Financing as a Supply Chain:

The Capital Structure of Banks and Borrowers

ONLINE APPENDIX

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A. Empirical evidence on bank risk taking

Empirical evidence supports the idea that some banks pursue a risky strategy while others pursue safer strategies. Increasing borrower asset volatility or the correlation between borrowers makes banks more willing to gamble. For example, increasing σ and ρ by 50% decreases the critical level of deposit insurance to 84%.

According to FDIC data for 2013:Q1, the median bank in the US has insured deposits equal to 79% of liabilities, with a 75th percentile bank having insured deposits equal to 85% of liabilities.[32] Our model suggests that this level of insured deposits is unlikely to generate substantial moral hazard for a representative bank. However, 7% of banks have insured deposits that make up in excess of 95% of their liabilities and as such would face substantial moral hazard. These banks are predominantly small, with the median having assets of only $52 million compared to $168 million for the full sample. Small regional banks are likely to have more highly correlated loans, which would increase their portfolio volatility and thus further increase moral hazard.

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[32]Authors' estimates based on bank-level FDIC data, which are publicly available from http://www2.fdic.gov/idasp/warp_download_all.asp.

B. Equity injections

In the main text, we consider the moral hazard produced by deposit insurance and by partial debt guarantees. In this appendix, we examine situations where market participants expect a bailout in the form of the purchase of a bank's equity at an above-market price. Regulators frequently employed this form of bailout during the recent financial crisis. For example, a number of US financial institutions, such as Citigroup and Bank of America, participated in the Troubled Asset Relief Program, in which the US government purchased common and preferred equity from distressed institutions. The Royal Bank of Scotland received massive injections of equity in dire circumstances and is still majority owned, at the time of writing, by the U.K. government.

We model this form of bailout as follows. Assume that if a bank's portfolio value is so low that it would otherwise default, the government purchases a fraction of the bank's equity at an above-market price. This equity injection occurs only if the bank will become solvent after receiving the cash. Suppose that when $B < R_B < (1 + \nu)B$, the government steps in with probability θ and gives the bank's equity holders the tax-free amount of νB in exchange for m portion of the bank's equity.

If such a bailout occurs, the bank's total value is equal to its portfolio value, B, plus the value of the fresh cash, νB. The bank does not default and the bank's creditors are repaid the full R_B they are owed. The remaining $(1+\nu)B - R_B$ is split between the taxpayers and the bank's original equity holders. The bank's equity holders are made better off at the expense of the taxpayers as equity holders would have received nothing if the bank defaulted. Instead, they receive $(1-m)((1+\nu)B - R_B)$, with the other $m((1+\nu)B - R_B)$ going to the government. The government pays νB for its equity stake, which is strictly above its fair market value of $m((1 + \nu)B - R_B)$.

As the bank's original equity holders benefit from bailouts, the possibility of bailouts changes the bank's time-zero equity value (10) to

$$V_{BE} = e^{-Tr_f}\mathbb{E}\left[(B - \tau\max\{0, B - V_{FD} - R_B + V_{BD}\} - R_B)\,\mathbb{I}\left[B \geq R_B\right]\right]$$
$$+ e^{-Tr_f}\theta(1 - m)\mathbb{E}\left[((1 + \nu)B - R_B)\,\mathbb{I}\left[B < R_B < (1 + \nu)B\right]\right]. \tag{B.1}$$

The bank's creditors also benefit as they are now fully repaid in some states of the world where the bank would otherwise have defaulted. The bank's debt value formula is adjusted to reflect the reduced bankruptcy risk:

$$V_{BD} = e^{-Tr_f}R_B\mathbb{P}\left[B \geq R_B\right] + e^{-Tr_f}\mathbb{E}\left[(1 - \alpha_B)B\,\mathbb{I}\left[B < R_B\right]\right]$$
$$+ \theta e^{-Tr_f}\mathbb{E}\left[(R_B - (1 - \alpha_B)B)\,\mathbb{I}\left[B < R_B < (1 + \nu)B\right]\right]. \tag{B.2}$$

This form of bailout also creates moral hazard. Fig. B.1 illustrate the leverage in the economy as the size of the equity injection varies from 0 to 0.2. For this illustration, we hold the probability of a bailout, θ, and the equity stake taken by the government, m, fixed at 0.5. As the size of the potential equity injection increases, the bank increases its own leverage from 85% to 90%. Equity injections subsidize risk taking and failure, and so banks take more risk. For any given leverage level, increasing the size or frequency of equity injections reduces the bank's default likelihood, as the bank is more likely to get an equity injection that allows it to repay that debt. However, the possibility of bailouts causes the bank to take so much additional risk that the bank's default likelihood actually increases, despite the bailout saving the bank from failure in some states of the world. Changing the other bailout parameters has a similar effect to changing the size of the bailout: Increasing the probability of a bailout or decreasing the equity stake taken by the government both increase bank leverage.

Similar to our results on debt guarantees, small interventions have only a very small effect on risk taking, but sufficiently high bailout expectations cause the bank to pursue destructive risk-
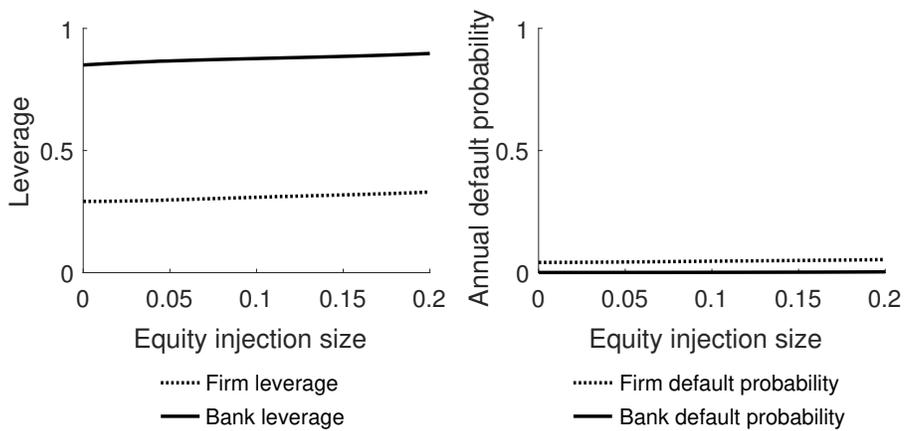
Fig. B.1. Impact of equity injections on leverage and default rates. Fig. B.1 shows how the size of a potential equity injection, ν, impacts the leverage and annual default probabilities of banks (solid) and firms (dotted). The bank is modeled using the parameters in Section 3.

seeking strategies. Government interventions may be optimal ex-post to avoid the social costs of bank bankruptcy; however, at least without capital regulation, the ex-ante expectation of bailouts leads to higher bank leverage and so interventions end up increasing the rate of bank failure.

C. Multiple periods

Our base model assumes that all loans mature at the same time. In order to test how critical that assumption is, we redo our analysis for a bank whose loans mature eat multiple times, in the same spirit as the Geske (1977, 1979) model.

We consider a bank with a portfolio of mortgages that mature at m distinct dates:

$$B\left(\frac{1}{m}T\right), B\left(\frac{2}{m}T\right), \ldots B\left(T\right). \tag{C.1}$$

Each of these repayments have the same form as Equation (4) in Section 2.1 and use the same parameters as Section 3.2, except for the maturity time that varies. We model the underlying mortgage assets as having value that follows a geometric Brownian motion with a shared correlation of ρ. Based on that, the collateral value of a single loan with a time t_1 repayment has a correlation of $\rho\sqrt{t_1/t_2}$ with the collateral value of a single loan with a time $t_2 > t_1$ repayment.

At time 0, the bank commits its own repayments:

$$R_B\left(\frac{1}{m}T\right), R_B\left(\frac{2}{m}T\right), \ldots R_B\left(T\right). \tag{C.2}$$

As before, these repayments introduce a tax shield, but they also create the possibility of default. Combining these yields the following cash flow to equity if the bank is not in default

$$CF_E(j) = B(j) - R_B(j) - \tau \max\left\{B(j) - V_{FD}(j) - (R_B(j) - V_{BD}(j)), 0\right\}, \tag{C.3}$$

similar to Equation (7). Bank creditors get a cash flow of $R_B(j)$ if the bank is not in default and a cash flow of $(1 - \alpha_B)B(j)$ if the bank is in default.

The bank's default decision is made on behalf of its equityholders. As in Geske (1977, 1979), the bank will default if the continuation value to equity is less than the cash injection required to keep the bank solvent. Write $V_{BE}(j)$ as the bank's value at time j, immediately after the cash

flow to equity holders. The bank will default if the sum of that cash flow and the continuation value is less than zero:

$$V_{BE}(j) + CF_E(j) < 0, \tag{C.4}$$

in which case ownership of the bank will transfer to its creditors with loss α_b.

Based on that, we can build up the value of the equity and debt securities by iterating backward. Writing F_j as the information set available at time j, we can write the value of equity this period (assuming the equity holders have not defaulted) as a function of the value of equity next period:

$$V_{BE}(j - 1) = e^{-r_f T/m} \mathbb{E}\left[\mathbb{I}\left[V_{BE}(j) + CF_E(j) \geq 0\right]\left(V_{BE}(j) + CF_E(j)\right)\right]. \tag{C.5}$$

If equityholders have defaulted, the value of equity is zero,

$$V_{BE,Default}(j) = 0. \tag{C.6}$$

We can similarly write out the value of debt if the equity holders have not yet defaulted,

$$V_{BD}(j - 1) = e^{-r_f T/m} \mathbb{E}\Big[\quad \mathbb{I}\left[V_{BE}(j) + CF_E(j) \geq 0\right]\left(V_{BD}(j) + R_B(j)\right)$$
$$+ \mathbb{I}\left[V_{BE}(j) + CF_E(j) < 0\right]\left(V_{BD,Default}(j) + (1 - \alpha_B)B(j)\right)\Big], \tag{C.7}$$

or if they have

$$V_{BD,Default}(j - 1) = e^{-r_f T/m} \mathbb{E}\Big[V_{BD,Default}(j) + (1 - \alpha_B)B(j)\Big]. \tag{C.8}$$

By iterating these values back to time zero, we can find the initial value of debt and equity.

In this setting, it is not clear how to allocate loan prices and tax benefits of debt between the multiple periods. Because the choice of method has little impact on the quantitative results,

we use the simplest methods for both. We set the bank's portfolio costs $(V_{FD}(j))$ as being proportional to the promised repayment, so that $V_{FD}(j) = \frac{1}{m}V_B$ for our competitive bank. We set the bank's interest tax benefit to be an equal amount in each of the m years, in the amount of $\frac{1}{m}\sum^m (R_B(j) - V_{BD}(j))$.

Adding in multiple periods has a surprisingly small impact on bank capital structure. Table C.1 shows that moving to multiple periods while keeping average maturity constant leads to a small increase in leverage an default rates. With two periods, leverage increases from 84% to 86%, with nine periods it increases to 90%. Because we keep average maturity constant, we consider longer maturities for the case for more periods. That leads annual default rates to decrease slightly, while the probability of a default at any time in the bank's life increases slightly.

Leverage increases in the multiple period case for two reasons. First, default at later periods is less costly. In the single repayment case, default resulted in losses across the bank's entire portfolio. With multiple periods, default generally occurs part way through, meaning it only affects a fraction of the banks portfolio value. Second, default at earlier periods is less likely due to the option value of defaulting in the future. In the single repayment model, the bank realized all cash flows at the same time and would default if the expected cash flow to equity was negative. With multiple repayments, bank equity has a valuable option to default in the future and so the bank may not default even when the expected future cash flows are less than the expected future repayments.

Table C.1

Bank leverage under an extension with multiple repayment dates.

Table C.1 reports how bank leverage varies under the extension in Appendix C which uses multiple repayment dates, in the style of Geske (1977). The first row is a base bank that lends only to 80% LTV mortgages as described in Section 3.2. The later rows consider banks that have multiple repayments of these same mortgages and of their own bank debt, with equally spaced repayment dates set so that the average maturity of the bank's portfolio stays constant.

Number of Repayments	Repayment Times (Years)	Leverage	Default Rate	Chance of Default Across Entire Period
1	5	84%	0.07%	0.35%
2	3.3, 6.7	86%	0.06%	0.37%
3	2.5, 5, 7.5	87%	0.05%	0.38%
4	2, 4, 6, 8	88%	0.05%	0.40%
5	1.7, 3.3, 5, 6.7, 8.3	89%	0.05%	0.41%
6	1.4, 2.9, 4.3, 5.7, 7.1, 8.6	89%	0.05%	0.43%
7	1.3, 2.5, 3.8, 5, 6.3, 7.5, 8.8	89%	0.05%	0.44%
8	1.1, 2.2, 3.3, 4.4, 5.6, 6.7, 7.8, 8.9	90%	0.05%	0.45%
9	1, 2, 3, 4, 5, 6, 7, 8, 9	90%	0.05%	0.45%

D. Alternative debt benefits

The main paper uses the tax benefit of debt to drive leverage. However, our analysis follows similarly for other types of debt benefit. We ignore taxes and in their place consider two types of debt benefit explored recently in the literature. As seniority and diversification reduce bank risk, banks pursue high leverage even when debt offers little benefit.

First, we consider a liquidity provision benefit as developed by DeAngelo and Stulz (2015), in which the holders of the bank's debt (for example, depositors) gets a liquidity benefit of b. The bank's debt obligation is then discounted at $r_f - b$. Although DeAngelo and Stulz (2015) do not discuss the magnitude of this benefit, values of 25 and 100 basis points are within a reasonable range. Therefore, we consider values of b equal to 0.0025, 0.005, and 0.01. This liquidity provision benefit increases the value of the bank's debt:

$$V_B^{DS} = V_{BE} + V_{BD}e^{bT}, \tag{D.1}$$

where V_{BE} and V_{BD} are from Section 2.1.

Second, we consider a discount penalty applied to equity. Baker and Wurgler (2015) argue that banks with low leverage do not appear to enjoy lower equity discount rates than their high leverage peers. Their data suggest that increasing bank equity requirements by 10% of assets would increase bank cost of capital by 100–130 basis points. To match this magnitude in the context of our model, we apply a penalty of $p = 0.1$ to bank equity so that

$$V_B^{BW} = V_{BE}e^{pT} + V_{BD}. \tag{D.2}$$

We vary this penalty from $p = 0.05$ and $p = 0.15$ to test sensitivity.

Table D.1 shows the results from these two models and from our base model. For simplicity, we apply these models to a bank that lends only through mortgage loans. We see that bank leverage remains high across all of these types of debt benefit.

Table D.1
Bank leverage under alternative debt benefits.
Table D.1 reports how bank leverage and default rates vary when the bank is subject to varying types of debt benefit. We consider a bank that hold only through mortgages, which are modeled using the parameters in Section 3.

	Bank Leverage	Bank Default Rate
Tax Benefit of τ		
$\tau = 0.15$	79.15%	0.05%
$\tau = 0.25$	85.01%	0.08%
$\tau = 0.35$	88.22%	0.11%
DeAngelo and Stulz (2015) Liquidity Provision Benefit		
$b = 0.0025$	81.70%	0.03%
$b = 0.005$	83.43%	0.06%
$b = 0.01$	85.45%	0.14%
Baker and Wurgler (2015) Equity Discount Rate Penalty		
$p = 0.05$	91.54%	0.77%
$p = 0.1$	94.60%	1.47%
$p = 0.15$	100.00%	100.00%

E. Bank bargaining power

The banking industry is not perfectly competitive and most banks have pricing power. This appendix explores how changing the division of surplus between firms and banks impacts financial decisions. We find that giving banks pricing power increases bank leverage.

Our base model assumes that banks price loans so that the bank earns zero economic profit. Suppose instead that the bank earns a fixed amount of profit on its loan to the firm. The loan is still set to maximize the firm's value; however, this maximization is now over loan sets that give the bank profit of δ fraction of the firm's pre-tax cash flow. Fig. E.1 shows how giving a bank a profit on each loan changes bank leverage. More profit for the bank drives up bank leverage through two channels. First, higher bank profit increases bank tax costs. This increases the value of the tax shield for the bank and directly increases bank leverage. Second, higher bank profit means higher interest costs for firms. That means firms get more tax benefit for each dollar of loans. This reduces the leverage firms take, which increases bank leverage through the strategic substitution effect.

Our base case has a bank that makes zero economic profit and chooses 85% leverage. Assuming that the bank makes an economic profit on loans to firms increases that leverage number. For example, a bank with an economic profit of $\delta = 0.05$ portion of the firms' pre-tax cash flows has leverage of 89%.
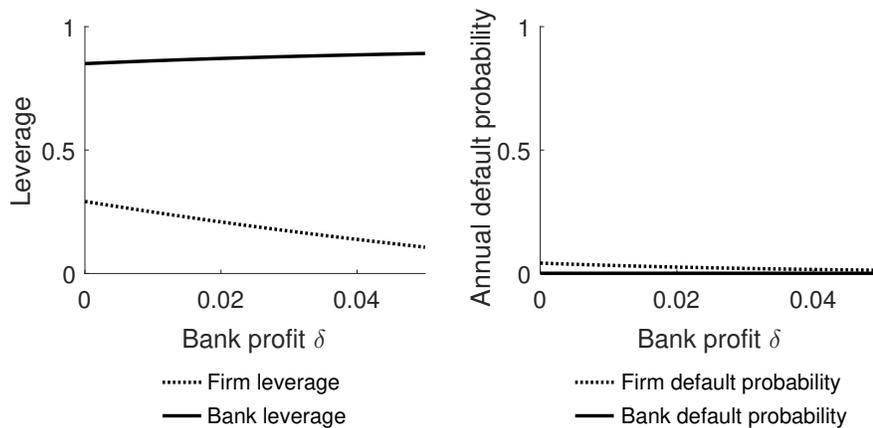
Fig. E.1. Impact of bank bargaining power on firm and bank leverage. Fig. E.1 shows the capital structure of firms and banks in an economy where the profit the bank makes on loans to firms is varied. δ is the bank's profit as a a percentage of firms' pre-tax cash flows. The bank is modeled using the parameters in Section 3.