrast, had banks used other hedging instruments, such as the SP500, their performance would have been significantly worse over this month.

Finally, for both the unhedged and index-hedged cases, we estimate value-at-risk and tail-risk for large banks. Table II reports the results. The first four monthly log stock return scaled moments (mean, standard deviation, skewness, and kurtosis) are estimated from our sample. Assuming an investment of $100 at the beginning of a month, we find that the 99% Value-at-Risk for the unhedged bank stock is $25.26 vs. $15.03 for the hedged bank stock. The difference (10.23 ± 1.93) is statistically and economically significant.

In addition, here we show that downside-risk is reduced not only because volatility is reduced, but also because unlevered bank returns exhibit negative skewness, whereas hedged returns exhibit positive skewness. To quantify this effect, we generate random variables using the first four empirical moments as input into the Pearson system in order to estimate tail-risk, which we define as the probability that the log stock return will be more than three standard deviations below its mean. Note that, by construction, a lower standard deviation does not help reduce this tail-risk statistic. We find that the tail risk measure after hedging (0.46%) is approximately one-half of the tail risk before hedging (0.91%). Moreover, their difference ($0.45\% \pm 0.16\%$) is also statistically significant.

III Optimal Joint Hedging and Capital Structure Policies of Banks

In this section, we generalize the framework of Gornall and Strebulaev (GS, 2018) by investigating a supply-chain model of financing in which firms choose their optimal capital structure by borrowing from a bank, and the bank chooses its optimal capital structure by issuing debt and equity to the public. The new feature in our model is that the bank also chooses an optimal risk-management policy in order to maximize shareholder wealth. We show that, by optimally hedging bank-index risk, shareholder wealth increases significantly due to banks choosing a higher leverage ratio, which in turn reduces their tax bill. In spite of this higher leverage policy, bank default probabilities drop considerably, due to significant drop in bank cash flow risk associated with their risk management policy, which in turn allows banks to sell their debt issuances for a higher price. Moreover, we show that systemic risk is mostly eliminated when banks selfishly choose to maximize shareholder wealth. The implication is that many of the negative externalities associated with bank distress (e.g., credit crunches and fires sales) are mostly eliminated when banks selfishly follow a value-maximizing strategy of hedging bank-index risk. Finally, we investigate the use of a convertible forward contract (rather than a standard forward contract) as the hedging instrument, which allows the bank to significantly decrease the likelihood of default conditional upon a bad industry shock without increasing the likelihood of default conditional upon a good industry shock. This occurs because, conditional upon a good industry shock, the bank (acting in the best interest of current shareholders) can fulfill its obligations on the forward contract by issuing equity to the forward counterparty, leaving the firm as a whole no worse off in terms of its decision to default (although current shareholders will suffer a dilution effect.)

A The Firm's Problem: Optimal Investment and Capital Structure Policies

In this section, we identify the optimal investment and capital structure decisions for firms. The revenues generated by firm-i at date-T are:

$$X_i(z_{i,T}) \;=\; I\, e^{(\mu-\frac{\sigma^2}{2})T+\sigma\sqrt{T}\, z_{i,T}}. \tag{5}$$

Here, I is the level of investment at date-0, $z_{i,T} \sim N(0,1)$ is a standard normal random variable, μ is a parameter that controls firm asset expected growth rate, and σ is a parameter that controls asset volatility. At date-0, the bank loans I_B to the firm. The firm in turn promises to pay F to the bank at date-T. Hence, if the firm does not default, it will pay back both principal I_B and interest:

$$INT \;=\; (F - I_B). \tag{6}$$

The firm's shareholders invest $I_E = (I - I_B)$ into the firm.

The firm's EBIT equals its revenues net of investment $I = (I_E + I_B)$:

$$EBIT_i(z_{i,T}) \;=\; X_i(z_{i,T}) - (I_E + I_B). \tag{7}$$

The firm's pre-tax earnings equals EBIT minus interest expense:

$$\begin{aligned} EBT_i(z_{i,T}) &= X_i(z_{i,T}) - (I_E + I_B) - INT \\ &= X_i(z_{i,T}) - (I_E + F). \end{aligned} \tag{8}$$

Assuming full tax-loss offset, taxes are:

$$\begin{aligned} Tax_i(z_{i,T}) &= \tau\left[X_i(z_{i,T}) - (I_E + F)\right] \\ &= \tau\left[X_i(z_{i,T}) - (I + INT)\right]. \end{aligned} \tag{9}$$

This last equation emphasizes that, by deducting interest payments from EBIT prior to calculating the tax bill, we capture the tax-benefits to debt.

The terminal dividend paid to equity, if positive, equals revenues minus payments to the bank and taxes:

$$\begin{aligned} X_{i,E}(z_{i,T}) &= X_i(z_{i,T}) - F - \tau\left[X_i(z_{i,T}) - (I_E + F)\right] \\ &= (1-\tau)\left(X_i(z_{i,T}) - F\right) + \tau I_E. \end{aligned} \tag{10}$$

Default occurs if dividends to shareholders are not positive. Thus, we can identify the default boundary X_{def} from equation (10) as that level of revenues $X_i(z_{i,T}) = X_{def}$ that generates a zero terminal dividend $X_{i,E}(z_{i,T}) = 0$:

$$0 \;=\; (1-\tau)\left(X_{def} - F\right) + \tau I_E. \tag{11}$$

Hence,

$$X_{def} \;=\; F - \left(\frac{\tau}{1-\tau}\right) I_E. \tag{12}$$

Subtracting equation (11) from equation (10), and now including the indicator function to emphasize dividends are non-negative, the dividend paid to equity can be expressed as:

$$X_{i,E}(z_{i,T}) \;=\; (1-\tau)\left(X_i(z_{i,T}) - X_{def}\right)\, \mathbf{1}_{(X_i(z_{i,T})>X_{def})}. \tag{13}$$

The date-0 equity claim to dividends is therefore:

$$\begin{aligned} V_{i,E}(0) &= e^{-rT}\mathcal{E}_t^Q\left[(1-\tau)\left(X_i(z_{i,T})-X_{def}\right)\ \mathbf{1}_{(X_i(z_{i,T})>X_{def})}\right] \\ &= (1-\tau)Ie^{(\mu-r)T}\,\Phi\left(\frac{\log(I/X_{def})+(\mu+\frac{\sigma^2}{2})T}{\sqrt{\sigma^2 T}}\right) \\ &\quad -(1-\tau)X_{def}e^{-rT}\,\Phi\left(\frac{\log(I/X_{def})+(\mu-\frac{\sigma^2}{2})T}{\sqrt{\sigma^2 T}}\right), \end{aligned} \tag{14}$$

where $\Phi(\cdot)$ is the cumulative normal function. We define firm shareholder profit as the difference between the date-0 value of the equity claim, and shareholder investment:

$$\text{Firm Shareholder Profit} \;=\; V_{i,E}(0) - I_E. \tag{15}$$

The pre-tax revenues for the debt claim owned by the bank are F if no default occurs, and $(1-\alpha)X_i(z_{i,T})$ if default does occur, where α captures bankruptcy costs. If the bank is all-equity, then its pre-tax earnings are:

$$EBT_B(z_{i,T}) \;=\; F\mathbf{1}_{(X_i(z_{i,T})>X_{def})} + (1-\alpha)X_i(z_{i,T})\mathbf{1}_{(X_i(z_{i,T})<X_{def})} - I_B. \tag{16}$$

Assuming full tax-loss offset, taxes are:

$$Tax_B(z_{i,T}) \;=\; \tau\left[F\mathbf{1}_{(X_i(z_{i,T})>X_{def})} + (1-\alpha)X_i(z_{i,T})\mathbf{1}_{(X_i(z_{i,T})<X_{def})} - I_B\right]. \tag{17}$$

Therefore, the terminal dividend paid to bank shareholders (which is guaranteed to be positive) is:

$$X_B(z_{i,T}) \;=\; (1-\tau)\left[F\mathbf{1}_{(X_i(z_{i,T})>X_{def})} + (1-\alpha)X_i(z_{i,T})\mathbf{1}_{(X_i(z_{i,T})<X_{def})}\right] + \tau I_B. \tag{18}$$

The date-0 value of the bank equity claim is therefore (the superscript "ND" refers to the assumption that the bank carries no-debt in this calculation):

$$\begin{aligned} V_{B,E}^{ND}(0) &= e^{-rT}\mathcal{E}_t^Q\left[(1-\tau)\left\{F\mathbf{1}_{(X_i(z_{i,T})>X_{def})} + (1-\alpha)X_i(z_{i,T})\mathbf{1}_{(X_i(z_{i,T})<X_{def})}\right\} + \tau I_B\right] \\ &= e^{-rT}(1-\tau)F\Phi\left(\frac{\log(I/X_{def})+(\mu-\frac{\sigma^2}{2})T}{\sqrt{\sigma^2 T}}\right) \\ &\quad +Ie^{(\mu-r)T}(1-\alpha)(1-\tau)\Phi\left(\frac{-\log\left(\frac{I}{X_{def}}\right)-(\mu+\frac{\sigma^2}{2})T}{\sqrt{\sigma^2 T}}\right) + e^{-rT}\tau I_B. \end{aligned} \tag{19}$$

We specify the model so that, due to their expertise in screening and monitoring, banks tend to profit from making loans. Specifically, we assume that, even if the bank were to choose to be unlevered, the loan would be a positive NPV project for the bank in that there is a spread s that creates a gap between the amount the bank loans to the firm (i.e., I_B), and the present value of the bank's equity claim (i.e., $V_{B,E}^{ND}(0)$):[21]

$$I_B = V_{B,E}^{ND}(0)\, e^{-sT}. \tag{20}$$

A.1 Calibration: Optimal Firm Policy

Table III reports the benchmark model parameters. Panel A in Table IV reports the optimal firm policy. We specify model parameters as follows: Firm asset expected growth rate $\mu = 0.052$, risk-free rate $r = 0.02$, firm asset volatility $\sigma = 0.4$, loan maturity $T = 5$, effective average corporate tax rate $\tau = 0.2$, and bank loan spread $s = 0.003$. These parameters satisfy the inequality expressed in equation (71), implying that the firm's project has a positive net present value. Due to a scaling feature in our model, it follows that we can set one parameter associated with the "size" of the firm to unity without loss of generality. For convenience, we set the level of investment by firm shareholders to $I_E = 1$. As such, maximizing firm shareholder profit $(V_{i,E}(0) - I_E)$ is equivalent to maximizing shareholder equity $V_{i,E}(0)$ as given in equation (14). We find that the firm chooses face value of debt (bank loan) $F = 0.6075$. This choice of F implies that the amount of bank loan $I_B = 0.5029$ and firm equity value $V_{i,E}(0) = 1.158$, implying that the firm chooses an optimal leverage ratio of $\left(\frac{I_B}{I_B + V_{i,E}(0)}\right) \approx 0.30$, which is mostly consistent with GS. The value of bank equity assuming it takes on no leverage is $V_{B,E}^{ND}(0) = 0.5105$. That this value is higher than I_B reflects the spread s specified in equation (20).

[21] Equation (20) defines the spread (s) via the (log) difference between what a banks loans to the firm (I_B) and the present value of the date-T after-tax cash flows associated with that loan ($V_{B,E}^{ND}(0)$) if the bank remains unlevered. We note that it would have been more in the spirit of GS had the spread s been defined as that earned by an optimally leveraged bank. Such a model would capture in reduced-form some notion of bank competition (or at least, some bargaining power for the firm), and further would imply that some of the tax benefits to debt received by the bank would have been passed on to firms. This added complexity, however, would not impact the main point of our paper, namely, that banks can both increase shareholder value and reduce the likelihood of default by hedging bank-index risk. Therefore, we focus on the simpler model proposed here, which allows us to identify the loan parameters (I_B, F) prior to identifying optimal bank policies, rather than needing to determine these jointly.

In Panel A of Figure 1, we plot firm shareholder profit $(V_{i,E}(0) - I_E)$ as a function of firm leverage to demonstrate the unique optimal solution, and quantify the benefits of debt compared to the no-leverage situation.

From the perspective of the firm, we define the bond yield (y) via

$$I_B = F\, e^{-yT}. \tag{21}$$

For this parameterization, we find $y = 3.78\%$. This implies a credit spread on the firm's loan of $(y - r) = 1.78\%$.

B Optimal Hedging and Capital Structure Policies of Banks

In the previous section, we identified the optimal investment and capital structure policies for the firm, which determined both the size of the loan I_B from the bank date-0, and the promised payment F to the bank at date-1. In this section, we identify the joint optimal risk management and capital structure policies of the bank.

We specify that the risk management tool used by the bank to hedge industry risk is a convertible forward contract, whose payoff is expressed in terms of an aggregate bank index. The convertible feature gives the bank the option to cover its losses on the forward contract via equity issuance rather than a cash outflow, and the decision to exercise this option is made in the best interests of current bank shareholders. The motivation for this contract comes from the work of Chowdry and Schwartz (2016), who investigate a firm with an exogenously specified capital structure that uses a standard forward contract to minimize financial distress costs. They show that, due to the presence of idiosyncratic shocks, the optimal hedge ratio is significantly less than the hedge ratio that minimizes return variance. For example, whereas a firm with a market beta equal to one will minimize *return variance* by choosing a hedge ratio equal to one, it will minimize *financial distress costs* by choosing a hedge ratio that is approximately equal to its leverage ratio. Thus, the amount of aggregate risk that a firm can hedge is limited when it uses a standard forward contract as its hedging instrument.

To overcome this limitation associated with standard forward contracts, here we investigate the optimal hedging of industry-risk when a convertible forward contract is used instead. Intuitively, the firm's option to fulfill its obligations on the forward contract via equity issuance rather than a cash payout allows the firm to hedge industry-risk more aggressively. Indeed, we demonstrate below that use of a convertible forward to hedge industry risk significantly reduces bank default probabilities when the industry shock is negative (i.e., when the payoff to the bank is positive), but does not increase bank default probabilities when the industry shock is positive (although current shareholders may be negatively impacted by a dilution effect).

Following Gornall and Strebulaev (2018), we assume that a bank originates $N \Rightarrow \infty$ loans, each with identical features as described in the previous section. As such, it is convenient to re-write equation (5) to decompose the Brownian motion $z_{i,T}$ driving the uncertainty in the cash flows of each firm-i in terms of a component common to all loans to bank-B (z_B), and a firm-specific component ($z_{i,idio}$):

$$\log X_i \;=\; \nu + \sigma \left[\sqrt{\rho T}\, z_B + \sqrt{(1-\rho)T}\, z_{i,idio} \right], \tag{22}$$

where we have defined the constant

$$\nu \;\equiv\; \log(I_E + I_B) + (\mu - \frac{\sigma^2}{2})T. \tag{23}$$

Revenues received by the bank from loan-i are:

$$X_{i,B} \;=\; F\mathbf{1}_{(X_i > X_{def})} + (1-\alpha)X_i\mathbf{1}_{(X_i < X_{def})}. \tag{24}$$

Summing over $N \to \infty$ firms and using the law of large numbers, the bank's pre-tax revenues at date-T due to these loans is a function of z_B only (and not the idiosyncratic $\{z_{i,idio}\}$):

$$\begin{aligned} X_B(z_B) \;&=\; F\,\mathrm{E}^Q \left[\mathbf{1}_{(X_i > X_{def})} | z_B \right] + (1-\alpha)\,\mathrm{E}^Q \left[X_i \mathbf{1}_{(X_i < X_{def})} | z_B \right] \\ &=\; F\,\Phi \left[\frac{\nu + \sigma z_B \sqrt{\rho T} - \log X_{def}}{\sigma\sqrt{(1-\rho)T}} \right] \\ &\quad + (1-\alpha) I\, e^{\sigma z_B \sqrt{\rho T} + (\mu - \frac{\sigma^2}{2}\rho)T}\, \Phi \left[\frac{\log X_{def} - \nu - \sigma^2(1-\rho)T - \sigma z_B\sqrt{\rho T}}{\sigma\sqrt{(1-\rho)T}} \right]. \end{aligned} \tag{25}$$

Equation (25) identifies the revenues of a single bank. Here we identify cash flows associated with a bank index that the forward contract will be written against. To accomplish this, we first decompose the Brownian motion z_B introduced in equation (22) into two parts, namely, a market component and a bank-specific component:

$$z_B = \sqrt{\rho_B}\, z + \sqrt{1-\rho_B}\, z_{B,idio}. \tag{26}$$

We calibrate the parameter ρ_B as follows: if in continuous time, bank stock returns follow:

$$\left(\frac{dS}{S} - r\,dt\right) = \mu_S\, dt + \sigma_S \left(\sqrt{\rho_B}\, dz + \sqrt{1-\rho_B}\, dz_{B,idio}\right), \tag{27}$$

Then hedged bank stock returns follow

$$\left(\frac{dS}{S} - r\,dt - \sigma_S \sqrt{\rho_B}\, dz\right) = \mu\, dt + \sigma_S \sqrt{1-\rho_B}\, dz_{B,idio}. \tag{28}$$

Calibrating to our empirical results in Table I, we set unhedged bank equity volatility to $\sigma_S = 0.34$, and hedged volatility to $\sigma_S\sqrt{1-\rho_B} = 0.23$. These choices imply that $\rho_B = 0.54$.

It is convenient to introduce the parameter $\rho^* = \rho\rho_B$. Analogous to equation (22) revenues generated by firm-i can be expressed as:

$$\log X_i = \nu + \sigma\left[\sqrt{\rho^* T}\, z + \sqrt{(1-\rho^*)T}\, \hat{z}\right], \tag{29}$$

where we have defined the standard normal $N(0,1)$ variable:

$$\hat{z} = \frac{1}{\sqrt{1-\rho^*}}\left(\sqrt{\rho}\sqrt{1-\rho_B}\, z_{B,idio} + \sqrt{1-\rho}\, z_{i,idio}\right). \tag{30}$$

Revenues received by bank-j from the loan to firm-i are still:

$$X_{i,B_j} = F\mathbf{1}_{(X_i > X_{def})} + (1-\alpha)X_i \mathbf{1}_{(X_i < X_{def})}. \tag{31}$$

Summing over $N \to \infty$ firms and $N_B \to \infty$ banks, and using the law of large numbers, the bank index pre-tax revenues at date-T due to these loans is a function of z only (and not the idiosyncratic normal random variables $\{\hat{z}\}$):

$$\hat{X}_B(z) = F\,\mathrm{E}^Q\left[\mathbf{1}_{(X_i > X_{def})}|z\right] + (1-\alpha)\,\mathrm{E}^Q\left[X_i \mathbf{1}_{(X_i < X_{def})}|z\right] \tag{32}$$

$$= \quad F\,\Phi\left[\frac{\nu + \sigma z\sqrt{\rho^* T} - \log X_{def}}{\sigma\sqrt{(1-\rho^*)T}}\right]$$
$$+(1-\alpha)I\, e^{\sigma z\sqrt{\rho^* T}+(\mu-\frac{\sigma^2}{2}\rho^*)T}\,\Phi\left[\frac{\log X_{def} - \nu - \sigma^2(1-\rho^*)T - \sigma z\sqrt{\rho^* T}}{\sigma\sqrt{(1-\rho^*)T}}\right].$$

The convertible forward contract is specified by three contract parameters (K, n_H, π), and is written on the bank index $\hat{X}_B(z)$. Its cash flows are the following:

- If $K \geq \hat{X}_B(z)$, then the counterparty pays the bank $n_H(K - \hat{X}_B(z))$.
- If $K < \hat{X}_B(z)$, then the bank has three choices: i) default, in which case the counterparty receives zero; ii) pay the counterparty $n_H(\hat{X}_B(z) - K)$ in cash; iii) give the counterparty a fraction π of outstanding stock, which in this one-period model, is equivalent to paying the counterparty a fraction π of the dividends. When making this decision, we assume that the bank manager will act in the best interest of current shareholders. Figure 2 reports the payoff as a function of the loan portfolio $X_B(z_B)$ under this scenario for a given z.

Intuitively, there exist states of nature with sufficiently high realizations of z (implying that the bank owes something to its forward contract counterparties), and sufficiently low realizations of $z_{B,idio}$ (implying the bank itself has performed poorly in its own operations) in which issuing equity rather than paying out cash to cover obligations on the forward contract is the better strategy for current shareholders. Indeed, there are cases in which this strategy allows the firm to avoid bankruptcy, in turn, allowing current shareholders to receive $(1-\pi)$ of the dividend (rather than zero in default). Below we will identify the regions for which the bank makes these different choices. For now, we simply refer to the cash flows paid by the bank on the convertible forward contract as $FOR(z, z_B)$.[22]

Given the bank's revenues from operations $X_B(z_B)$ in equation (25) and the cash flows associated with the forward contract $FOR(z, z_B)$, we now determine the value of bank debt and bank equity. To begin, we account for the fact that a large portion

[22]If $FOR(z, z_B)$ is negative, then the bank receives cash flows.

of bank debt is supported by FDIC insurance.[23] Specifically, we define DEP as the amount of insured deposits the bank has on their books. These deposits are guaranteed a risk-free return of $DEP\, e^{\hat{r}T}$ at date-T. In addition, the bank raises $I_{B,E}$ in equity and $I_{B,D}$ in risky debt, which promises a face value payment of F_B at the maturity date-T.

The bank's revenues from operations and risk management positions are

$$REV \;=\; X_B(z_B) - FOR(z, z_B). \tag{33}$$

The banks's EBIT equals these revenues net of investment:

$$EBIT_B(z_B, z) \;=\; X_B(z_B) - FOR(z, z_B) - \left(DEP + I_{B,E} + I_{B,D}\right). \tag{34}$$

Conditional upon the bank not defaulting, its pre-tax earnings are determined by subtracting interest paid on deposits and risky debt:

$$EBT_B(z_B, z) \;=\; X_B(z_B) - FOR(z, z_B) - \left(DEP\, e^{\hat{r}T} + I_{B,E} + F_B\right). \tag{35}$$

Hence, assuming full tax-loss offset, taxes paid by the bank are:

$$Tax_B(z_B, z) \;=\; \tau\left[X_B(z_B) - FOR(z, z_B) - (DEP\, e^{\hat{r}T} + I_{B,E} + F_B)\right]. \tag{36}$$

Therefore, the cash flow (i.e., terminal dividend) paid to equity, if positive, is:

$$\begin{aligned} X_{B,E}(z, z_B) \;&=\; X_B(z_B) - FOR(z, z_B) - DEP\, e^{\hat{r}T} - F_B \\ &\qquad -\tau\left[X_B(z_B) - FOR(z, z_B) - \left(DEP\, e^{\hat{r}T} + I_{B,E} + F_B\right)\right] \\ &=\; (1-\tau)\left[X_B(z_B) - FOR(z, z_B) - DEP\, e^{\hat{r}T} - F_B\right] + \tau I_{B,E}. \end{aligned} \tag{37}$$

First consider the case $(K > \hat{X}_B(z))$, which implies the counterparty of the forward contract pays the bank $n_H\left(K - \hat{X}_B(z)\right)$. Thus

$$X_{B,E}^{\left(K>\hat{X}_B(z)\right)}(z, z_B) \;=\; (1-\tau)\left[X_B(z_B) + n_H\left(K - \hat{X}_B(z)\right) - DEP\, e^{\hat{r}T} - F_B\right] + \tau I_{B,E}. \tag{38}$$

[23] See, for example, Song and Thakor (2007), Allen and Carletti (2013).

We define the z-dependent location of the default boundary $X_{B,def}^{\left(K>\hat{X}_B(z)\right)}$ as that value of $X_B(z_B)$ which would generate zero dividend:

$$0 = (1-\tau)\left[X_{B,def}^{\left(K>\hat{X}_B(z)\right)} + n_H\left(K - \hat{X}_B(z)\right) - DEP\, e^{\hat{r}T} - F_B\right] + \tau I_{B,E}. \quad (39)$$

Simplifying, we find:

$$X_{B,def}^{\left(K>\hat{X}_B(z)\right)} = DEP\, e^{\hat{r}T} + F_B - \left(\frac{\tau}{1-\tau}\right) I_{B,E} - n_H(K - \hat{X}_B(z)). \quad (40)$$

Subtracting equation (39) from equation (38), we find:

$$X_{B,E}^{\left(K>\hat{X}_B(z)\right)}(z, z_B) = (1-\tau)\left(X_B(z_B) - X_{B,def}^{(K>\hat{X}_B(z))}\right). \quad (41)$$

Now consider the case $(K < \hat{X}_B(z))$. As noted above, there are three regions of interest: i) $X_B(z_B) > X_B^*$, where it is optimal for the bank to satisfy its obligations on the forward contract by paying $n_H\left(\hat{X}_B(z) - K\right)$ in cash; ii) $X_B(z_B) \in \left(X_{B,def}^{(K<\hat{X}_B(z))}, X_B^*\right)$, where it is optimal for the bank to satisfy its obligations on the forward contract by issuing equity; iii) $X_B(z_B) < X_{B,def}^{(K<\hat{X}_B(z))}$, where it is optimal for the bank to default. Here, we identify $\left(X_{B,def}^{(K<\hat{X}_B(z))}, X_B^*\right)$, and the dividend payments in these regions.

For the case $X_B(z_B) > X_B^*$, everything is the same as in equation (38) above, although we use a slightly different notation in order to emphasize the condition $(K < \hat{X}_B(z))$:

$$X_{B,E}^{\left(I,K<\hat{X}_B(z)\right)}(z, z_B) = (1-\tau)\left[X_B(z_B) + n_H\left(K - \hat{X}_B(z)\right) - DEP\, e^{\hat{r}T} - F_B\right] + \tau I_{B,E}. \quad (42)$$

We use the Roman numeral I to emphasize that this dividend payment occurs in the region $X_B(z_B) > X_B^*$.

In contrast, for the case $X_B(z_B) \in \left(X_{B,def}^{\left(K>\hat{X}_B(z)\right)}, X_B^*\right)$, we claim that it is in the best interest of current shareholders to satisfy its obligations on the forward contract by issuing a fraction π of the equity claim to the forward counterparty. Hence, we have

$$FOR(z, z_B) = \pi\left(FOR(z, z_B) + X_{B,E}^{(II,K<\hat{X}_B(z))}(z, z_B)\right), \quad (43)$$

where we have used the Roman numeral II in the superscript to emphasize that we are considering the second region: $X_B(z_B) \in \left(X_{B,def}^{\left(K>\hat{X}_B(z)\right)}, X_B^*\right)$. Simplifying, we find:

$$FOR(z, z_B) = \left(\frac{\pi}{1-\pi}\right) X_{B,E}^{(II,K<\hat{X}_B(z))}(z, z_B). \quad (44)$$

Plugging this into equation (37) and simplifying, we find

$$X_{B,E}^{\left(II,K<\hat{X}_B(z)\right)}(z,z_B) \;=\; \left(\frac{1-\pi}{1-\tau\pi}\right)\left\{(1-\tau)\left[X_B(z_B)-DEP\,e^{\hat{r}T}-F_B\right]+\tau I_{B,E}\right\}, \quad (45)$$

and thus

$$FOR(z,z_B) \;=\; \left(\frac{\pi}{1-\tau\pi}\right)\left\{(1-\tau)\left[X_B(z_B)-DEP\,e^{\hat{r}T}-F_B\right]+\tau I_{B,E}\right\}, \quad (46)$$

We define the location of the default boundary $X_{B,def}^{\left(K<\hat{X}_B(z)\right)}$ as that value of $X_B(z_B)$ which would generate zero dividend:

$$0 \;=\; \left(\frac{1-\pi}{1-\tau\pi}\right)\left\{(1-\tau)\left[X_{B,def}^{\left(K<\hat{X}_B(z)\right)}-DEP\,e^{\hat{r}T}-F_B\right]+\tau I_{B,E}\right\}. \quad (47)$$

Simplifying, we find:

$$X_{B,def}^{\left(K<\hat{X}_B(z)\right)} \;=\; DEP\,e^{\hat{r}T}+F_B-\left(\frac{\tau}{1-\tau}\right)I_{B,E}. \quad (48)$$

Subtracting equation (47) from equation (45), we find:

$$X_{B,E}^{\left(II,K<\hat{X}_B(z)\right)}(z,z_B) \;=\; \left(\frac{(1-\pi)(1-\tau)}{1-\tau\pi}\right)\left(X_B(z_B)-X_{B,def}^{(K<\hat{X}_B(z))}\right). \quad (49)$$

To identify the location $X_B^*(z)$ that separates the regions where the firm decides to pay cash versus issue equity to settle their forward contract obligations, we combine equations (42) and (45) after replacing $X_B(z_B)$ with $X_B^*(z)$:

$$\begin{aligned}(1-\tau)&\left[X_B^*(z)+n_H\left(K-\hat{X}_B(z)\right)-DEP\,e^{\hat{r}T}-F_B\right]+\tau I_{B,E}\\ &=\left(\frac{1-\pi}{1-\tau\pi}\right)\left\{(1-\tau)\left[X_B^*(z)-DEP\,e^{\hat{r}T}-F_B\right]+\tau I_{B,E}\right\}\end{aligned} \quad (50)$$

Simplifying, we find

$$X_B^*(z) \;=\; X_{B,def}^{\left(K<\hat{X}_B(z)\right)}+\left(\frac{1-\tau\pi}{\pi(1-\tau)}\right)n_H(\hat{X}_B(z)-K). \quad (51)$$

The policy parameters (K,π,n_H) must be chosen so that the date-0 present value of the forward contract is zero:

$$\begin{aligned}0 \;=\; &\mathrm{E}_t^Q\left[n_H\left(\hat{X}_B(z)-K\right)\left(\mathbf{1}_{(K>\hat{X}_B(z))}+\mathbf{1}_{(K<\hat{X}_B(z))}\mathbf{1}_{\left(X_B(z_B)>X_B^*(z)\right)}\right)\right] \quad (52)\\ +&\mathrm{E}_t^Q\left[\pi\left(\frac{1-\tau}{1-\tau\pi}\right)\left(X_B(z_B)-X_{def}^{(\hat{X}_B(z)>K)}\right)\,\mathbf{1}_{(K<\hat{X}_B(z))}\,\mathbf{1}_{\left(X_B(z_B)\in\left(X_{def}^{(\hat{X}_B(z)>K)},X_B^*(z)\right)\right)}\right].\end{aligned}$$

It is convenient to define a default indicator that takes the value one if default occurs and zero otherwise:

$$default \;=\; \mathbf{1}_{(K>\hat{X}_B(z))}\,\mathbf{1}_{\left(X_B(z_B)<X_{B,def}^{\left(K>\hat{X}_B(z)\right)}\right)} + \mathbf{1}_{(K<\hat{X}_B(z))}\mathbf{1}_{\left(X_B(z_B)<X_{B,def}^{\left(K<\hat{X}_B(z)\right)}\right)}. \quad (53)$$

The value of bank equity and debt can therefore be expressed as

$$V_{B,E}(0) \;=\; e^{-rT}\mathcal{E}_t^Q\left[X_{B,E}(z,z_B)\;\mathbf{1}_{(default=0)}\right] \quad (54)$$

$$V_{B,D}(0) \;=\; e^{-rT}\mathcal{E}_t^Q\left[F_B\;\mathbf{1}_{(default=0)} + Recov\;\mathbf{1}_{(default=1)}\right], \quad (55)$$

where we have defined the recovery in the event of default as:

$$Recov \;=\; \max\left\{0,\;(1-\alpha_B)\left[X_B(z_B)+n_H\left(K-\hat{X}_B(z)\right)\mathbf{1}_{(K>\hat{X}_B(z))}\right]-DEP\,e^{\hat{r}T}\right\}. \quad (56)$$

We assume that the bank pays fair value for deposit insurance. If the bank defaults, the amount the FDIC will have to pay out, if positive, equals:

$$X_{INS} \;=\; DEP\,e^{\hat{r}T}-(1-\alpha_B)\left(X_B(z_B)+n_H\left(K-\hat{X}_B(z)\right)\mathbf{1}_{(K>\hat{X}_B(z))}\right). \quad (57)$$

As such, the bank must pay as an insurance premium

$$V_{INS}(0) \;=\; e^{-rT}\mathcal{E}_0^Q\left[X_{INS}\,\mathbf{1}_{(X_{INS}>0)}\,\mathbf{1}_{(default=1)}\right]. \quad (58)$$

The bank covers both the amount loaned to firms I_B and deposit insurance $V_{INS}(0)$ through some combination of deposits, issuing risky debt, and issuing equity:

$$I_B+V_{INS}(0) \;=\; DEP+I_{B,E}+I_{B,D}. \quad (59)$$

At date-0, the firm will choose the risk management policy parameters (K,π,n_H) and capital structure parameter F_B in order to maximize date-0 bank shareholder profit, subject to this constraint:

$$\text{Bank Shareholder Profit} \;=\; \max_{(K,\pi,n_H,F_B)}\left(V_{B,E}(0)-I_{B,E}\right). \quad (60)$$

B.1 Optimal Bank Risk Management and Capital Structure Policies

Here we continue with the numerical example began in the previous section, with model parameters as specified in Table III. We solve for the optimal bank policy when the bank does not hedge ($n_H = 0$). The result is reported in the column labelled "Unhedged" in Panel B of Table IV. We find that the optimal face value of defaultable bank debt is $F_B = 0.056$. This implies that bank shareholders invest $I_{B,E} = 0.026$ at date-0, and that the bank raises $I_{B,D} = V_{B,D}(0) = 0.05$ via debt issuance at date-0. The date-0 value of the equity claim is $V_{B,E}(0) = 0.059$, and thus shareholder profit is $\left(V_{B,E}(0) - I_{B,E}\right) = 0.0033$. This captures wealth gains to shareholders due to their screening and monitoring skills, and their ability to reduce their tax bill via debt issuance.

Given the numbers above, the optimal bank leverage ratios are

$$\text{Defaultable debt / Asset} \quad = \quad \frac{V_{B,D}(0)}{V_{B,E}(0) + V_{B,D}(0) + DEP} = 0.09 \tag{61}$$

$$\text{Total debt / Asset} \quad = \quad \frac{V_{B,D}(0) + DEP}{V_{B,E}(0) + V_{B,D}(0) + DEP} = 0.89 \tag{62}$$

Again, this prediction is mostly consistent with Hanson et al. (2015).

In Panel B in Figure 1, we plot the bank shareholder's profit $\left(V_{B,E}(0) - I_{B,E}\right)$ as a function of bank leverage to demonstrate the unique optimal solution, and to quantify the benefits of debt compared to the no-leverage situation.

We define the yield on bank debt y_B via the equation

$$V_{B,D}(0) \quad = \quad F_B \, e^{-y_B T}. \tag{63}$$

The example above generates a bond yield equal to $y_B = 2.36\%$. Hence, the spread on the bank defaultable bond over the risk free rate $(y_B - r)$ is equal to 36bp.

B.2 Results

Table V reports the results when a bank hedges the index risk with the convertible forward. We solve the model for the conversion ratio $\pi = (0.2, 0.4, 0.6, 0.8, 1)$. For each given value of π, the bank determines the optimal hedge ratio n_H and face value of bank debt F_B to maximize shareholder profit. In general, we find that the bank chooses to hedge more systematic risk (i.e., chooses a higher value for n_H) and takes higher leverage (i.e., higher F_B and $\frac{V_{B,D}(0)}{V_{B,E}(0)+V_{B,D}(0)+DEP}$) when the bank pledges more equity to the convertible forward (i.e., chooses a higher value for π). This, in turn, reduces bank default risk, lowers the cost of bank debt, and increases bank shareholder profit. If the bank is allowed to choose π, it is optimal for the bank to pledge all its equity $\pi = 1$ to the convertible forward in order to maximize its shareholder profit. Therefore, we set $\pi = 1$ for the rest of the analysis.

In Figure 3, we plot the following quantities as a function of n_H: Panel A: optimal face value of bank debt $F^*_B(n_H)$; Panel B: bank shareholder profit $\big(V_{B,E}(0) - I_{B,E}\big)$; Panel C: bank leverage $\left(\frac{DEP}{V_{B,E}(0)+V_{B,D}(0)+DEP}\right)$ and $\left(\frac{V_{B,D}(0)+DEP}{V_{B,E}(0)+V_{B,D}(0)+DEP}\right)$; ; Panel D: 5-year risk neutral default probability: $\mathcal{E}^Q_t\left[\mathbf{1}(default = 1)\right]$; and Panel E: the credit spread of defaultable bank debt. When plotting these last four figures, we set F_B to its optimal value $F^*_B(n_H)$ for each value of n_H.

As Panel B demonstrates, bank shareholder profit is maximized when the bank chooses $n_H = 4.0$.[24] For this policy choice, total bank debt to asset ratio is 94.3%, compared to 89% when the bank does not hedge. Moreover, even though Panel C demonstrates that optimally chosen leverage ratios generally increase with n_H over the range $n_H \in (0, 4)$, Panel D shows that default probabilities decrease monotonically over this same range. Panel E demonstrates that the credit spreads decrease monotonically over this same range as well. This is one of the main results of our paper: banks can simultaneously increase their leverage compared to the no-hedge case – in turn increasing the level of liquid assets in the economy – while greatly reducing default probabilities by hedging index risk. Thus, hedging index risk significantly circumvents the micro-prudential dilemma discussed in the introduction. Moreover, as we demonstrate below, this hedging also has important macroprudential implications.

[24] The column labelled "Co. Forward" in Panel B of Table IV documents salient features associated with the $n_H = 4$ optimal hedge policy.

Figure 4 reports the expected payoff associated with shorting the forward contract conditional on z for values $n_{H} = \{0, 1, 4\}$.[25] In the face of a large negative systematic shock z, the payoff associated with shorting this forward contract is high, providing a significant hedge to the bank's exposure to bank-index risk. However, because the underlying asset is a portfolio of bonds with face value F, the loss on the forward contract is bounded above by $\underline{X}_{f} = n_{H}(K - F)$.

In Figure 5 we report the location of the default boundary (expressed in terms of $z_{B,idio}$) as a function of z for several values of n_{H}. Note that for the case $n_{H} = 4$, the largest value of $z_{B,idio}$ that generates default is $z^{*}_{B,idio} = -1.74$, which is associated with a cumulative probability of 4%, since $z_{B,idio}$ is a standard normal random variable. Moreover, this event is associated with a value of z near zero. This has two implications: First, as we discuss in detail below, default correlations across banks are nearly zero when banks optimally hedge index risk. Second, although we do not investigate it in this paper, low values of industry bank risk z are associated with poor overall economic performance. Hence, in our model, bank default probabilities are extremely low for those states of nature in which a healthy banking system may be most needed.

In Figure 6, we report the 5-year risk-neutral bank default probabilities as a function the systematic shock variable z for several different values of n_{H}.[26] Because default probabilities differ so much across different values of n_{H}, we plot them on two different figures, whose y-axes have scales that differ by approximately two orders of magnitude. The conditional default probability is computed as $\mathcal{E}^{Q}_{t}\left[\mathbf{1}(default = 1)\,|z\right]$. Panel A reports conditional default probabilities for two cases: $n_{H} = \{0, 1\}$, whereas Panel B reports conditional default probabilities for three cases: $n_{H} = \{2, 3, 4\}$. Note that $z \sim N(0, 1)$ is a standard normal variable. Hence, values of z closer to zero are more likely, and $z \in (-3, 3)$ captures approximately 99.7% of the probability density.

[25] Recall that the forward price K is chosen so that expected payoff is zero. We emphasize that this is not inconsistent with the fact that the "area under the curve" is clearly positive. This is because z is distributed normally $z \sim^{Q} N(0, 1)$, implying that payoffs near $z = 0$ are weighted most heavily, and because the payoff crosses the x-axis at a negative value of z (namely, $z = -0.33$).

[26] For each different value of n_{H}, we set firm leverage to its optimal value.

Panel A shows that for the case in which banks do not hedge (i.e., $n_H = 0$), the bank default probability decreases monotonically with z. Moreover, for values of $z < -4$ the default probability is close to one. For the case $n_H = 1$, default probability is reduced across almost all states of nature z. This example emphasizes that even partial hedging of bank index risk can reduce default risk significantly.

As shown in Panel B, default risk can be reduced further by choosing larger values of n_H. Indeed, for the case $n_H = 4$ which maximizes shareholder wealth, the maximum 5-year conditional default probability across all states of nature is only 4.1%. The convertible feature of the forward contract lowers the default risk on the upside and hence makes the conditional default probability function negatively skewed.

Here we investigate the macroprudential implications of banks hedging index risk. Specifically, we assume there are $N_B = 20$ identical banks, whose revenues are driven by a common risk source z, but have iid idiosyncratic bank shocks $z_{B,idio}$. For several values of n_H (and F_B set to its optimal value $F_B^*(n_H)$), we consider 1,000,000 realizations for $(z, \{z_{B,idio}\})$ in order to estimate the percentage of events in which 1, 2, ... 20 banks default. We then determine the mean, the standard deviation and skewness of this distribution, and plot these three moments separately as a function of $n_H \in (0, 4)$ in Panels A, B and C in Figure 7. Consistent with the result in Panel D in Figure 3, Panel A shows that the expected number of defaults decreases with hedge ratio n_H. Furthermore, Panels B and C report that both volatility and skewness decrease with hedge ratio n_H. This implies that defaults become more idiosyncratic as we increase the bank-index hedge.

We also plot the distribution of defaults for the cases $n_H = 0$ and $n_H = 4$ in Figure 8. Because the great majority of cases are associated with zero defaults, we do not report the case $N_B = 0$. This choice allows the figure to better illustrate the differences between the cases $n_H = 0$ and $n_H = 4$. In all of these figures, it is clear that the selfish act of banks hedging index risk in order to maximize bank shareholder value significantly reduces the likelihood of correlated defaults.

Finally, for each value of n_H, we run 1,000,000 simulations in order to estimate the default correlation between two ex-ante identical banks i an j:

$$\mathbf{Corr}\left(\mathbf{1}_{\left(X^i_{B,E}<0\right)}, \mathbf{1}_{\left(X^j_{B,E}<0\right)}\right) = \frac{\mathrm{E}\left[\mathbf{1}_{\left(X^i_{B,E}<0\right)}\mathbf{1}_{\left(X^j_{B,E}<0\right)}\right] - \mathrm{E}\left[\mathbf{1}_{\left(X^i_{B,E}<0\right)}\right]^2}{\mathrm{Var}\left[\mathbf{1}_{\left(X^i_{B,E}<0\right)}\right]}. \quad (64)$$

We report default correlation as a function of n_H in Figure 9. We find that default correlations drop monotonically across the domain $n_H \in (0, 4)$ from approximately **corr** $= 0.18$ for $n_H = 0$ to **corr** $= 0.01$ for $n_H = 4$.

B.3 Dynamic vs. Static Hedge

In the previous section, we investigated how banks can increase shareholder value by taking a short position in the bank-index. Consistent with our 2-date $(0, T)$ framework, we restricted our attention to only *static* hedges created by shorting the bank index. This leaves open the question of how much better a *dynamic* hedge could perform. One issue with directly investigating a dynamic hedge is that we would need to take a stand on what the bank does with its profits and losses during each intermediate date between the initial date $t = 0$ and final date $t = T$.

To circumvent these issues, here we identify an upper bound to the benefits of hedging by investigating the optimal capital structure decision of a bank for which we impose the restriction that bank index risk equals zero: $z = 0$. The results are reported in the column labelled "No Sys. Risk" in Panel B of Table IV. Under this scenario, we find that the optimal bank leverage ratios are 13.6% for the defaultable debt to asset ratio and 92.8% for the total debt to asset ratio, bank shareholder profit is 3.69%, and the annualized risk-neutral default probability is 0.22%. The implication is that a dynamic hedge may be able to provide significant additional benefits over and above what can be gained from a static hedge.

Series "No Sys. Risk ($z = 0$)" in Figure 9 shows the distribution of the number of bank defaults under this scenario. Comparing with the banks optimally hedging with the convertible forward, we find that a dynamic hedge may further reduce the chance of correlated bank defaults.

IV Conclusion

There is strong disagreement in the academic literature regarding how the financial system should be regulated. At the micro-prudential level, many have argued that banks should be forced to hold significantly more equity capital (especially during economic booms) in order to both reduce the likelihood of bank defaults during a crisis, and to facilitate recovery after a crisis. In contrast, others argue that high bank leverage is socially optimal because high leverage allows banks to create large supplies of liquid assets, which are in great demand by society. There is also disagreement regarding how much regulation should focus on the health of individual banks versus the banking system as a whole (i.e., macroprudential policy). Moreover, many have voiced their concern that increased regulation costs may push more money toward the less-regulated shadow banking system, which may undermine any hoped-for improvements for the stability of the financial system.

In this paper, we demonstrate that all of these concerns across discordant camps can be simultaneously alleviated if banks hedge bank-index risk. First, we demonstrate that in the absence of bank bailouts, hedging bank-index risk maximizes bank shareholder value. Specifically, we show that when banks choose their optimal hedging and capital structure policies jointly, a bank's default-risk drops substantially – in spite of banks choosing *higher* leverage ratios – in turn allowing banks to create even more safe, liquid assets. Second, we show that this policy mostly eliminates systemic risk in the banking system, in turn greatly reducing the negative externalities associated with credit crunches and fire sales. Moreover, this policy accomplishes these feats while increasing bank value, thus allowing banks to compete even more favorably with the less-regulated shadow banking system. Finally, we demonstrate the advantages of using *convertible* forward contracts to hedge industry risk. Compared to banks purchasing a put option to hedge industry-risk, forward contracts involve no initial cash outlay, which reduces default risk. In addition, the convertible features allows banks the option to fulfill their obligations on the forward contract by issuing equity rather than needing to pay out cash. This feature allows banks to hedge index-risk even more efficiently.

We interpret the empirical fact that banks do not choose to hedge bank-index risk as evidence for them internalizing the benefits of government bailouts. If this is indeed the explanation, then banks are acting rather iniquitously, as they are colluding to remain systematically important, and rent-seeking by forcing taxpayers to bail out the system during financial crises. That is, banks are guilty of much more serious acts than simply not internalizing negative externalities associated with credit crunches and fire sales.

Most of the literature has attributed the social value of the banking system to its ability to create liquidity and to monitor and screen loans. We emphasize that having banks short the bank index should serve only to increase these benefits to society. Indeed, by shorting the index, banks face significantly less default risk, which increases incentives for monitoring, and decreases incentives for asset substitution and regulatory arbitrage. Moreover, hedging index risk may allow bank managers with superior skills to signal these skills to investors more quickly, which in turn may allow shareholders to more quickly remove managers with inferior skills. Finally, whereas some of the literature has argued that there may be an inherent tension between micro-prudential and macro-prudential regulation of the financial sector, our channel in which banks optimally choose to hedge bank-index risk does not seem to suffer from this concern.

We note that the largest banks are very active in risk management, especially towards hedging exposure to interest rate and foreign exchange rate risk. Our analysis suggests that this choice of risk management is basically a side-show which diverts attention from the fact that banks do not hedge bank-index risk, which would offer significantly greater reduction in asset volatility. Moreover, note that if unhedged banks face similar interest rate exposures, then hedging the bank index would provide a natural interest rate hedge.

Although our paper mostly focuses on banks, its implications are easily extended to all firms. Indeed, as we demonstrate in the Appendix, the hotel and airline industries would have been well-served during the pandemic of 2020 by shorting their industry index. However, firms have little motivation to hedge industry-risk if they can anticipate government bailouts whenever their industry suffers a disaster. In the absence of anticipated bailouts, hedging industry-risk increases firm value. Anticipated government bailouts do more damage than just privatize gains and socialize losses. Indeed, they also generate negative externalities. Moreover, how government bailouts are doled out are often determined more by political connections than what is best for society. If all firms hedged industry risk, there would be little need for bailouts.

As noted by Mian and Sufi (2014) and others, our proposal of hedging "industry risk" can be applied to the real estate market, too. For example, families that wish to purchase a home should take a short position in real estate prices in their zip code. This would allow them to hedge downside house-price exposure by sacrificing some of their upside exposure. Such a policy may have greatly reduced the severity of the housing crisis that began in 2008.

References

[1] Viral V. Acharya. A theory of systemic risk and design of prudential bank regulation. *Journal of Financial Stability*, 5:224–255, 2009.

[2] Viral V. Acharya, Robert Engle, and Matthew Richardson. Capital shortfall: A new approach to ranking and regulating systemic risks. *American Economic Review*, 102:59–64, 2012.

[3] Viral V. Acharya, Hamid Mehran, Til Schuermann, and Anjan Thakor. Robust capital regulation. Current Issues in Economics and Finance, Federal Reserve Bank of New York, May issue, 2012.

[4] Viral V. Acharya, Hamid Mehran, and Anjan V. Thakor. Caught between scylla and charybdis? regulating bank leverage when there is rent seeking and risk shifting. *The Review of Corporate Finance Studies*, 5(1):36–75, 2016.

[5] Viral V. Acharya, Lasse H. Pedersen, Thomas Philippon, and Matthew Richardson. Measuring systemic risk. *Review of Financial Studies*, 30(1):2–47, 2017.

[6] Viral V. Acharya and Anjan Thakor. The dark side of liquidity creation: Leverage and systemic risk. *Journal of Financial Intermediation*, 28:4–21, 2016.

[7] Viral V. Acharya and Tanju Yorulmazer. Too many to fail-an analysis of time-inconsistency in bank closure policies. *Journal of Financial Intermediation*, 16:1–31, 2007.

[8] Anat R. Admati, Peter M. DeMarzo, Martin F. Hellwig, and Paul Pfleiderer. Fallacies, irrelevant facts, and myths in the discussion of capital regulation: Why bank equity is not socially expensive. Working Paper, Stanford University, 2013.

[9] Tobias Adrian and Markus K. Brunnermeier. Covar. *American Economic Review*, 106(7):1705–1741, 2016.

[10] Franklin Allen and Elena Carletti. What is systemic risk. *Journal of Money, Credit and Banking*, 45:121–127, 2013.

[11] Franklin Allen, Elena Carletti, and Robert Marquez. Credit market competition and capital regulation. *The Review of Financial Studies*, 24(4):983–1018, 2011.

[12] Franklin Allen, Elena Carletti, and Robert Marquez. Deposits and bank capital structure. *Journal of Financial Economics*, 118:601–619, 2015.

[13] Ilona Babenko, Hendrik Bessembinder, and Yuri Tserlukevich. Debt financing and risk management. Working Paper, Arizona State University, 2021.

[14] Jennie Bai, Robert S. Goldstein, and Fan Yang. The leverage effect and the basket-index put spread. *Journal of Financial Economics*, 131(1):186–205, 2019.

[15] Allen N. Berger and Christa H. S. Bouwman. How does capital affect bank performance during financial crises? *Journal of Financial Economics*, 109:146–176, 2013.

[16] Ben Bernanke and Mark Gertler. Agency costs, net worth, and business fluctuations. *American Economic Review*, 79(1):14–31, 1989.

[17] Marianne Bertrand and Sendhil Mullainathan. Are ceos rewarded for luck? the ones without principals are. *The Quarterly Journal of Economics*, 116:901–932, 2001.

[18] Bruno Biais and Catherine Casamatta. Optimal leverage and aggregate investment. *Journal of Finance*, 54(4):1291–1323, 1999.

[19] Claudio Borio. Towards a macroprudential framework for financial supervision and regulation? Working Paper, Bank for International Settlements, 2003.

[20] Claudio Borio, Craig Furfine, and Philip Lowe. Procyclicality of the financial system and financial stability: issues and policy options. Marrying the macro- and micro-prudential dimensions of financial stability, 2001.

[21] Nicole Boyson, Rudiger Fahlenbrach, and Rene M. Stulz. Why don't all banks practice regulatory arbitrage? evidence from the usage of trust preferred securities. *The Review of Financial Studies*, 29(7):1821–1859, 2016.

[22] Douglas T. Breeden and S. Viswanathan. Why do firms hedge? an asymmetric information model. *Journal of Fixed Income*, 25(3):1–19, 2016.

[23] Markus K. Brunnermeier, Andrew Crocket, Charles Goodhart, Avinash D. Persaud, and Hyun Shin. The fundamental principles of financial regulation. *Geneva Reports on the World Economy 11*, 2009.

[24] Markus K. Brunnermeier and Yuliy Sannikov. A macroeconomic model with a financial sector. *American Economic Review*, 104(2):379–421, 2014.

[25] Markus K. Brunnermeier and Yuliy Sannikov. The i theory of money. Working Paper #22533, National Bureau of Economic Research, 2016.

[26] Charles W. Calomiris and Joseph R. Mason. Fundamentals, panics, and bank distress during the depression. *American Economic Review*, 93:1615–1647, 2003.

[27] Murillo Campello, Chen Lin, Yue Ma, and Hong Zou. The real and financial implications of corporate hedging. *Journal of Finance*, 66(5):1615–1647, 2011.

[28] Jorge A. Chan-Lau. Regulatory capital charges for too-connected-to-fail institutions: A practical proposal. *Financial Markets, Institutions and Instruments*, 19:355–379, 2010.

[29] Gabriel Chodorow-Reich. The employment effects of credit market disruptions: Firm-level evidence from the 2008-09 financial crisis. *Quarterly Journal of Economics*, 129(1):1–59, 2014.

[30] Bhagwan Chowdhry and Eduardo Schwartz. How should firms hedge market risk? *Critical Finance Review*, 5:399–415, 2016.

[31] Joshua D. Coval and Anjan V. Thakor. Financial intermediation as a beliefs-bridge between optimists and pessimists. *Journal of Financial Economics*, 75:535–569, 2005.

[32] Andrew Crockett. International financial arrangements: Architecture and plumbing. *Australian Economic Review*, 33:109–119, 2000.

[33] Harry DeAngelo and Rene M. Stulz. Liquid-claim production, risk management, and bank capital structure: Why high leverage is optimal for banks. *Journal of Financial Economics*, 116:219–236, 2015.

[34] Peter DeMarzo and Darrell Duffie. Corporate incentives for hedging and hedge accounting. *Review of Financial Studies*, 8:743–771, 1995.

[35] Douglas W. Diamond and Raghuram G. Rajan. A theory of bank capital. *Journal of Finance*, 55(6):2431–2465, 2000.

[36] Douglas W. Diamond and Raghuram G. Rajan. Liquidity risk, liquidity creation, and financial fragility: A theory of banking. *Journal of Political Economy*, 109(2):287–327, 2001.

[37] Douglas W. Diamond and Raghuram G. Rajan. The credit crisis: Conjectures about causes and remedies. *American Economic Review*, 99:606–610, 2009.

[38] Itamar Drechsler, Alexi Savov, and Philipp Schnabl. The deposits channel of monetary policy. *The Quarterly Journal of Economics*, 132(4):1819–1876, 2017.

[39] Alex Edmans and Qi Liu. Inside debt. *Review of Finance*, 15:75–102, 2011.

[40] Mark Egan, Stefan Lewellen, and Aditya Sunderam. The cross section of bank value. Working Paper, Harvard University and Pennsylvania State University, 2018.

[41] Andrew Ellul and Vijay Yerramilli. Stronger risk controls, lower risk: Evidence from u.s. bank holding companies. *Journal of Finance*, 68(5):1757–1803, 2013.

[42] Rudiger Fahlenbrach, Robert Prilmeier, and Rene M. Stulz. Why does fast loan growth predict poor performance for banks? *The Review of Financial Studies*, 31(3):1014–1063, 2018.

[43] Emmanuel Farhi and Jean Tirole. Leverage and the central banker's put. *American Economic Review*, 99:589–593, 2009.

[44] Emmanuel Farhi and Jean Tirole. Collective moral hazard, maturity mismatch, and systemic bailouts. *American Economic Review*, 102:60–93, 2012.

[45] Kenneth R. French, Martin N. Baily, John Y. Campbell, John H. Cochrane, Douglas W. Diamond, Darrell Duffie, Anil K Kashyap, Frederic S. Mishkin, Raghuram G. Rajan, David S. Scharfstein, Robert J. Shiller, Hyun Song Shin, Matthew J. Slaughter, Jeremy C. Stein, and René M. Stulz. The squam lake report: Fixing the financial system. Princeton University Press, 2010.

[46] Kenneth A. Froot, David S. Scharfstein, and Jeremy C. Stein. Risk management: Coordinating corporate investment and financing policies. *Journal of Finance*, 48:1629–1658, 1993.

[47] Gerald T. Garvey and Todd T. Milbourn. Asymmetric benchmarking in compensation: Executives are rewarded for good luck but not penalized for bad. *Journal of Financial Economics*, 82(1):197–225, 2006.

[48] Céline Gauthier, Alfred Lehar, and Moez Souissi. Macroprudential capital requirements and systemic risk. *Journal of Financial Intermediation*, 21(4):594–618, 2012.

[49] Mark Gertler and Nobuhiro Kiyotaki. Chapter 11 - financial intermediation and credit policy in business cycle analysis. *Handbook of Monetary Economics*, 3:547–599, 2010.

[50] Matthieu Gomez, Augustin Landier, David Sraer, and David Thesmard. Banks' exposure to interest rate risk and the transmission of monetary policy. Forthcoming, Journal of Monetary Economics, 2020.

[51] Will Gornall. Safe assets and dangerous liabilities: How bank-level frictions explain bank seniority. Working Paper, University of British Columbia, 2018.

[52] Will Gornall and Ilya A. Strebulaev. Financing as a supply chain: The capital structure of banks and borrowers. *Journal of Financial Economics*, 129(3):510–530, 2018.

[53] Gary Gorton. Questions and answers about the financial crisis. Working Paper, Yale University, 2010.

[54] Gary Gorton and Andrew Metrick. Regulating the shadow banking system. *Brookings Papers on Economic Activity*, pages 261–312, 2010.

[55] Gary Gorton and Andrew Winton. Banking in transition economies: Does efficiency require instability? *Journal of Money, Credit, and Banking*, 3(2):621–650, 1998.

[56] Gary Gorton and Andrew Winton. Financial intermediation. Handbook of the Economics of Finance, 2003.

[57] Reint Gropp and Florian Heider. The determinants of bank capital structure. *Review of Finance*, 14(4):587–622, 2010.

[58] Valentin Haddad and David A. Sraer. The banking view of bond risk premia. Forthcoming, Journal of Finance, 2020.

[59] Samuel G. Hanson, Anil K. Kashyap, and Jeremy C. Stein. A macroprudential approach to financial regulation. *Journal of Economic Perspectives*, 25(1):3–28, 2011.

[60] Samuel G. Hanson, Andrei Shleifer, Jeremy C. Stein, and Robert W. Vishny. Banks as patient fixed-income investors. *Journal of Financial Economics*, 117:449–469, 2015.

[61] John P. Harding, Xiaozhong Liang, and Stephen L. Ross. Bank capital requirements, capital structure and regulation. *Journal of Financial Services Research*, 43:127–148, 2013.

[62] Martin F. Hellwig. Systemic risk in the financial sector: An analysis of the subprime-mortgage financial crisis. *De Economist*, 157:129–207, 2009.

[63] Peter Hoffmann, Sam Langfield, Federico Pierobon, and Guillaume Vuillemey. Who bears interest rate risk? *The Review of Financial Studies*, 32(8):2921–2954, 2019.

[64] Bengt Holmstrom and Jean Tirole. Financial intermediation, loanable funds, and the real sector. *Quarterly Journal of Economics*, 112(3):663–691, 1997.

[65] Bengt Holmstrom and Jean Tirole. Inside and outside liquidity. The MIT Press, 2011.

[66] Xin Huang, Hao Zhou, and Haibin Zhu. Systemic risk contributions. *Journal of Financial Services Research*, 42:55–83, 2012.

[67] Victoria Ivashina and David Scharfstein. Loan syndication and credit cycles. *American Economic Review*, 100(2):57–61, 2010.

[68] Anil K. Kashyap, Raghuram G. Rajan, and Jeremy C. Stein. Rethinking capital regulation. 2008 Economic Symposium, 2008.

[69] Anil K Kashyap and Jeremy C. Stein. Cyclical implications of the basel ii capital standards. *Economic Perspectives*, pages 18–31, 2004.

[70] Bryan Kelly, Hanno Lustig, and Stijn Van Nieuwerburgh. Too-systemic-to-fail: What option markets imply about sector-wide government guarantees. *American Economic Review*, 106(6):1278–1319, 2016.

[71] Arvind Krishnamurthy and Annette Vissing-Jorgensen. The aggregate demand for treasury debt. *Journal of Political Economy*, 120:233–267, 2012.

[72] Hamid Mehran and Anjan Thakor. Bank capital and value in the cross-section. *The Review of Financial Studies*, 24:1019–1067, 2011.

[73] Hamid Mehran and Anjan Thakor. Bank capital and value in the cross-section. *The Review of Financial Studies*, 24(4):1020–1067, 2011.

[74] Robert C. Merton and Richard T. Thakor. Customers and investors: A framework for understanding the evolution of financial institutions. *Journal of Financial Intermediation*, 39:4–18, 2019.

[75] Atif Mian and Amir Sufi. *House of Debt*. University of Chicago Press, 2014.

[76] Erwan Morellec and Julien Hugonnier. Bank capital, liquid reserves, and insolvency risk. *Journal of Financial Economics*, 125(2):266–285, 2017.

[77] Stefan Nagel and Amiyatosh Purnanandam. Banks' risk dynamics and distance to default. *Review of Financial Studies*, 33(6):2421–2467, 2020.

[78] Gianni De Nicolo, Andrea Gamba, and Marcella Lucchetta. Microprudential regulation in a dynamic model of banking. *Review of Financial Studies*, 27(7):2097–2138, 2014.

[79] Joe Peek and Eric S. Rosengren. The international transmission of financial shocks: The case of japan. *American Economic Review*, 87(4):495–505, 1997.

[80] Joe Peek and Eric S. Rosengren. Collateral damage: Effects of the japanese bank crisis on real activity in the united states. *American Economic Review*, 90(1):30–45, 2000.

[81] Amiyatosh Purnanandam. Interest rate derivatives at commercial banks: An empirical investigation. *Journal of Monetary Economics*, 54(6):1769–1808, 2007.

[82] Adriano A. Rampini, Amir Sufi, and S. Viswanathana. Dynamic risk management. *Journal of Financial Economics*, 111(2):271–296, 2014.

[83] Adriano A Rampini and S Viswanathan. Financial intermediary capital. *The Review of Economic Studies*, 86(1):413–455, 2019.

[84] Adriano A Rampini, S Viswanathan, and Guillaume Vuillemey. Risk management in financial institutions. Forthcoming the Journal of Finance, 2019.

[85] Glenn Schepens. Taxes and bank capital structure. *Journal of Financial Economics*, 120(3):585–600, 2016.

[86] Garry J. Schinasi. Safeguarding financial stability theory and practice. International Monetary Fund, 2005.

[87] Andrei Shleifer and Robert W. Vishny. Liquidation values and debt capacity: A market equilibrium approach. *Journal of Finance*, 47:1343–1366, 1992.

[88] Andrei Shleifer and Robert W. Vishny. Unstable banking. *Journal of Financial Economics*, 97(3):306–318, 2010.

[89] Clifford W. Smith and Rene M. Stulz. The determinants of firms' hedging policies. *Journal of financial and quantitative analysis*, 20:391–405, 1985.

[90] Fenghua Song and Anjan V. Thakor. Relationship banking, fragility, and the asset-liability matching problem. *The Review of Financial Studies*, 20:2129–2177, 2007.

[91] Jeremy C. Stein. Securitization, shadow banking, and financial fragility. *Daedalus*, 139(4):41–51, 2010.

[92] Suresh Sundaresan and Zhenyu Wang. Bank liability structure. Working Paper, Columbia University, 2014.

[93] Anjan V. Thakor. Bank capital and financial stability: An economic trade-off or a faustian bargain? *Annual Review of Financial Economics*, 6:185–223, 2014.

[94] Pietro Veronesi and Luigi Zingales. Paulson's gift. *Journal of Financial Economics*, 97(3):339–368, 2010.

A All-Equity Firm

The revenues generated by firm-i at date-T are:

$$X_i(z_{i,T}) \;=\; I\, e^{(\mu - \frac{\sigma^2}{2})T + \sigma\sqrt{T}\, z_{i,T}}. \tag{65}$$

Here, I is the level of investment by firm shareholders at date-0, $z_{i,t} \sim N(0,1)$ is a standard normal random variable, μ is a parameter that controls expected return on investment, and σ is a parameter that controls return volatility. The firm's pre-tax earnings equal its revenues minus its investment:

$$EBT_i(z_{i,T}) \;=\; X_i(z_{i,T}) - I. \tag{66}$$

Therefore, assuming full tax-loss offset, the tax bill is:

$$Tax_i(z_{i,T}) \;=\; \tau\left[X_i(z_{i,T}) - I\right]. \tag{67}$$

Hence, the terminal dividend paid to equity is

$$\begin{aligned} X_{i,E}(z_{i,T}) &= X_i(z_{i,T}) - \tau\left[X_i(z_{i,T}) - I\right] \\ &= (1-\tau)X_i(z_{i,T}) + \tau I. \end{aligned} \tag{68}$$

The value of equity equals the date-0 present value of the dividend:

$$\begin{aligned} V_{i,E}(0) &= e^{-rT}\,\mathrm{E}^Q\left[(1-\tau)X_i(z_{i,T}) + \tau I\right] \\ &= (1-\tau)Ie^{(\mu-r)T} + \tau I e^{-rT}. \end{aligned} \tag{69}$$

Because we want to specify this growth opportunity as a positive NPV project, below we choose model parameters so that the value of equity is larger than the investment level I:

$$(1-\tau)Ie^{(\mu-r)T} + \tau Ie^{-rT} > I, \tag{70}$$

or equivalently,

$$(1-\tau)e^{(\mu-r)T} + \tau e^{-rT} > 1. \tag{71}$$

B Equilibrium Restrictions

In our empirical section, we used past excess returns on both individual banks and the index to identify out-of-sample hedge ratios. Here we show, however, that if several banks simultaneously began to hedge index-risk, then the estimated hedge-ratios for each bank would have to be adjusted.[27] Intuitively, this occurs because, as other banks reduce their exposure, each bank will have to take larger positions in the forward market to hedge their own exposure.

Note that all banks cannot completely eliminate bank-index risk. This logically follows because, if they did, then by definition the index would also have zero exposure to bank-index risk, which would imply that bank-index risk has been eliminated from the economy. Instead, this section demonstrates that total bank-index risk is neither created nor destroyed by banks hedging bank-index risk. Rather, whatever fraction of bank index risk is removed from individual banks must be transferred to the forward market. Hence, the representative investor who initially was exposed to bank index risk by owning banks will now be exposed to bank index risk both by owning banks, and by taking the opposite side of the forward contract that the banks are shorting.

[27] Gauthier, Lehar and Souissi (2012) face a similar situation when investigating macroprudential capital requirements.

To demonstrate this, we specify $N_B \to \infty$ banks, each of which has unhedged cash flows at date-T equal to:

$$X_j \quad = \quad X + \epsilon_j, \tag{72}$$

where all $\{\epsilon_j\}$ are iid, and uncorrelated with bank index risk X. Hence, each bank is ex-ante identical.

We first investigate the case in which only bank-i hedges bank-index risk. As such, whereas all other banks $j \neq i$ have date-T cash flows as in equation (72), firm-i has hedged cash flows equal to:

$$\widehat{X}_i \quad = \quad X + \epsilon_i + n_H \left(K - \widehat{X}_0\right). \tag{73}$$

where the bank index $\widehat{X}_0$ is defined as the average bank cash flows:

$$\begin{aligned}
\widehat{X}_0 \quad &= \quad \lim_{N_B \to \infty} \left(\frac{1}{N_B}\right) \sum_{j=1}^{N_B} \widehat{X}_j \\
&= \quad X + \lim_{N_B \to \infty} \left(\frac{1}{N_B}\right) \left[\left(\sum_{j=1}^{N_B} \epsilon_j\right) + n_H \left(K - \widehat{X}_0\right)\right] \\
&= \quad X,
\end{aligned} \tag{74}$$

where we have used the law of large numbers to eliminate the idiosyncratic term. The interpretation of this result is that if only one out of $N_B \to \infty$ chooses to hedge index risk, it has no impact on bank index cash flows.

Plugging equation (74) into equation (73), the hedged cash flows of bank-i are:

$$\widehat{X}_i \quad = \quad (1 - n_H)X + \epsilon_i + n_H K. \tag{75}$$

As such, if the bank chooses $n_H = 1$, it can fully hedge bank-index risk X, leaving it with only idiosyncratic risk ϵ_i.

In contrast, now consider an economy in which all banks simultaneously choose to short n_H shares of a forward contract on the bank index. Hence, bank-i has hedged cash flows at date-T equal to:

$$\widehat{X}_i = X + \epsilon_i + n_H \left(K - \widehat{X} \right). \tag{76}$$

We identify the index of hedged bank cash flows by averaging over banks:

$$\begin{aligned} \widehat{X} &= \lim_{N_B \to \infty} \left(\frac{1}{N_B} \right) \sum_{i=1}^{N_B} \widehat{X}_i \\ &= X + n_H \left(K - \widehat{X} \right), \end{aligned} \tag{77}$$

where we used the law of large numbers to eliminate the idiosyncratic term. Simplifying equation (77), we find

$$\widehat{X} = \left(\frac{1}{1+n_H} \right) X + \left(\frac{n_H}{1+n_H} \right) K. \tag{78}$$

Plugging equation (78) into equation (76), we find bank-i has hedged cash flows equal to:

$$\widehat{X}_i = \left(\frac{1}{1+n_H} \right) X + \epsilon_i + \left(\frac{n_H}{1+n_H} \right) K. \tag{79}$$

Interpreting, whereas unhedged bank cash flows are exposed to bank-index risk with a factor loading equal to one, hedged bank cash flows are exposed to bank-index risk with factor loading equal to $\left(\frac{1}{1+n_H} \right)$. Thus, for high values of n_H, most bank-index risk can be eliminated from the cash flows of individual banks. Interestingly, whereas $n_H = 1$ completely eliminates index risk when only one bank hedges, that same strategy only hedges $\left(\frac{1}{1+n_H} \right) = \frac{1}{2}$ of index risk when all banks decide to hedge index risk.

Note that when all banks hedge, the forward market has exposure equal to

$$n_{_H}\left(\widehat{X}-K\right) \;=\; \left(\frac{n_{_H}}{1+n_{_H}}\right)(X-K)\,. \tag{80}$$

That is, as $n_{_H}$ becomes large, almost all bank-index risk gets transferred from the individual banks to the forward market.

C The Impact of Hedging Industry-Risk Across Other Industries

In this section, we investigate the broader implications of firms shorting their industry indices in the light of the bailouts associated with the recent Covid-19 pandemic. Specifically, we apply our empirical analysis of Section II to the airline and hotel industries by investigating unhedged and industry-index-hedged returns of 9 major airline companies and 7 major hotel chains. We choose these two industries because they are two of the hardest hit industries during the Covid-19 pandemic. The 9 airline companies are: Alaska Air Group (Ticker: ALK), Allegiant Air (ALGT), American Airlines Group (AAL), Delta Air Lines (DAL), Hawaiian Holdings (HA), JetBlue Airways (JBLU), Southwest Airlines (LUV), Spirit Airlines (SAVE), and United Airlines Holdings (UAL). The 7 hotel chains are Marriott International (MAR), Hilton (HLT), InterContinental Hotels Group (IHG), Hyatt Hotels (H), Choice Hotels International (CHH), Extended Stay America (STAY), and Red Lion Hotels (RLH). For each industry, we define the returns on the industry index as equal to the returns on an equally-weighted portfolio of companies that comprise the industry. Table VI reports the results for airlines, whereas Table VII reports the results for hotel chains. Strikingly similar to the results found for the banking industry, we find that hedging industry risk reduces individual stock volatility by 40% for airlines, and 35% for hotel chains. Moreover, the downside tail risk of individual stock returns (measured by negative skewness) is reduced significantly for both industries as well. Specifically, average skewness increases from -0.73 for unhedged airline returns to -0.29 for hedged airline returns, and from -1.12 for unhedged airline returns to -0.03 for hedged hotel returns. In March 2020, the airline index fell 42%, and the hotel index fell 34%. However, had firms hedged index-risk, average hedge returns would have been zero in both cases (almost by definition). Moreover, the worst performing airline stock (SAVE) would have lost only 13% (rather than 55%), while the worst performing hotel stock (CHH) would have lost only 8.9% (rather than 33%). Clearly, the ability of firms to reduce their equity volatility by hedging index risk extends well beyond the banking industry.

Table I: Hedging Bank Stock Risk

This table reports the out-of-sample volatility and skewness of the hedged stock returns of the largest banks in the US. The last column reports simple averages across all the banks in the sample. The hedge ratios (betas) are estimated using the rolling regressions with 36-month windows. Panel A reports the annualized volatility. Panel B reports the skewness of log returns. Panel C reports the realized stock excess return in March 2020 during the Covid-19 pandemic. For each panel, we reports the unhedged bank stock excess returns; hedging by shorting other bank stocks; and hedging by shorting the stock market (S&P 500 excess return), the financial sector index (XLF) excess return, or the changes in other bank related aggregate variables. The sample is in monthly frequency from January 2000 to March 2020.

Hedging Instrument	BAC	BK	BCS	C	CS	DB	GS	JPM	MS	STT	UBS	WFC	Mean
Panel A: Volatility													
Unhedged	40.05	25.35	43.41	42.07	32.83	40.22	31.68	30.55	35.11	30.37	32.01	27.32	34.25
Other Banks	23.37	20.27	35.03	26.41	22.32	28.29	21.38	18.13	31.39	26.27	29.71	19.89	25.20
MKT	33.50	18.48	36.38	31.99	23.61	30.56	22.42	20.79	26.26	23.55	26.03	23.54	26.43
XLF	23.00	17.25	31.86	22.45	22.08	29.65	21.57	14.27	26.07	21.74	24.35	16.84	22.59
Other Banks, MKT, and XLF	22.04	21.02	36.40	25.42	23.90	29.62	23.21	17.38	33.59	26.23	27.57	18.66	25.42
Mortgage Rates	44.29	25.60	47.04	45.66	33.71	42.89	30.99	29.15	35.35	31.65	34.42	29.58	35.86
Treasury Rates	42.73	21.95	46.14	44.03	29.21	41.13	27.42	26.26	31.37	29.91	32.26	28.02	33.37
Corporate Bonds	42.57	22.68	44.18	43.58	29.14	39.81	28.39	26.30	34.82	29.98	35.24	30.11	33.90
Home Price	44.41	25.82	48.46	45.51	37.69	44.01	32.34	30.81	35.86	33.06	34.56	29.79	36.86
VIX	40.00	21.38	41.12	41.74	28.54	34.79	24.61	25.92	28.18	26.61	29.17	27.33	30.78
Panel B: Skewness													
Unhedged	-1.31	-0.14	-0.98	-1.68	-0.29	-0.76	-0.24	-0.59	-0.97	-0.88	-0.11	-1.19	-0.76
Other Banks	-0.25	-0.15	1.03	-2.36	-0.08	-1.10	0.16	-0.59	-1.50	-1.79	-0.28	-0.48	-0.62
MKT	-0.60	0.22	-0.05	-0.17	-0.38	-0.04	0.61	0.47	0.59	-0.31	0.16	-0.70	-0.02
XLF	1.14	-0.18	0.33	-0.08	-0.72	0.03	0.61	1.22	0.26	0.04	0.38	0.67	0.31
Other Banks, MKT, and XLF	-0.18	0.21	0.57	-1.45	-0.24	-0.15	0.65	-0.13	-0.27	-1.63	0.68	-0.27	-0.19
Mortgage Rates	-1.36	-0.64	-1.11	-1.60	-0.57	-0.80	-0.89	-1.05	-1.82	-1.05	-0.47	-1.07	-1.04
Treasury Rates	-2.47	-0.21	-0.39	-2.32	-0.31	-0.47	-0.32	-0.75	-1.11	-0.99	-0.37	-1.49	-0.93
Corporate Bonds	-4.52	-0.14	-0.58	-4.50	-0.33	-0.70	0.20	-0.81	0.22	-1.94	0.28	-1.93	-1.23
Home Price	-0.06	-0.11	-0.25	-0.43	-0.20	-0.23	-0.16	-0.41	-0.62	-0.50	0.35	-0.67	-0.27
VIX	-1.40	0.11	-0.53	-1.83	-0.33	0.05	-0.21	-0.08	-0.02	-0.92	-0.40	-1.11	-0.56
Panel C: Stock Excess Return in March 2020 (Covid-19)													
Unhedged	-25.62	-15.70	-39.01	-33.74	-28.39	-26.49	-22.64	-22.57	-24.60	-21.90	-15.93	-29.10	-25.47
MKT	-4.87	-0.84	-25.98	-9.07	-10.12	-8.39	-4.76	-6.44	-7.41	-0.72	-0.63	-13.11	-7.70
XLF	5.20	5.40	-18.18	-0.01	-1.97	-2.68	3.09	3.49	1.32	7.33	5.58	-5.25	0.28
Other Banks, MKT, and XLF	2.80	6.84	-22.61	-5.29	-5.82	-9.45	9.70	1.68	-3.10	-0.61	7.97	-9.89	-2.31

Table II: Tail Risk Before and After Index Hedging

This table reports estimated tail risks for the average bank deemed systemically relevant before and after hedging with the financial sector index (XLF). The first four monthly log stock return moments (mean, stdev., skewness, and kurtosis) are estimated from our sample. We also estimate the probability of log stock return lower than three standard deviations below its mean and the 99% 1-month Value-at-Risk when we invest $100 at the beginning of a month. In the estimation, we use the Pearson system random numbers. The last column reports the difference. The standard errors are computed using the bootstrap method.

Moment	Unhedged	Hedged	(Hedged - Unhedged)
Mean (μ)	-0.002	-0.004	-0.003
S.E.	(0.006)	(0.002)	(0.005)
Stdev. (σ)	0.099	0.064	-0.035
S.E.	(0.007)	(0.004)	(0.004)
Skewness	-0.786	0.255	1.042
S.E.	(0.342)	(0.210)	(0.325)
Kurtosis	7.708	7.939	0.231
S.E.	(0.889)	(0.877)	(0.987)
$Pr((r-\mu)/\sigma < -3)$ (%)	0.911	0.461	-0.450
S.E.	(0.173)	(0.083)	(0.155)
99% Value-at-Risk	25.26	15.03	-10.23
S.E.	(2.31)	(0.73)	(1.93)

Table III: Benchmark Model Parameters

This table reports the benchmark model parameters.

Parameter	Value	Description
T	5	Bank loan maturity
r	0.02	Risk-free rate
s	0.003	Bank loan spread
μ	0.052	Firm asset expected growth rate
σ	0.4	Firm asset volatility
τ	0.2	Corporate tax rate
α	0.1	Firm bankruptcy cost
ρ	0.2	Borrowers' asset correlation within a bank
α_B	0.05	Bank bankruptcy cost
I_E	1	Firm initial equity investment
ρ_B	0.54	Asset correlation among banks
DEP/I_B	0.85	Deposit-loan ratio

Table IV: Bank Model Results

This table reports the model results for the unhedged bank ($n_H = 0$), the optimally-hedged bank with a convertible forward written on aggregate loan portfolio ($n_H = 4, \pi = 1$), and the bank when systematic risk is hedged entirely ($z = 0$). In the model, the bank asset is a diversified loan portfolio which exposes to the systematic risk z and the bank-specific risk $z_{B,idio}$ factors. The bank finances its assets through equity, insured deposit and defaultable debt.

Variable	Value	Description
	Panel A: Firm	
F	0.607	Face value of bank loan
$V_{i,E}(0)$	1.158	Firm equity value
I_B	0.503	Bank loan
$\frac{I_B}{V_{i,E}(0)+I_B}$	0.303	Firm leverage
DR_F (%)	1.530	Annual firm default rate
y (%)	3.779	Bank loan yield

Panel B: Bank

	Unhedged	Co. Forward	No Sys. Risk	
π		1.000		Conversion ratio
n_H	0.000	4.000	0.000	Hedge ratio
K		0.578		Forward price
F_B	0.056	0.087	0.081	Face value of bank debt
$V_{B,E}(0)$	0.059	0.031	0.039	Bank equity value
$V_{B,D}(0)$	0.050	0.079	0.073	Bank debt value
$I_{B,E}$	0.026	-0.003	0.002	Bank equity issued
$I_{B,D}$	0.050	0.079	0.073	Bank debt issued
V_{INS}	0.000	0.000	0.000	Deposit insurance premium
$\frac{V_{B,D}(0)}{V_{B,E}(0)+V_{B,D}(0)+DEP}$	0.093	0.147	0.136	Defaultable debt / Asset
$\frac{V_{B,D}(0)+DEP}{V_{B,E}(0)+V_{B,D}(0)+DEP}$	0.890	0.943	0.928	Total debt / Asset
DR_B (bps)	41.939	22.584	22.438	Annual bank default rate
$y_B - r$ (bps)	35.731	10.628	2.112	Credit spread of defaultable bank debt
$V_{B,E}(0) - I_{B,E}$ (%)	3.290	3.370	3.694	Bank shareholder profit

Table V: Bank Hedging with Convertible Forwards

This table reports the results for a deposit insured bank using the convertible forward to hedge the systematic risk. The column (no hedge) reports the results without hedging. The bank optimizes bank debt F_B to maximize its shareholder profit $V_{B,E}(0) - I_{B,E}$. The columns (hedge) report the results with hedging. The convertible forward is designed so that if the bank does not have enough cash flow to pay off the convertible forward at maturity T, it can pay off with π fraction of its equity. We solve the model for $\pi = 0.2, 0.4, 0.6, 0.8, 1$. Under each π, the bank optimizes hedge ratio n_H and bank debt F_B to maximize its shareholder profit $V_{B,E}(0) - I_{B,E}$.

	No hedge	Hedge					Description
π		0.200	0.40	0.600	0.800	1.000	Conversion ratio
n_H	0.000	2.100	2.60	3.100	3.500	4.000	Hedge ratio
K		0.569	0.57	0.576	0.577	0.578	Forward price
F_B	0.056	0.071	0.08	0.082	0.085	0.087	Face value of bank debt
$V_{B,E}(0)$	0.059	0.045	0.04	0.035	0.033	0.031	Bank equity value
$V_{B,D}(0)$	0.050	0.064	0.07	0.074	0.076	0.079	Bank debt value
$I_{B,E}$	0.026	0.011	0.01	0.002	-0.001	-0.003	Bank equity issued
$I_{B,D}$	0.050	0.064	0.07	0.074	0.076	0.079	Bank debt issued
V_{INS}	0.000	0.000	0.00	0.000	0.000	0.000	Deposit insurance premium
$\frac{V_{B,D}(0)}{V_{B,E}(0)+V_{B,D}(0)+DEP}$	0.093	0.120	0.13	0.138	0.142	0.147	Defaultable debt / Asset
$\frac{V_{B,D}(0)+DEP}{V_{B,E}(0)+V_{B,D}(0)+DEP}$	0.890	0.917	0.93	0.934	0.939	0.943	Total debt / Asset
DR_B (bps)	41.939	23.486	22.32	21.879	21.846	22.584	Annual bank default rate
$y_B - r$ (bps)	35.731	14.827	12.46	11.332	10.739	10.628	Credit spread of defaultable bank debt
$V_{B,E}(0) - I_{B,E}$ (%)	3.290	3.340	3.35	3.361	3.367	3.370	Bank shareholder profit

Table VI: Hedging Airline Stock Risk

This table reports the out-of-sample volatility and skewness of the index hedged stock returns of the largest airlines in the US. The last column reports simple averages across all the airline companies in the sample. The index is constructed as the equal weighted average across airline stock excess returns. The hedge ratios (betas) are estimated using the rolling regressions with 36-month windows. Panel A reports the annualized volatility. Panel B reports the skewness of log returns. Panel C reports the realized stock excess return in March 2020 during the Covid-19 pandemic. The sample is in monthly frequency from January 2000 to May 2020.

Hedging Instrument	ALK	ALGT	AAL	DAL	HA	JBLU	LUV	SAVE	UAL	Mean
Panel A: Volatility										
Unhedged	36.75	38.91	69.84	44.81	61.37	41.81	31.39	40.77	59.25	47.21
Index	23.88	27.86	31.23	17.50	45.67	26.62	22.70	28.64	29.20	28.14
Panel B: Skewness										
Unhedged	-1.09	-0.70	-0.30	-0.79	-0.19	-0.46	-0.28	-2.23	-0.58	-0.73
Index	-0.62	0.00	0.11	-0.27	-0.28	0.09	-0.67	-0.80	-0.20	-0.29
Panel C: Stock Excess Return in March 2020 (Covid 19)										
Unhedged	-43.38	-39.44	-35.89	-37.85	-49.91	-43.40	-23.03	-54.81	-48.89	-41.85
Index	-5.02	3.30	14.02	-5.89	4.00	-4.48	18.29	-12.98	-11.24	0.00

Table VII: Hedging Hotel Stock Risk

This table reports the out-of-sample volatility and skewness of the index hedged stock returns of the largest hotel companies in the US. The last column reports simple averages across all the hotel companies in the sample. The index is constructed as the equal weighted average across hotel stock excess returns. The hedge ratios (betas) are estimated using the rolling regressions with 36-month windows. Panel A reports the annualized volatility. Panel B reports the skewness of log returns. Panel C reports the realized stock excess return in March 2020 during the Covid-19 pandemic. The sample is in monthly frequency from January 2000 to May 2020.

Hedging Instrument	MAR	HLT	IHG	H	CHH	STAY	RLH	Mean
Panel A: Volatility								
Unhedged	30.01	24.64	31.25	26.00	31.00	36.03	41.33	31.47
Index	17.12	12.36	21.01	11.70	21.14	24.34	32.02	19.96
Panel B: Skewness								
Unhedged	-0.71	-1.73	-0.55	-1.69	-0.55	-0.18	-2.43	-1.12
Index	-0.22	-0.05	-0.02	-0.05	0.32	1.12	-1.28	-0.03
Panel C: Stock Excess Return in March 2020 (Covid 19)								
Unhedged	-39.55	-29.81	-23.66	-37.44	-33.02	-33.54	-43.31	-34.33
Index	-2.62	0.18	8.39	-3.91	-8.90	7.18	-0.31	0.00

Figure 1: Optimal Firm and Unhedged Bank Leverage Ratios

Panel A reports firm shareholder profit $(V_{i,E}(0) - I_E)$ as a function of the firm leverage. Panel B reports the unhedged bank shareholder profit $\left(V_{B,E}(0) - I_{B,E}\right)$ as a function of the bank leverage which is measured as the total debt to asset ratio. We solve the unhedged bank by setting $n_H = 0$ in the model. Note that total bank debt consists of both defaultable bank debt and deposits which are insured by the government. In both cases, the highest value of shareholder profit identifies the optimal leverage ratio.

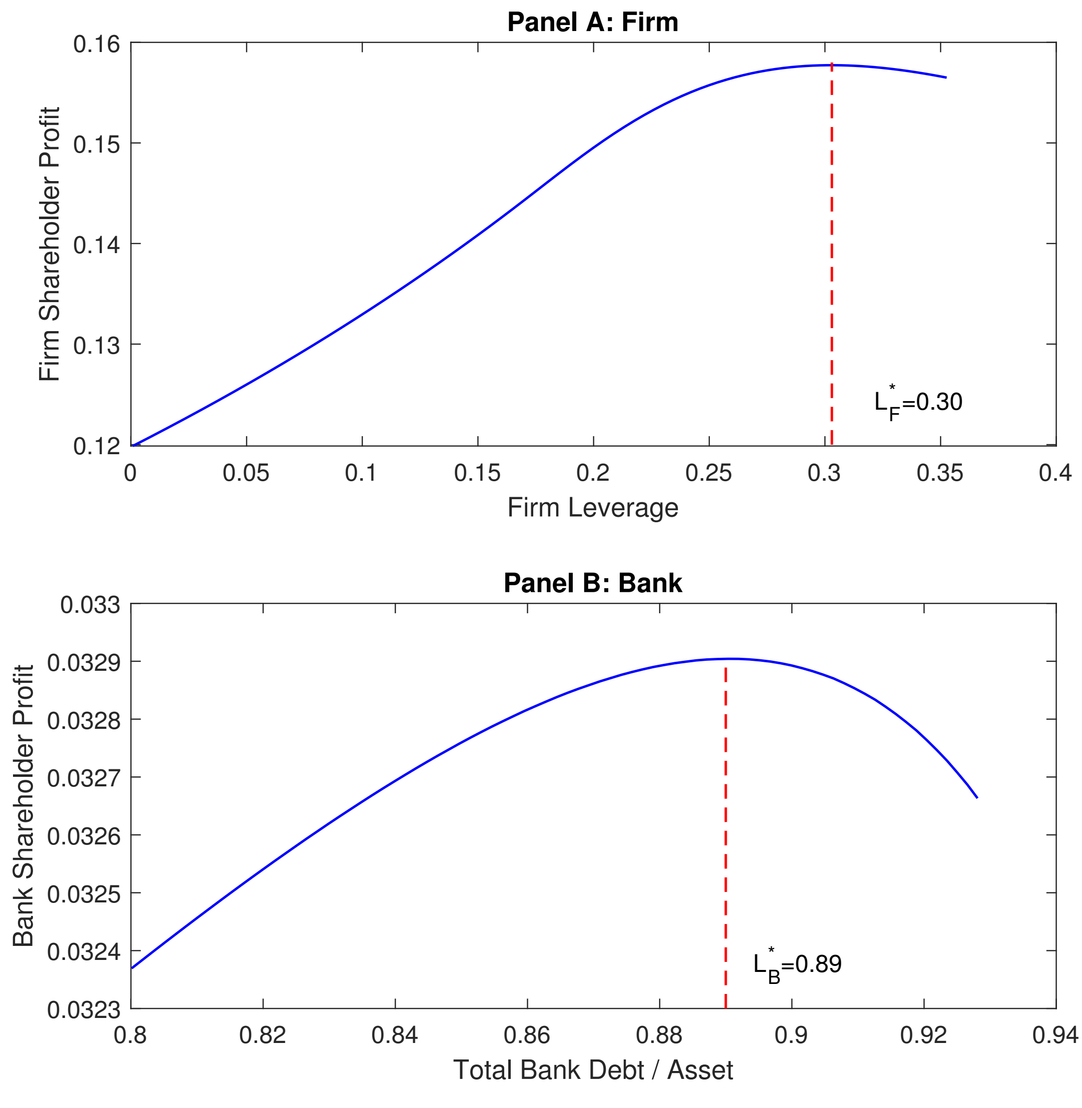

Figure 2: Payoff of the Convertible Forward

This figure shows the typical payoff of the convertible forward for a given z when $K < X_B(z)$. There are three regions (I, II, III) of the payoff depending on the payoff the loan portfolio $X_B(z_B)$. In region I, $X_B(z_B) > X_B^*$, the bank pays off the forward with a full amount $n_H(\hat{X}_B(z) - K)$. In region II, $X_{B,def}^{(K<\hat{X}_B(z))} < X_B(z_B) < X_B^*$, the bank pays off the forward with a fraction π of its equity. In region III, $X_B(z_B) < X_{B,def}^{(K<\hat{X}_B(z))}$, the bank defaults. $\pi = 1$ and $n_H = 4$ are chosen to maximize the bank shareholder profit.

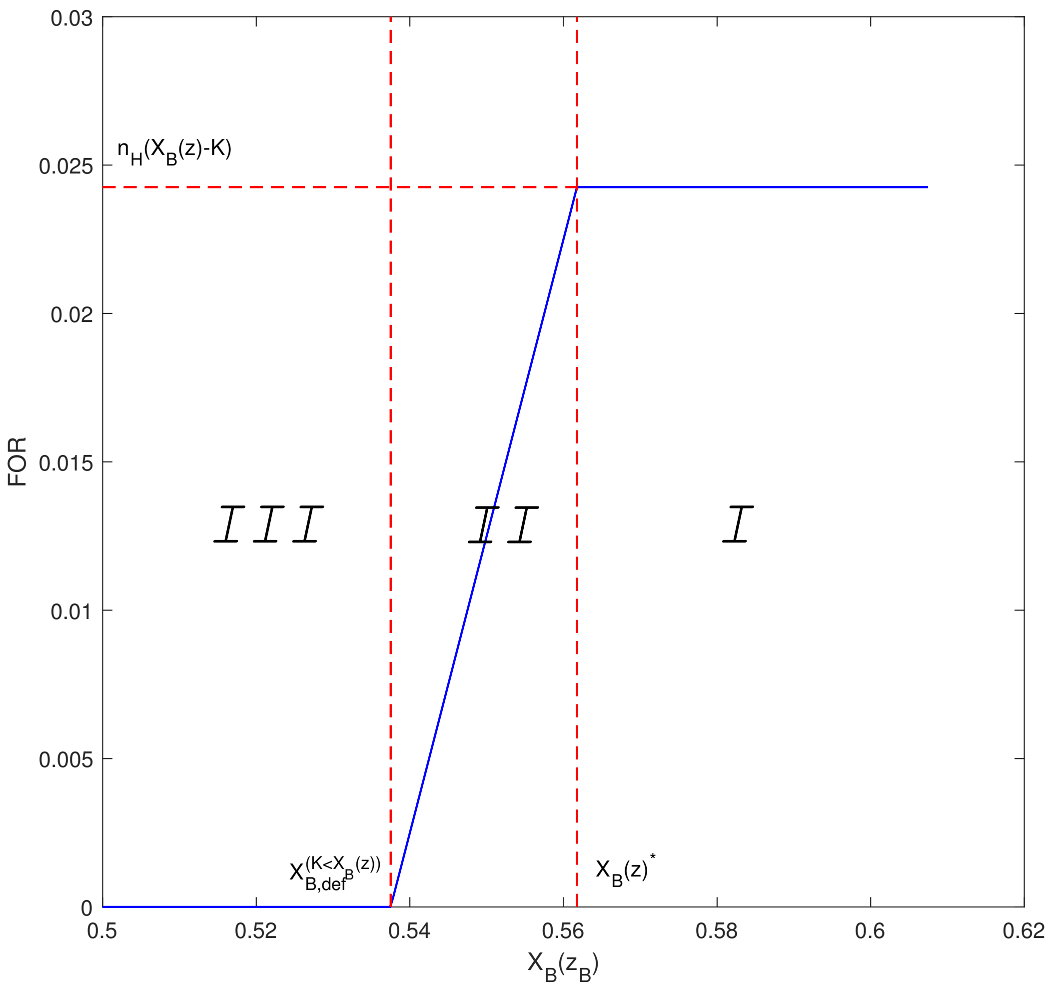

Figure 3: Optimal Hedging and Capital Structure Policies of Banks

This figure reports the optimal hedging and capital structure policies of banks with deposits when banks can hedge the systematic risk using a convertible forward contract written on aggregate loan portfolio with conversion ratio $\pi = 1$. Banks are required to purchase the full coverage deposit insurance at date-0. Panel A reports the optimal face value of bank debt F_B as a function of hedge ratio n_H. Panel B reports the bank shareholder profit $\left(V_{B,E}(0) - I_{B,E}\right)$ as a function of hedge ratio n_H. The hedge ratio $n_H^* = 4$ maximizes bank shareholder profit. Panel C reports the optimal bank leverages defined as 1) (Total Debt / Asset) ($\frac{V_{B,D}(0)+DEP}{V_{B,E}(0)+V_{B,D}(0)+DEP}$) and 2) (Deposit / Asset) ($\frac{DEP}{V_{B,E}(0)+V_{B,D}(0)+DEP}$) as a function of hedge ratio n_H. Panel D reports the 5-year risk-neutral default probability of the bank. Panel E reports the credit spread of bank defaultable debt. When plotting Panels B, C, D, and E we set F_B to its optimal value $F_B^*(n_H)$ for each value of n_H.

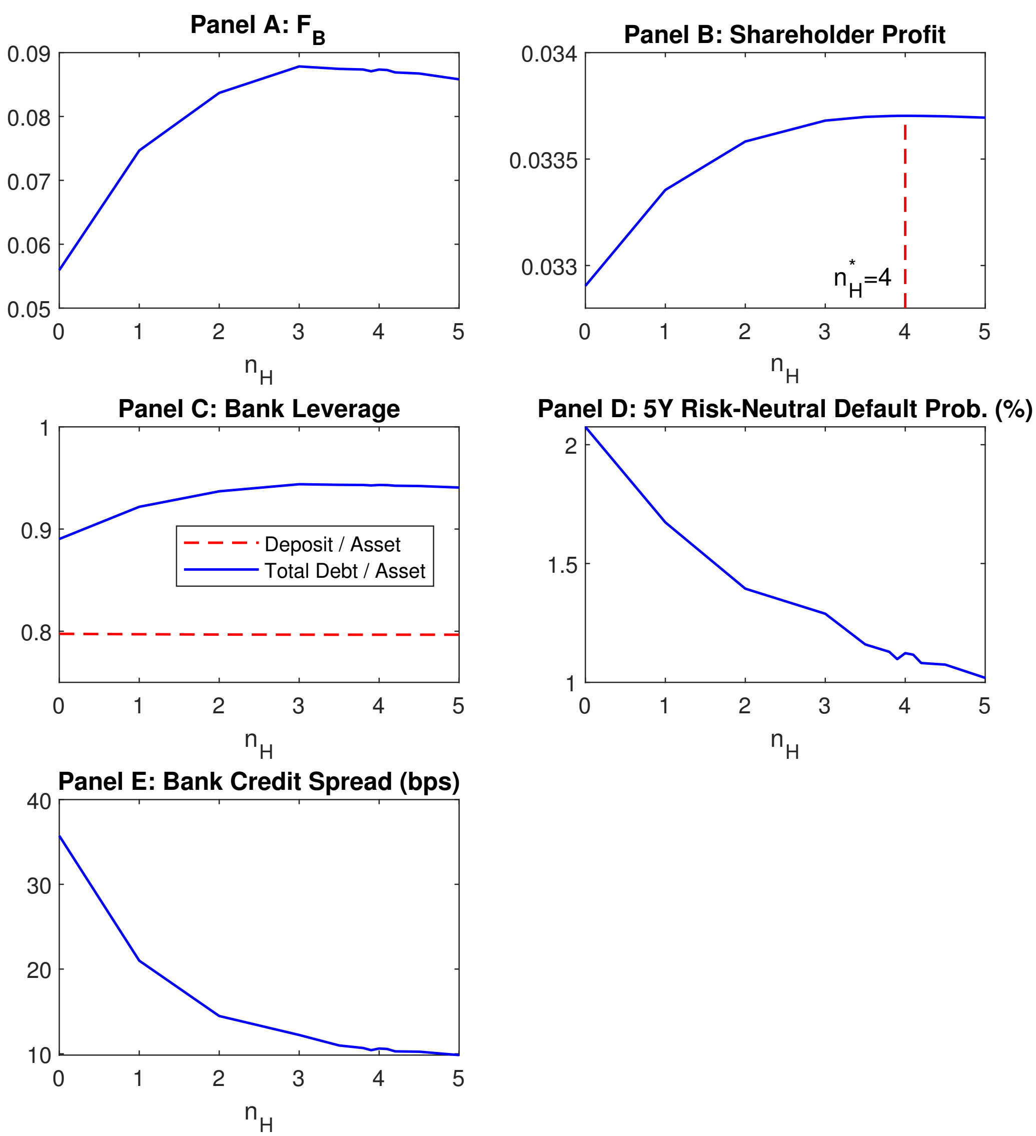

Figure 4: Expected Payoff of Hedged Position Conditional on Systematic Shock z

This figure reports the expected payoff of the hedged position at year 5 conditional on the systematic shock z. The bank shorts a convertible forward written on aggregate loan portfolio to hedge the systematic risk z. z is a standard normal variable. The payoff of the convertible forward is given in Equation 52 in which $n_H = 4$ is optimized to maximize the bank shareholder profit $V_{B,E}(0) - I_{B,E}$. We also plot the cases $n_H = 0$ and $n_H = 1$ as a comparison. The conversion ratio $\pi = 1$ to maximize the bank shareholder profit.

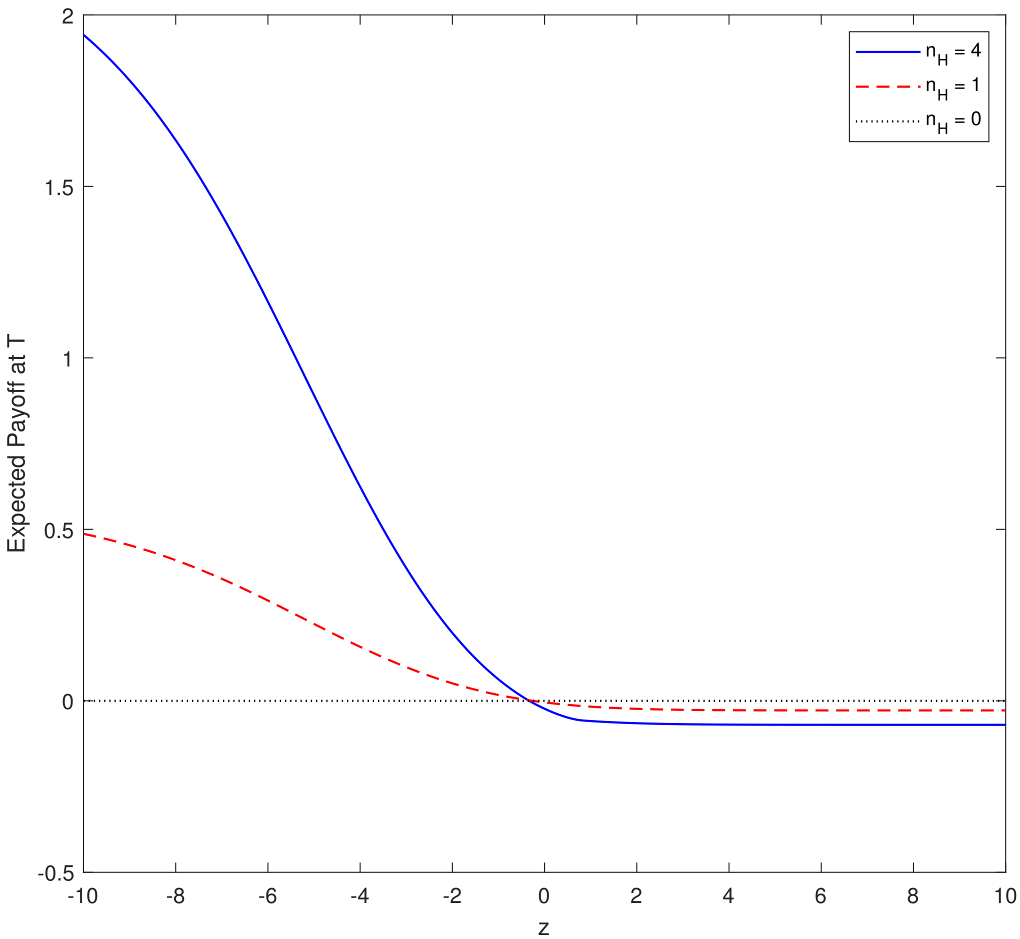

Figure 5: Bank Default Boundary in Terms of the Bank-Specific Risk $z_{B,idio}$ Conditional on z

This figure reports the location of the default boundary in terms of the bank-specific risk $z_{B,idio}$ as a function of the systematic risk z. Under a systematic shock z, if a bank-specific shock $z_{B,idio} \leq z^*_{B,idio}$ as reported then the bank defaults. Both z and $z_{B,idio}$ are independent standard normal variables. We report three series: $n_H = (0, 1, 4)$. The conversion ratio $\pi = 1$ to maximize bank shareholder profit.

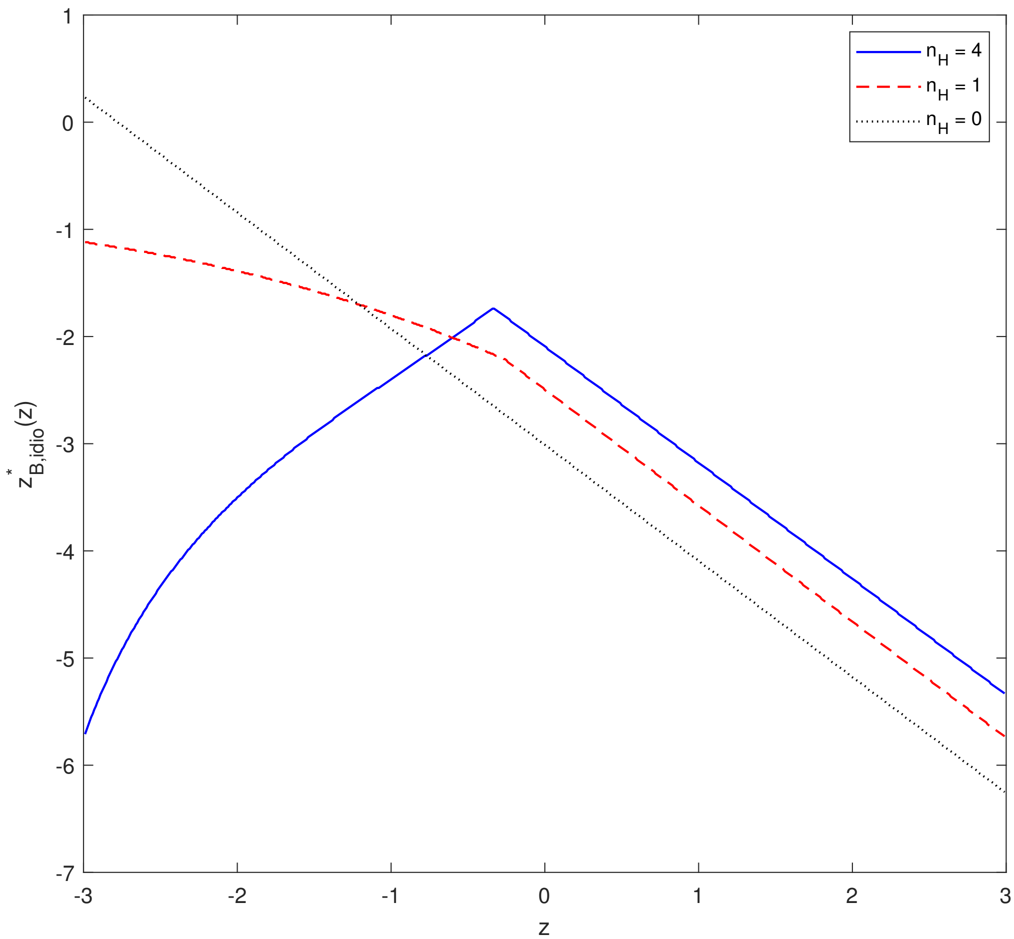

Figure 6: Bank Default Probability Conditional on the Systematic Shock z

This figure reports the 5-year risk-neutral bank default probability conditional on the systematic shock z. The default probability is computed as $\mathcal{E}_t^Q[default = 1|z]$. z is a standard normal variable. A negative z represents bad times and a positive z represents good times. Panel A reports the conditional default probability when hedge ratios $n_H = 0, 1$ and bank leverage ratio is optimized. Panel B reports the conditional default probability when hedge ratios $n_H = 2, 3, 4$ and bank leverage ratio is optimized. The conversion ratio $\pi = 1$ to maximize the bank shareholder profit. The bank deposits are insured.

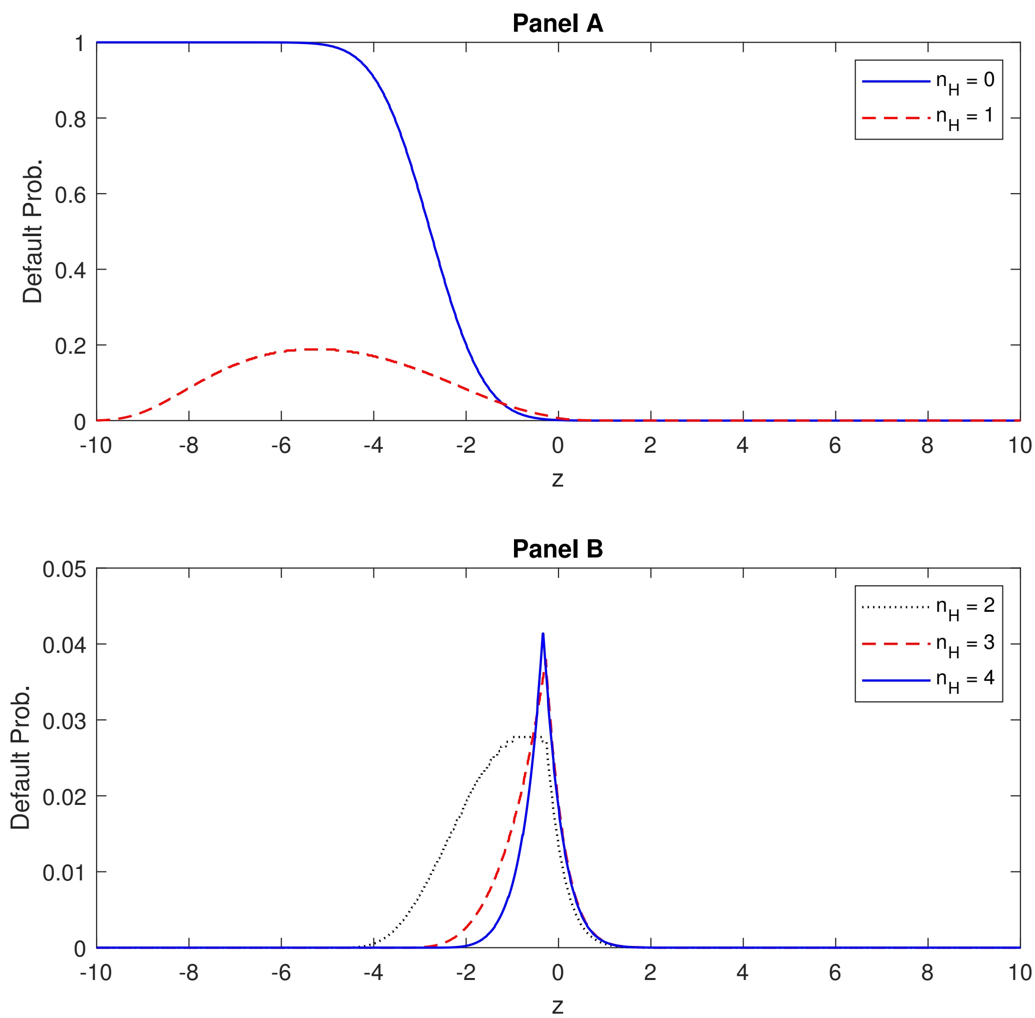

Figure 7: Moments of the Number of Defaults

This figure reports the macroprudential implications of banks hedging index risk. Panel A reports the expected number of defaults across hedge ratios n_H. Panel B reports the standard deviation of the number of default banks across hedge ratios n_H. Panel C reports the skewness of the number of default banks across hedge ratios n_H. We create 1,000,000 samples. In each sample, we simulate $N_B = 20$ banks with a common systematic shock z and different bank-specific shocks $z_{B,idio}$. The conversion ratio $\pi = 1$. The bank deposits are insured.

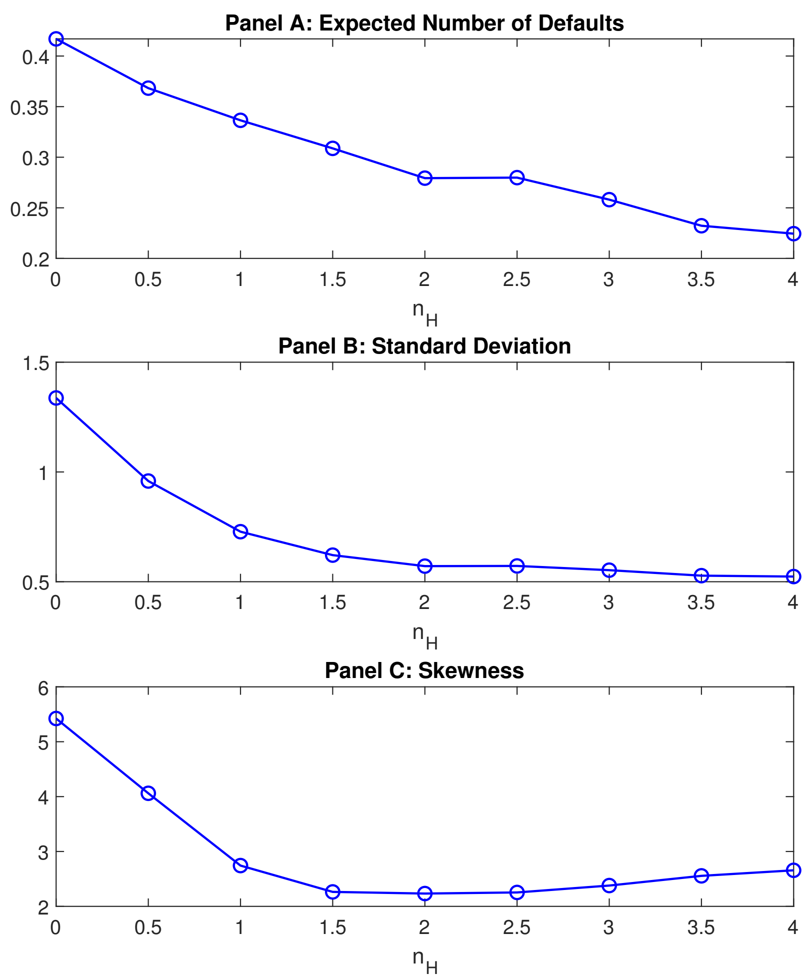

Figure 8: Distribution of the Number of Defaults

In this figure, we report the distribution of the number of bank defaults by creating 1,000,000 samples in which we simulate the returns on $N_B = 20$ banks for a given systematic shock z and iid bank-specific shocks $z_{B,idio}$. We consider three cases: i) banks are unhedged (i.e., $n_H = 0$), ii) banks use a convertible forward contract, and choose an optimal hedge ratio and an optimal conversion ratio ($\pi = 1, n_H = 3$), and iii) when systematic risk is turned off entirely (i.e., $z = 0$). Among all three cases, the bank deposits are insured.

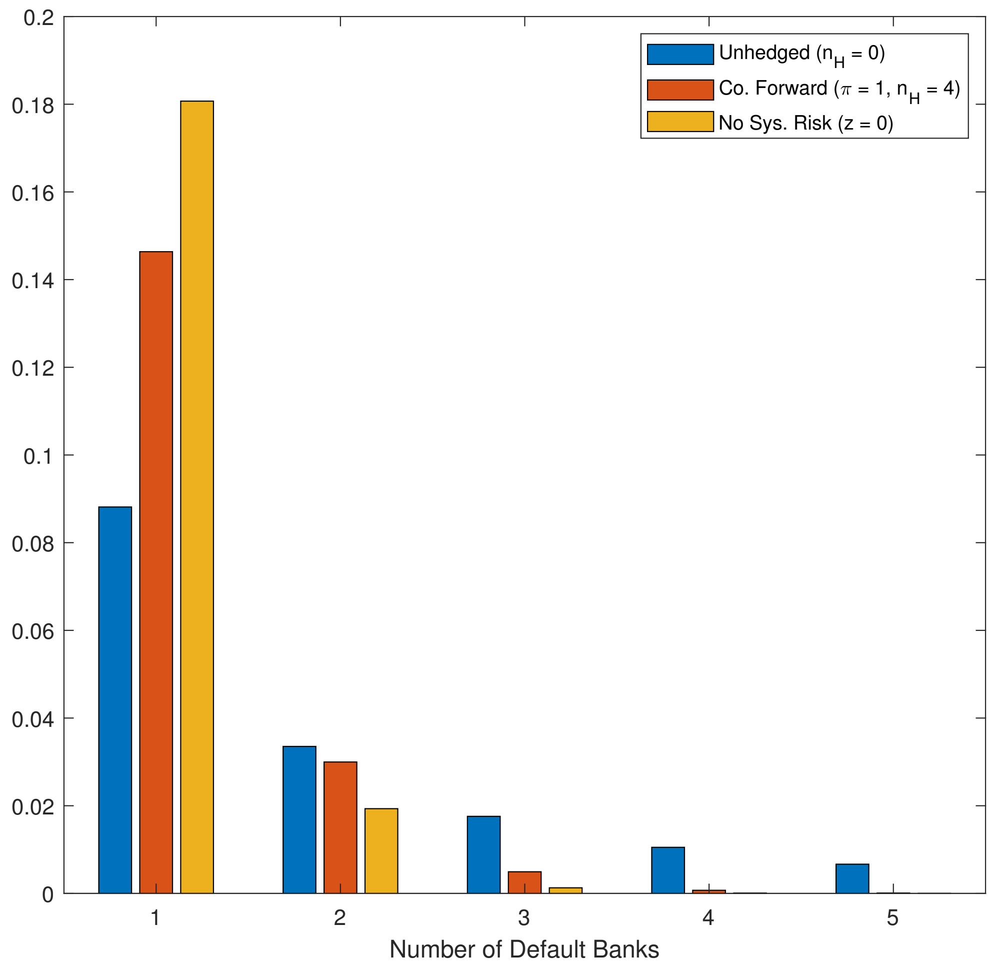

Figure 9: Bank Default Correlation across the Hedge Ratio n_H

This figure reports the model implied bank default correlation across the hedge ratio n_H. The conversion ratio $\pi = 1$ to maximize the bank shareholder profit. The bank deposits are insured.