Financing as a Supply Chain: The Capital Structure of Banks and Firms*

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Abstract

We develop a model of the joint capital structure decisions of banks and non-financials. Our framework explains the high leverage of financial institutions and can be used by both policy makers and academics to quantify the impact of financial regulation. Highly levered financial institutions arise naturally as bank's are diversified senior creditors whose leverage is pushed upward by a previously unstudied strategic substitution effect. The low leverage of non-financial firms is similarly natural as these borrowers internalize the systematic risk costs they impose on their lenders. Risk assessment techniques from the Basel II Framework underlie our structural model and so we can easily analyze the effects of capital regulation and other government interventions on bank leverage, firm leverage, and fragility. Deposit insurance and the expectation of government bailouts lead not only to risk taking by banks, but increased risk taking by firms. Capital regulation lowers bank leverage but can lead to compensating increases in the leverage of non-financials and a small increase in borrowing costs.

1 Introduction

In the wake of the recent financial crisis, there have been repeated calls from academics, practitioners, and policy makers to tighten the regulation of financial institutions and force banks to hold more equity capital. Business leaders have responded that leverage is a natural part of the banking business and that limiting it will stunt credit access and quench economic growth. This paper builds a quantitative model of banking that explains bank capital structure decisions and answers fundamental questions about the nature of banking.

There is disagreement on the causes and effects of high bank; however there is no disagreement that banks and other financial institutions are indeed highly indebted. The average leverage of US banks, measured as the ratio of debt to assets, has been in the range of 85–95% over most of the past century.[1] At the same time, the average leverage of public U.S. non-financials, measured in the same way, has been in the range of 20–30% over a long period, below the predictions of many theoretical models.[2] This dramatic difference in financial structure is puzzling at first glance.

This paper explains this gap by modeling the interaction between a bank's debt decisions and the debt decisions of that bank's borrowers. Our framework blends the Vasicek (2002) model of bank portfolio risk, as used in the Basel regulatory framework, with standard capital structure models. The interaction between banks and borrowers explains the high leverage of banks and the low leverage of firms. In our base case, banks opt for leverage of 88% while firms chose only 37% leverage, close to real world values.

High bank leverage arises from the confluence of several economic mechanisms. First, banks have low portfolio volatility because they are diversified (as in Diamond (1984)) and hold senior claims on borrower assets. Low asset volatility allows banks to carry high debt without undue default risk. Beyond these standard mechanisms, we identify two supply chain effects that arise from the interaction between bank and borrower leverage.

First, we find a strategic substitution effect. Imagine a scenario where banks are very highly levered and thus are less capable of weathering losses during economic downturns. If financial distress is costly, competitive banks will pass this cost on to their borrowers. These borrowers will respond by taking on less debt. In the opposite scenario, where banks have low leverage, these systemic risk costs are lessened and bank borrowers borrow more.

Second, we find a strategic complementarity effect. Banks pass their own debt benefits, such as tax benefits, downstream to their borrowers by charging lower loan interest rates. In a competitive banking

[1] Authors' estimates based on historical FDIC data, which are publicly available from `http://www2.fdic.gov/hsob/HSOBRpt.asp`.

[2] For example, see Goldstein, Ju, and Leland (2001); Morellec (2004); and Strebulaev and Yang (2013).

environment, banks that use equity financing are competed out of business by more levered banks that can offer lower interest rates. A bank's borrowers get their own benefits from debt, but by paying interest to the bank, they decrease the bank's debt benefits unless the bank's debt is correspondingly increased. This once again demonstrates the close interrelatedness between decisions of banks and firms in the economy.

Although these forces are general enough to apply to a variety of frictions and borrowers, we focus on firms borrowing from banks and subject to both bankruptcy costs and tax benefits of debt. Banks and firms deduct interest payments from their taxes and face proportional default costs in bankruptcy. The diversification, seniority, and the supply chain mechanisms we identify are much more general and should play a similar role in the presence of other incentives to issue debt and other classes of borrower.

Regulators can use our framework to analyze the impact of bailouts, deposit insurance, and capital regulation, both qualitatively and quantitatively. We find that both deposit insurance and bailout expectations lead to moral hazard and increase bank leverage. These effects are highly nonlinear – a moderate amount of insured deposits (below 94% of bank liabilities) or bailouts with low probability (below 50%) has minimal impact on bank risk taking but larger interventions can cause dramatic gambling strategies.

Effective capital regulation reduces moral hazard, but ineffective capital regulation has its own hazards. Capital regulation that fails to take into account borrower risk can cause banks to lend to riskier firms, due to the substitution effect, and lead to higher rates of non-financial corporate defaults. These effects are particularly pronounced in the presence of deposit insurance, bailouts, or other subsidies to failed banks. Stronger capital regulation or appropriately risk-weighted capital regulation is effective at preventing these effects, but may still be subject to gaming. For example, we consider the possibility that banks can change loan characteristics such as systematic exposure - such freedom dramatically increases moral hazard and bank risk taking. This suggests current capital regulation may be inadequate to the extent that banks can manipulate between-exposure correlation or other loan parameters.

Current capital regulation standards may be insufficiently strong and insufficiently targeted. We find that doubling equity requirements significantly reduces the risk of bank failure and increases efficiency. Our model shows capital requirements increase the costs of credit by 1.5 basis points for each percentage point of bank equity, a low number that suggests additional capital regulation would generate value.

Beyond this, capital regulation should be better targeted and the banks that face the most moral hazard should face tougher restrictions. The Basel III proposal moves towards this by imposing additional requirements on systemically important financial institution, we argue capital regulation

should go farther and also impose higher equity requirements on banks with high levels of insured deposits. Even when subject to Basel-style capital regulation, banks with insured deposits accounting for more than 95% of their liabilities have an incentive to gamble. Many banks have such high levels of insured deposits, we argue these banks should face heightened capital requirements.

The model allows us to analyze the impact of varying economically important parameters. For example, consider an increase in the default costs of firms. First, banks react by decreasing their leverage as they now have riskier portfolios. Second, firms decrease their leverage as their distress costs have increased. Lower firm leverage reduces bank portfolio volatility and pushes bank leverage up, through the strategy substitution effect. Surprisingly, the overall effect is to increase bank leverage, at least for our parameters.

Our analysis yields a number of empirical predictions. Banks with large insured deposit bases or banks likely to be subject to government bailouts, will have higher leverage and make riskier loans. Better diversified banks, such as national banks, will have higher leverage and less asset volatility than less diversified banks, such as local banks. Borrowers with more systemic risk will pay higher interest rates than otherwise similar borrowers with less systemic risk – unless their loans are priced by banks subject to bailouts or deposit insurance. Capital regulation with crude risk weightings will lead banks to make riskier loans to the highest risk firms with any given risk weight.

Beyond capital regulation and bank specific policy, our results suggest that equalizing the tax treatment of debt and equity will reduce systemic risk. Because tax benefits to debt are a transfer and do not obviously create value. such a change could be more efficient and less costly than other proposals for financial regulation.

The rest of the paper is structured as follows. Section 2 develops a supply chain model of bank and firm financing. Section 3 discussed the major driving economic forces of the model. Section 4 presents the estimation results of bank and firm leverage for the base model. Section 5 analyzes the impact of government bailouts and deposit insurance and Section 6 explores the impact of capital regulation. In Sections 7 and 8 we extend the model to cover banks' bargaining power and bond markets, respectively. Finally, Section 9 discusses possible extensions to the model and Section 10 concludes. blue]ILYA Add relation to literature. There is literature on IO structure of banks but none is even remotely close to what we do. Banks monitor firms but smbd has to monitor banks – similar "chain" very different otherwise. Paper by Harding, Liang, and Ross (2006) needs to be mentioned

2 A Supply Chain Model of Financing

This paper blends a structural model of bank portfolio returns with the trade-off theory of capital structure. We model bank assets using the Vasicek (2002) framework which applies a Merton (1974)

style intuition to bank portfolios by assuming they are composed of loans secured by correlated lognormally distributed assets. The Vasicek model has been widely used in financial regulation: in fact, it underlies the Internal Ratings-Based Approach to capital regulation in Basel II and Basel III.[3] Because of this, our model of capital structure decision-making can be readily be applied to the existing capital regulation framework.

2.1 Capital Structure of Banks

Consider a bank with a portfolio of loans. Each loan i is collateralized by an asset that pays a one-off cash flow of A^i at the loan's time-T maturity. The value of this cash flow is lognormally distributed with

$$\log A^i \sim N\left(-\frac{1}{2}T\sigma^2, T\sigma^2\right), \tag{1}$$

where $N(\mu, \sigma^2)$ denotes the normal distribution with mean μ and standard deviation σ. This specification has the property that $\mathbb{E}\left[A^i\right] = 1$.

Each loan has a promised repayment of R_A due at time T. The time-T asset value A^i determines whether the loan is repaid or defaults. If A^i is greater than some threshold C_A, the loan does not default and the bank receives a full repayment of R_A. (In Section 2.2, where a firm's optimal capital structure decision is considered, optimal default thresholds and debt repayments are derived.) If the asset value is low, $A^i < C_A$, the loan defaults and ownership of the collateral passes to the bank. The bank recovers $(1 - \alpha_A)A^i$, where α_A is the proportional bankruptcy cost incurred on defaulted bank loans.

The bank's payoff from any loan i, B^i, is thus given by

$$B^i = R_A \mathbb{I}\left[A^i \geq C_A\right] + (1 - \alpha_A)A^i \mathbb{I}\left[A^i < C_A\right], \tag{2}$$

where $\mathbb{I}[\cdot]$ is the indicator function.

A bank's portfolio consists of n identically structured loans. The assets that underlie these loans are exposed both to a common systematic shock and to loan-specific idiosyncratic shocks. We can write the time-T value of the asset collateralizing loan i in terms of these shocks:

$$\log A^i = \sqrt{\rho T}\sigma Y + \sqrt{(1-\rho)T}\sigma Z^i - \frac{1}{2}T\sigma^2, \tag{3}$$

[3] See paragraph 272 of Basel Committee on Banking Supervision (2004) and paragraph 2.102 of Basel Committee on Banking Supervision (2013), respectively.

where Y is the systematic shock, Z^i is a loan-specific idiosyncratic shock, and the shock random variables $Y, Z^1, Z^2, \ldots, Z^n$ are jointly independent and standard normal.

The bank's realized portfolio value per loan, B, is the average of the payoffs (2) from each of the bank's loans:

$$B = \frac{1}{n}\sum_i B^i = \frac{1}{n}\sum_i \left(R_A \mathbb{I}\left[A^i \geq C_A\right] + (1-\alpha_A)A^i \mathbb{I}\left[A^i < C_A\right]\right). \tag{4}$$

If the bank's loan portfolio is composed of many small loans, the idiosyncratic shocks to each loan are diversified away and the only variation that matters is the systematic shock which can cause multiple firms to default at once. Taking $n \to \infty$ so that the bank's portfolio is perfectly fine-grained, we get $B \to \mathbb{E}\left[B^i|Y\right]$ almost surely from the Strong Law of Large Numbers.[4]

For a bank with many small loans, we can rewrite the realized portfolio value in terms of the aggregate shock Y:

$$\begin{aligned} B &= \mathbb{E}\left[B^i|Y\right] = R_A \mathbb{P}\left[A^i \geq C_A|Y\right] + (1-\alpha_A)\mathbb{E}\left[A^i \mathbb{I}\left[A^i < C_A\right]|Y\right] \\ &= R_A \Phi\left(\frac{-\log C_A - \frac{1}{2}T\sigma^2 + \sqrt{\rho T}\sigma Y}{\sqrt{(1-\rho)T}\sigma}\right) \\ &\quad + (1-\alpha_A)e^{\sqrt{\rho T}\sigma Y - \frac{1}{2}\rho T\sigma^2}\,\Phi\left(\frac{\log C_A - (\frac{1}{2}-\rho)T\sigma^2 - \sqrt{\rho T}\sigma Y}{\sqrt{(1-\rho)T}\sigma}\right), \end{aligned} \tag{5}$$

where Φ is the cumulative distribution function of the standard normal.

Models of capital regulation, including those based on the Vasicek (2002) framework, typically assume the exogenous existence of bank capital. In reality, banks make capital structure decisions in response to capital regulation and financial frictions. We focus on the twin frictions of corporate tax and distress costs, which underly the trade-off theory of capital structure that is commonly applied to nonfinancial firms.

A profitable bank owes corporate income tax and can reduce this tax expense by deducting the interest payments on debt. Banks are assumed to have access to competitive debt markets, and the bank's debt is thus fairly priced.[5] As in the Merton (1974) model, we assume that the bank's debt is zero-coupon. Let V_{BD} denote the price of the bank's debt and R_B denote the amount the bank must pay to its creditors at time T. The bank's interest obligation is then $R_B - V_{BD}$, and it can use this interest payment to reduce its tax bill. We limit the bank's borrowing to it's portfolio cost, so $V_{BD} \leq V_{AD}$.

We assume the bank pays corporate income tax at rate τ on its pre-tax profit, where the bank's pre-tax profit consists of the value of its portfolio, B; less the cost of its portfolio, V_{AD}; less the interest paid,

[4] As $\mathbb{E}\left[B^i|Y\right] - B^i$ is zero mean, bounded and pairwise uncorrelated a law of large numbers (e.g. Theorem 4.80 in Modica and Poggiolini (2012)) ensures $\frac{1}{n}\sum_i^n \left(\mathbb{E}\left[B^i|Y\right] - B^i\right)$ converges to zero almost surely.

[5] Allen and Carletti (2013) argue that deposits with below market interest rates are a subsidy on bank borrowing, which means bank's debt is not fairly priced. This could easily be incorporated into our framework.

$R_B - V_{BD}$.[6] (Once again, the cost of the bank's loan portfolio is exogenous for now, but is endogenously derived in Section 2.3.) Thus, the bank faces a tax obligation of $\tau\left(B - V_{AD} - (R_B - V_{BD})\right)$, provided this number is positive.[7] The total free cash flow available to the bank's debt and equity holders is the after-tax value of the bank's portfolio:

$$B - \tau \max\left\{0, \underbrace{B - V_{AD}}_{\text{Tax base}} - \underbrace{(R_B - V_{BD})}_{\text{Tax benefit}}\right\}. \tag{6}$$

Debt introduces the possibility of financial distress. The bank defaults if this free cash flow is less than the amount the bank owes to its creditors, so that the bank's payoff to equity holders would be negative if default did not occur. We can write the bank's default condition as

$$B - \tau \max\left\{0, B - V_{AD} - (R_B - V_{BD})\right\} < R_B. \tag{7}$$

Because $V_{AD} > V_{BD}$, this condition simplifies to

$$B < R_B. \tag{8}$$

The bank defaults if and only if its portfolio value is below the amount it owes its creditors. Ownership of a defaulting bank passes to its creditors (ignoring for now the possibility of government intervention.) These creditors recover $(1 - \alpha_B)B$, the bank's portfolio value less proportional bankruptcy costs of α_B.

The resulting cash flows to bank's claimholders are summarized in Table 1. Discounting these payoffs to time 0, the bank's equity value V_{BE} and debt value V_{BD} are given by

$$V_{BE} = e^{-Tr_f}\mathbb{E}\left[\left(B - \tau \max\left\{0, B - V_{AD} - R_B + V_{BD}\right\} - R_B\right)\mathbb{I}\left[B \geq R_B\right]\right] \quad \text{and} \tag{9}$$

$$V_{BD} = e^{-Tr_f}\mathbb{E}\left[R_B\mathbb{I}\left[B \geq R_B\right] + (1 - \alpha_B)B\mathbb{I}\left[B < R_B\right]\right], \tag{10}$$

where r_f is the instantaneous risk-free rate.

The bank's total value is the sum of the values of the debt and equity claims:

$$V_B = V_{BD} + V_{VE} = e^{-Tr_f}\mathbb{E}\Bigg[\underbrace{(1-\tau)B}_{\text{Unlevered value}} + \underbrace{\tau \min\left\{B, V_{AD} + R_B - V_{BD}\right\}}_{\text{Tax shield}} - \underbrace{\alpha_B B\mathbb{I}\left[B < R_B\right]}_{\text{Bankruptcy costs}}\Bigg]. \tag{11}$$

This value, V_B, can be maximized by promising an appropriate repayment, R_B. As in the standard trade-off model, an overly high repayment will result in excessive default costs, while an overly low repayment will forgo tax benefits.

[6] In the U.S., interest tax credits are based on the annual interest implied by the original issue discount. These annual tax credits will add up to the full original issue discount. In our model, the only cash flows occur at time T and thus this tax credit can only be applied against the corporate tax due at that time.

[7] In this asymmetric tax system, the bank pays tax on its profit but does not get a tax rebate on its losses. Alternatively, the bank can be assumed to recover a proportional tax rebate on losses. Such a tax system produces similar results. More complicated tax systems could easily be introduced within this model.

2.2 Capital Structure of Nonfinancial Firms

We model the capital structure decisions of nonfinancial firms by adding firm-level tax and bankruptcy costs to the Merton (1974) model of risky corporate debt. Doing so allows us to endogenize the loan variables that we took as exogenous in the previous section.

Consider a single firm that balances the tax benefit of debt against the cost of financial distress. The firm has a single, time-T, pre-tax cash flow F^i with

$$\log F^i \sim N\left(-\frac{1}{2}T\sigma^2, T\sigma^2\right). \tag{12}$$

This firm pays corporate income tax at a linear rate τ on this cash flow and so faces a total tax burden of τF^i. To reduce that tax burden, the firm can issue zero-coupon debt with face value R_F, maturity T, and price V_{FD}. For now, assume that the firm's debt is priced by competitive, risk neutral investors without financing frictions. (In Section 2.3, the firm's interest rate will be tied to the bank's funding decision.) As with the bank, the firm's interest payment reduces its tax liability. The firm pays $R_F - V_{FD}$ in interest at time T, and so the firm's equity holders realize a tax benefit of $\tau(R_F - V_{FD})$ against any tax owed by the firm.

Under these assumptions, the firm's time-T free cash flow is

$$F^i - \tau \max\left\{0, F^i - (R_F - V_{FD})\right\}. \tag{13}$$

The firm defaults if this free cash flow is less than the firm's debt obligations, i.e.

$$F^i - \tau \max\left\{0, F^i - (R_F - V_{FD})\right\} < R_F. \tag{14}$$

As $R_F > V_{FD}$, the firm's default condition can be simplified to

$$F^i < C_F = R_F + \frac{\tau}{1-\tau}V_{FD}, \tag{15}$$

where C_F is the firm's default threshold.

In default, ownership of the firm passes to its creditors with the firm's value impaired by proportional bankruptcy costs of α_F, so that the firm's creditors receive $(1-\alpha_F)(1-\tau)F^i$ in default.[8]

The resulting cash flows are summarized in Table 1. Discounting the expectation of these cash flows, the firm's time-0 equity and debt values can be written as

$$V_{FE} = e^{-Tr_f}\mathbb{E}\left[\left(F^i - \tau \max\left\{0, F^i - R_F + V_{FD}\right\} - R_F\right)\mathbb{I}\left[F^i \geq C_F\right]\right] \text{ and} \tag{16}$$

$$V_{FD} = e^{-Tr_f}\mathbb{E}\left[R_F\mathbb{I}\left[F^i \geq C_F\right] + (1-\tau)(1-\alpha_F)F^i\mathbb{I}\left[F^i < C_F\right]\right]. \tag{17}$$

[8] A defaulting firm does not pay interest and so cannot deduct it; therefore, the firm's creditors get a cash flow of $(1-\alpha_F)F^i$ less tax costs of $\tau(1-\alpha_F)F^i$.

The firm's initial value, V_F, is the sum of the values of the debt and equity claims:

$$V_F = e^{-Tr_f}\mathbb{E}\Big[\underbrace{1-\tau}_{\text{Unlevered value}} + \underbrace{\tau\left(R_F - V_{FD}\right)\mathbb{I}\left[F^i \geq C_F\right]}_{\text{Tax shield}} - \underbrace{\alpha_F(1-\tau)F^i\mathbb{I}\left[F^i < C_F\right]}_{\text{Bankruptcy costs}}\Big]. \tag{18}$$

A firm subject to these financing frictions chooses a promised repayment, R_F, that maximizes the above expression of the firm's time-0 value. Note that Expression (18) of the firm's value and Expression (11) of the bank's value are very similar, which is as we would expect given the same frictions are imposed on the non-financial and financial sectors of the economy.[9]

2.3 Joint Capital Structure Decision of Firms and Banks

This section links the model of bank financing in Section 2.1 with the model of firm financing in Section 2.2 in order to develop a model of the joint capital structure decisions of banks and firms. By endogenizing the capital structure of both banks and firms simultaneously, we derive a plethora of interesting results. For simplicity, we assume that firms can raise financing only by issuing equity and borrowing from banks. While a reasonable assumption for small and medium-size firms, this is less realistic for large firms that can choose between debt markets and banks. In Section 8, we extend the model to include firm's with access to debt markets.

Consider a bank as described in Section 2.1 that lends to a large number of firms where each firm is as described in Section 2.2 and each firm pursues identical financing policy.[10] Each firm i uses its future cash flow F^i as collateral to borrow V_{FD} from the bank with an agreed repayment of R_F at time T, with these variables replacing A^i, V_{AD}, and R_A, respectively, in the bank's loan equation. The bank's recovery on a defaulted loan, formerly $(1-\alpha_A)A^i$, is replaced by the firm's creditor's recovery in bankruptcy, $(1-\alpha_F)(1-\tau)F^i$. Therefore, the bank's loan payoff expression (2) becomes

$$B^i = R_F\mathbb{I}\left[F^i \geq C_F\right] + (1-\alpha_F)(1-\tau)F^i\mathbb{I}\left[F^i < C_F\right], \tag{19}$$

with the other bank value equations being similarly adjusted.

The bank funds its lending by issuing equity with value V_{BE} and debt with promised repayment R_B and value V_{BD}. The banking system is perfectly competitive and thus the bank makes zero profit in expectation. This arises naturally with costless entry and exit of banks. With a competitive banking sector, the proceeds of the firm's debt issuance V_{FD} are exactly equal to the value the firm's loan

[9]The slight structural difference between Expressions (11) and (18) arises because banks deduct their loan costs from their taxable income while firms lack a similar deduction. Enriching our model by allowing firms to deduct investment costs from their taxes does not change the model's results.

[10]It is possible that in our model it would be optimal for firms to coordinate and choose heterogeneous financing in equilibrium. We allow only for a symmetric equilibrium.

adds to the bank. As the borrower firms are ex-ante identical and we have scaled the bank's value by their number, this means that $V_{FD} = V_B = V_{BE} + V_{BD}$. Under this assumption, banks and firms set their capital structures to maximize their joint value, $V_F = V_{FE} + V_B$. Effectively, banks that do not maximize firm value are competed out of business as other banks are able to offer firms better financing terms. Competitiveness of the banking system implies that any bank surplus gets passed down to firms in the form of lower interest rates. In Section 7, we extend the model to the general distribution of surplus between firms and banks.

The total firm value at date 0 is thus the sum of the value of the firm's equity (16) and the value the firm's loan contributes to the bank (11):

$$V_F = e^{-Tr_f}\mathbb{E}\Bigg[\underbrace{1-\tau}_{\text{Unlevered value}} \underbrace{-\alpha_F(1-\tau)F^i\mathbb{I}\left[F^i < C_F\right]}_{\text{Firm bankruptcy costs}} - \underbrace{\alpha_B B\mathbb{I}\left[B < R_B\right]}_{\text{Bank bankruptcy costs}} + \underbrace{\tau\left(R_F - V_{FD}\right)\mathbb{I}\left[F^i \geq C_F\right]}_{\text{Firm tax shield}} \underbrace{-\tau\max\left\{0, B - V_{FD} - R_B + V_{BD}\right\}}_{\text{Bank tax costs and tax shield}}\Bigg]. \tag{20}$$

The financing frictions driving the policies of both banks and firms are present in this combined value. The total firm value V_F is maximized by appropriately choosing the capital structure parameters R_F and R_B.

2.4 Supply Chain Effects

Firms can deduct interest expenses from their tax bills. The consequences of this interest tax shield have been recognized and explored by generations of corporate finance models. However, banks that receive interest payments from firms must pay corporate tax on that interest. Expanding Expression (21) highlights how these countervailing tax effects cause the firm interest tax shield to have an ambiguous effect on total tax:

$$V_F = e^{-Tr_f}\mathbb{E}\Bigg[\underbrace{1-\tau}_{\text{Unlevered value}} \underbrace{-\alpha_F(1-\tau)F^i\mathbb{I}\left[F^i < C_F\right]}_{\text{Firm bankruptcy costs}} - \underbrace{\alpha_B B\mathbb{I}\left[B < R_B\right]}_{\text{Bank bankruptcy costs}} + \underbrace{\tau(V_{FD} - (1-\alpha_F)(1-\tau)F^i)\mathbb{I}\left[F^i < C_F\right]}_{\text{Tax benefit of loan losses}} + \underbrace{\tau\min\left\{R_B - V_{BD}, B - V_{FD}\right\}}_{\text{Bank interest tax shield}}\Bigg]. \tag{21}$$

Effectively, firm interest payments constitute bank profit and thus a firm's increased interest deduction is a bank's increased taxable profit. Because these effects cancel each other, the *only* real tax savings come from the bank's interest tax shield. Interest tax benefits only emerge when borrowing directly from debt markets, at the top level of the financing supply chain. This important realization is at the root of the "supply chain" model of financing. Traditional models of capital structure (as well as

contingent-claim models of credit risk) do not specify the identity of debt buyers, but the supply chain intuition shows that they can't be banks or similar institutions as these institutions would impose their own financing frictions.

This supply chain model is fundamentally similar to models of corporate and personal tax. In models such as Miller (1977) or DeAngelo and Masulis (1980), firms get tax benefits from debt but issuing debt causes a firm's investors to pay higher personal tax. In the supply chain model, a firm's debt issuance increases the corporate tax of the bank holding that debt. In both types of model, firms cannot capture the full tax benefits of debt because of the tax costs debt imposes on upstream debt holders.

3 Driving Economic Forces

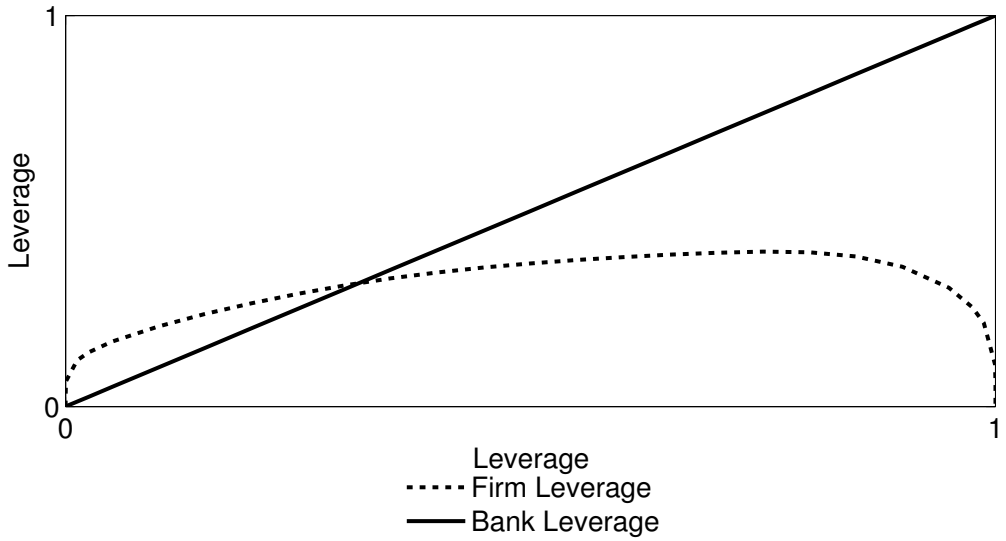
The confluence of several economic mechanisms drives the capital structure decisions of banks and firms and the fragility of the resulting system. To illustrate these mechanisms, Figure 1 (and 2) shows how firm (bank) leverage optimally responds to exogenous variation in bank (firm) leverage, where leverage is defined as the ratio of debt to total value.

Figure 1 shows that bank and firm leverage can be both *strategic substitutes* and *strategic complements.* These effects arise because a firm's optimal reaction to changing bank leverage is influenced by two competing effects.

First, lower bank leverage reduces a firm's ability to capture the tax benefits of debt. A bank with low leverage pays substantial tax on its interest income and must charge high interest rates to make up for that tax burden. As shown in Expression (21), a firm's interest payment generates a net tax benefit only to the extent that the receiver of that interest payment can avoid paying tax on it. The only real tax benefits are generated by upstream borrowers, such as banks, and low bank leverage prevents these upsteam borrowers from generating tax benefits. This supply chain effect makes bank and firm leverage strategic complements. At the extremum, consider a firm borrowing from an all equity bank as shown on the left of Figure 1. An all equity bank cannot pass on any tax benefits of debt and thus a firm borrowing from such a bank gains no tax benefit from leverage whatsoever. The firm's interest tax deductions are effectively the bank's taxable income and thus the net tax benefit is zero. The presence of distress costs means the firm then issues no debt at all. For relatively low bank leverage, this strategic complementarity effect dominates, which reduces the total indebtedness of the economy.

Second, lower bank leverage reduces the risk of bank failure and therefore expected bank distress costs. This strategic substitution effect decreases firm borrowing costs and allows firms to increase their leverage without jeopardizing the bank's financial stability. Of course, this effect is only important if the firm is properly incentivized to increase its leverage, i.e. if bank leverage is high enough that

Figure 1: Optimal Firm Leverage for Given Bank Leverage

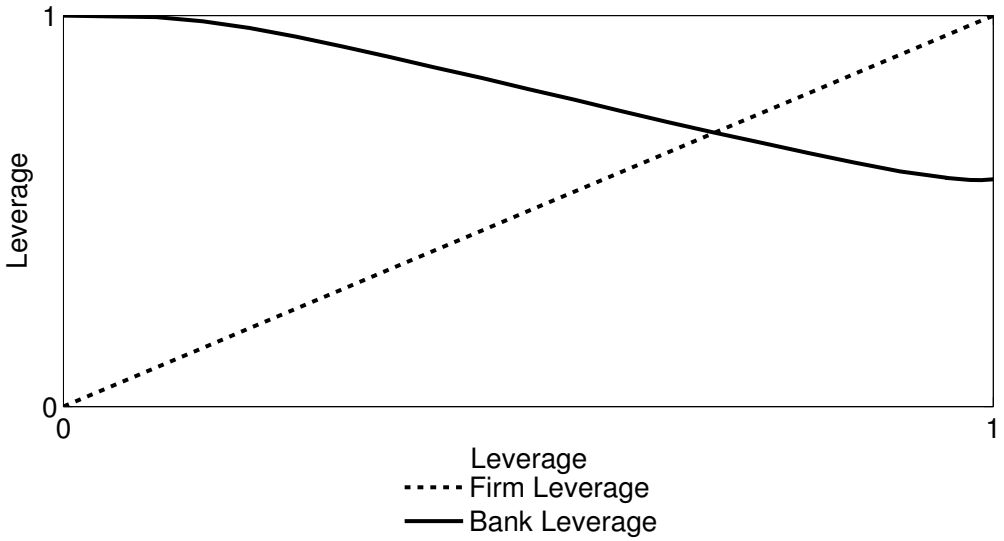


This figure illustrates how varying bank leverage (solid) impacts firm leverage (dotted).

tax benefits are marginally important. The strategic substitution effect is thus likely to dominate for relatively high bank leverage. Consider an extremely highly levered bank that will be pushed into distress by even a small negative shock. This instability translates into higher firm borrowing costs which will reduce firm debt issuance. Effectively, firms build up a safety cushion to protect their bank. At the extreme, with a fully levered bank, optimal firm leverage attenuates to zero, as shown on the right of Figure 1.

Another important driver of bank capital structure is the low volatility of bank assets. This is caused by two mechanisms: a diversification effect and a seniority effect. The diversification effect arises because banks lend to a large number of firms and so experience aggregate returns that are less volatile than the returns on any single loan. The strength of this effect is governed by the correlation between the loans in a bank's portfolio, in other words, the systematic exposure of the firms to which the bank lends. Less correlated borrowers reduce the bank's loan portfolio volatility which means the bank can pursue high leverage without a correspondingly high default risk. In the extreme case where the bank's borrowers experience independent shocks, the bank would have an effectively riskless portfolio and could be fully levered with no risk of default. Firms borrowing from such a bank would capture all the tax benefits of debt as their bank would be passing along those tax benefits with perfect efficiency. We use ρ to denote the correlation between bank loans. For a national bank, this would be the exposure of a bank's portfolio firms to systematic shocks. For a regional bank, ρ would also incorporate regional shocks and so might be higher. We would expect such banks to pursue lower leverage or lend to safer firms to compensate for their increased portfolio volatility.

Figure 2: Optimal Bank Leverage for Given Firm Leverage



This figure illustrates how varying firm leverage (dotted) impacts bank leverage (solid).

The second mechanism arises from the seniority of the bank in firm's capital structure. Banks are generally senior creditors and as such are paid first in bankruptcy, before a firm's equity holders and other creditors such as public debt holders. This seniority effect is a critical phenomenon, because it means that banks will not suffer losses unless their borrowers perform very poorly.[11] Correspondingly, for a bank to experience financial distress, a non-trivial fraction of its borrowers must lose a large fraction of their value. In our basic model, banks are the only holders of the debt issued by firms. In reality, large firms finance themselves in the bond market and small firms finance themselves using trade credit. Bank borrowing is typically senior to these types of obligation, which reduces bank losses even further in the event of a default. The seniority of banks in firms' capital structure allows banks to pursue high leverage without high default risk. Some intuition can be grasped by analyzing Figure 2 which shows that as firm leverage decrease, and firm debt becomes senior to a larger tranche of firm equity, bank leverage increases correspondingly. Section 8 explores this mechanism in further detail by introducing junior bond debt into a firm's capital structure.

Figure 3 shows the combined impact of these two mechanisms: diversification alone significantly reduces the spread of returns; diversification and seniority together dramatically reduce portfolio volatility. The first row of Table 2 provides numerical values that further support these observations. Both diversification and seniority reduce volatility, but the impact of seniority is more profound. When compared to the base case, diversification alone halves volatility, seniority alone decreases volatility by a factor of five. Diversification and seniority together reduce volatility by a factor of twenty, suggesting

[11] For example, Acharya, Bharath, and Srinivasan (2007) and Ou, Chlu, and Metz (2011) show that banks recover more than other creditors when their borrowers default.

there is a synergy between the two effects, with seniority providing a greater reduction in volatility to a diversified portfolio. Later rows of Table 2 provide standard deviation and skewness for varying levels of correlation and leverage. As expected, increasing the correlation between firms decreases the diversification effect and increasing the firm's leverage decreases the seniority effect.

After taking into account these two effects, bank asset volatility is only 0.014, much lower than the volatility of the borrower firms. This number is in line with empirical estimates of bank asset volatility such as Ronn and Verma (1986) who find bank asset volatility of 0.013 and Hassan, Karels, and Peterson (1994) who find bank asset volatility ranging from $0.009 - 0.023$ using different methodologies and bases.

blue]Steve: In Vasicek, the question is about the distribution of the number of defaults. However, it is also the distribution of returns of the loan portfolio if we assume constant LGD. In our case, we don't assume constant LGD (by the way, we have to make it clear in the paper). Steve is wondering to what extent this makes the distribution different. I.e., if we produce two return distribution, one is ours (on loans) and another one assuming constant LGD (so that the mean LGD of both distributions coincide), on the same scale, how these distributions will look. WG: I don't think we should include this. I don't think it adds enough and I don't think that many people are familiar enough with the technicalities of the Vasicek model to notice the difference.

blue]ILYA: We should have more here, very important contributions of different factors WG: Not sure what else to add

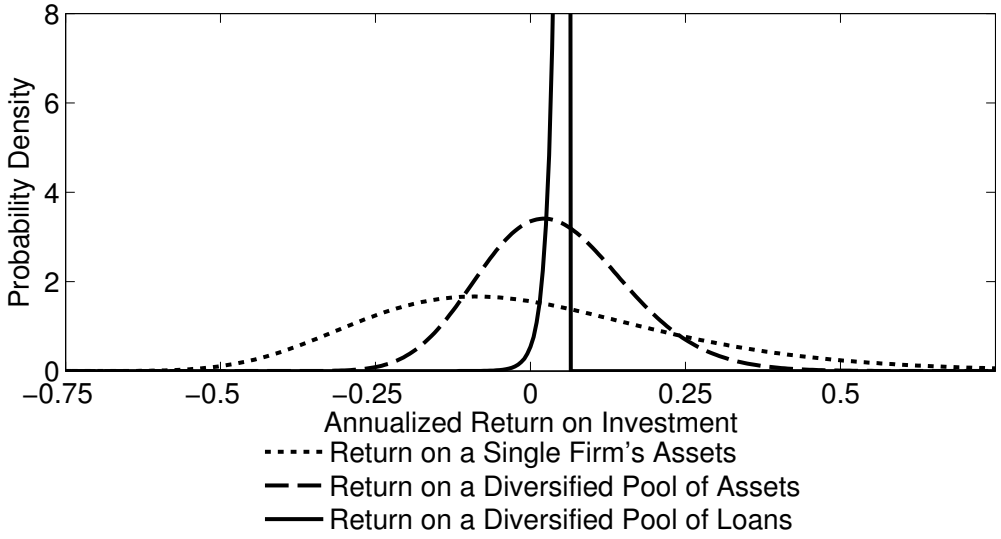
4 Capital Structure and Default Likelihoods of Firms and Banks

Because our framework is a combination of two popular models, the Vasicek (2002) model used by bank regulators and the trade-off model used in the corporate finance literature, we can readily quantify our results. This section explores the optimal equilibrium capital structure of banks and firms. We are interested in economic magnitudes of both bank and firm default probabilities and the market leverage of banks and firms, which we define as $V_{BD}/(V_{BE} + V_{BD})$ for banks and $V_{FD}/(V_{FE} + V_{FD})$ for firms.

4.1 Benchmark Parameter Values

Our benchmark parameter values are based on empirically motivated proxies. Because many parameters of interest are challenging to estimate with good precision, we conduct extensive comparative statics exercises.

Figure 3: Impact of Seniority and Diversification on Distribution of Returns



This figure shows the probability density function of returns on a single firm's assets (dotted), a diversified portfolio of firm assets (dashed), and a diversified portfolio of loans to those same firms (solid) as in Expression (5) with $C_A = 0.4$. The chart was generated using parameters values from Section 4.2.

We set the benchmark value of our firm asset correlation parameter, ρ, to 0.2. This is similar to the values assumed by regulators. The Basel II (and Basel III) Internal Ratings-Based Approach sets its loan-specific correlation parameter, $\hat{\rho}$, to between 0.12 and 0.24 based on the following formula:

$$\hat{\rho} = 0.12 \, \frac{1 - e^{-50PD}}{1 - e^{-50}} + 0.24 \, \left(1 - \frac{1 - e^{-50PD}}{1 - e^{-50}} \right), \tag{22}$$

where PD is the loan default probability (see paragraph 272 of Basel Committee on Banking Supervision (2004) for more details.)[12] Our value of 0.2 is also similar the values estimated by Lopez (2004), who uses KMV software to derive values ranging from 0.1 to 0.3 based on firm size. However, the finance literature lacks a consensus on the appropriate value for this parameter. For example, Dietsch and Petey (2004) find asset correlations in the range of 0.01–0.03 for European small and medium enterprises.

We set annual firm asset volatility, σ, to 0.4, a number broadly consistent with empirical estimates. Annualizing the figures from Choi and Richardson (2008) gives volatilities in the 0.25–0.65 range, varying with firm leverage. Schaefer and Strebulaev (2008) find asset volatility to be on the order of 0.2–0.28 for large bond issuers. The Basel Committee on Banking Supervision (2002) prescribes a time to maturity of 2.5 years (see paragraph 279) and we use this value in our estimates. While public

[12]The regulatory correlation is subject to a further downward adjustment of up to 0.04 for loans to small firms.

corporate debt typically has a maturity of 7–15 years at origination, bank debt is of substantially shorter duration. For example, the loans studied by Roberts and Sufi (2009) have a time to maturity that averages four years, but are renegotiated, on average, after 538 days. Time to maturity is important primarily due to its impact on total volatility $\sigma\sqrt{T}$.

Several estimates suggest the effective tax rate U.S. companies pay is less than the statutory federal corporate tax rate of 0.35 and so we use a value of 0.25. For example, Graham and Tucker (2006) show that the average S&P 500 firm paid less than 18 cents of tax per dollar of profit in each year between 2002 and 2004 (see also Graham (1996) and Graham (2000)). We set firm and bank distress costs, α_F and α_B respectively, at 0.1. For firms, this assumption is likely conservative. Some recent estimates, such as Davydenko, Strebulaev, and Zhao (2012), find that, conditional on experiencing distress, large firms incur sizeable total distress costs of 20–30% of asset value at time of distress onset. In a theoretical work, Glover (2012) suggests that distress costs can be even higher. There is little empirical evidence on bank bankruptcy costs. James (1991) finds direct bank bankruptcy costs equal to 10% of assets. Because distress costs are a primary driver in our model, we conduct extensive robustness tests with respect to these two parameters. Finally, we set the risk-free rate, r_f, to 0.05.

4.2 Benchmark Estimates

Table 3 shows our results for a variety of parameter values. The first two columns show the capital structure of a firm borrowing from a bank and the associated annual firm default probability. The next two columns show the capital structure and default rate of that bank. The final two columns show the capital structure and default probability of a firm that issues bonds in the public market. Three results immediately stand out.

First, bank leverage is indeed very high. Our benchmark case yields banks with 88% leverage, a value that would be extremely high for a nonfinancial firm (indeed, a nonfinancial firm with such a leverage would be almost automatically regarded as a firm in distress) but in line with the empirical evidence on the capital structure of financial firms. For example, FDIC data shows that aggregate bank leverage has stayed in the range of 85–95% for the past 75 years.[13] Furthermore, all of the parameter variations in Table 3 produce high bank leverage.

Second, firm leverage is substantially lower than bank leverage, as has been widely empirically documented. The average quasi-market leverage ratio for U.S. public firms between 1962–2009 is in the range of 25-30%, with more than 20% of firms having less than 5% leverage (see e.g. Strebulaev and Yang (2013)). A tendency of nonfinancial firms to exhibit low leverage and a failure of many standard models to explain such low leverage is known as the low-leverage puzzle and has generated a lot of

[13] Authors' estimates based on historical FDIC data, which are publicly available from `http://www2.fdic.gov/hsob/HSOBRpt.asp`.

research (see e.g. Leland (1994); Leland (1998); Goldstein, Ju, and Leland (2001); Morellec (2004); Ju, Parrino, Poteshman, and Weisbach (2005); Strebulaev (2007)). For the benchmark parameter estimates, our model produces the firm leverage of 37%, substantially smaller than in many trade-off models.[14] This low leverage arises because banks price systemic risk into their loans which reduces borrowing.

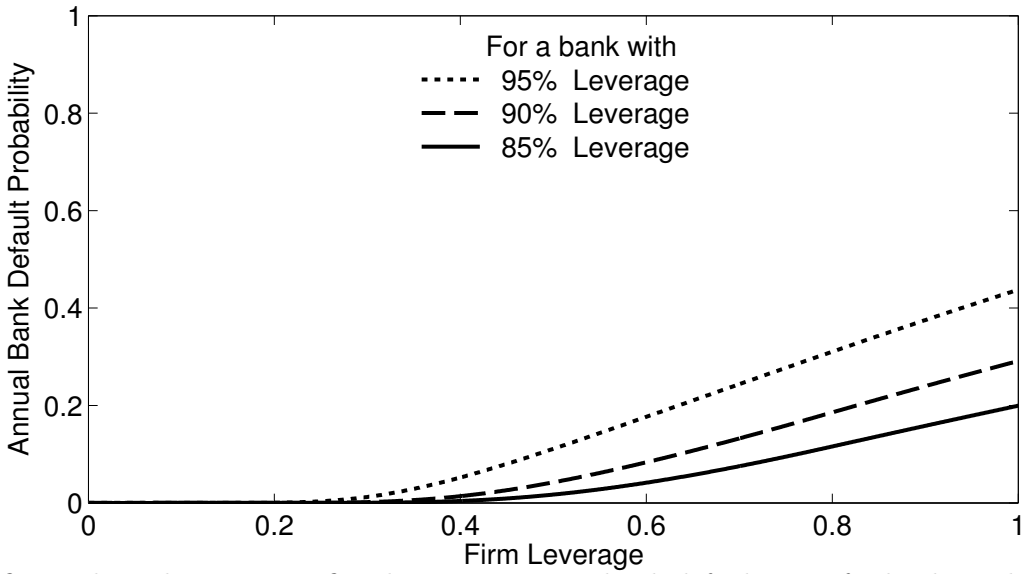
Third, firms that borrow through banks have lower leverage (37%) than firms with direct access to the capital markets (55%).[15] This is again in line with empirical evidence, such as Faulkender and Wang (2006) who show that firms with public bond market access issue are more highly levered. Among firms with positive debt, they show firms with bond market access have 28.5% leverage versus 20.5% leverage for those firms without bond market access.

These results conform closely to an otherwise puzzling observation of low firm leverage and high bank leverage. What can explain a more than 50% difference in bank-firm leverage? As most of the trade-off benefits in the system originates at the upstream end, in the banking sector, it is optimal for the bank to be highly levered. As bank leverage increases, the substitution effects causes firms to decrease their reliance on debt. In effect, each additional dollar of debt issued by the bank adds more private value to the agents than each additional dollar issued by the firms. The major countervailing force is the possibility of the bank distress. Thus, firms choose a relatively lower leverage to minimize the chance of the bank going bust. For the base case, even though bank leverage is 88%, low firm leverage means that banks have an annual default rate of only 0.53%.

Importantly, bank default probability is highly sensitive to changes in borrower leverage as illustrated by Figure 4. Holding bank leverage at the benchmark optimum of 88% we see that increasing firm leverage can dramatically increase bank default probabilities. For example, increasing firm leverage from 37% to 50% causes the bank's one-year default probability to increase sixfold, from 0.53% to 3.18%. Increasing firm leverage to 75% causes the bank's default probability to increase to 13.5%. Both high firm leverage and high bank leverage are associated with more frequent bank defaults.

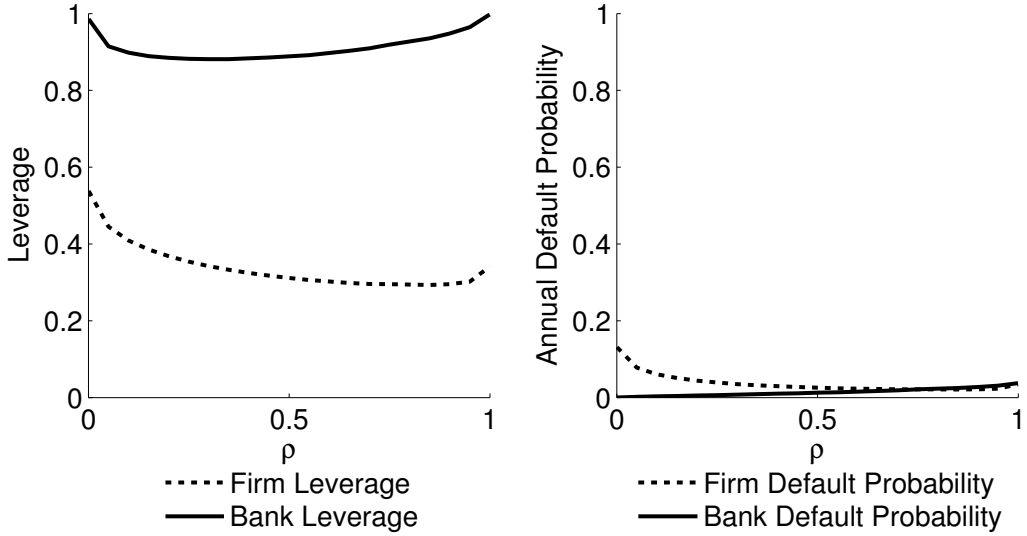
The run up to the recent financial crisis was associated with a dramatic increase in the leverage of households. Banks that failed to appropriately model such an increase in leverage would be extremely exposed to systemic shocks due to their unexpectedly inadequate seniority.

Figure 4: Impact of Firm Leverage on Bank Default Rates



This figure shows how varying firm leverage impacts bank default rates for banks with fixed capital structures. The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

Figure 5: Impact of Systematic Risk on Leverage and Default Rates



This figure shows how varying systematic risk ρ impacts the leverage and annual default probabilities of banks (solid) and firms (dotted). The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

4.3 Impact of Systematic Risk

Varying the extent to which risk is systematic has a nonmonotonic effect on bank and firm leverage as illustrated by Figure 5. Low systematic risk lead to highly levered banks and firms because better diversified exposures reduce the systemic risk costs. In the extreme example of $\rho = 0$, the Diamond (1984) case, banks are optimally fully levered as their risk is completely diversified. Adding systematic risk causes a gradual decrease in both firm and bank leverage. There are two related effects. First, banks reduce their leverage to protect against default as increasing correlation raises their portfolio volatility. Lower bank leverage makes banks less effective at passing along the tax benefits of debt, which raises borrowing costs for firms and reduces firm leverage in due turn. This once again demonstrates the close interrelatedness between decisions of banks and firms in the economy. Second, because firms internalize the costs of systemic failure they impose on banks, an increase in systematic risk causes the firm to borrow less. More correlated firms means bank need to hold more equity and charge higher interest rates, which reducing firm borrowing.

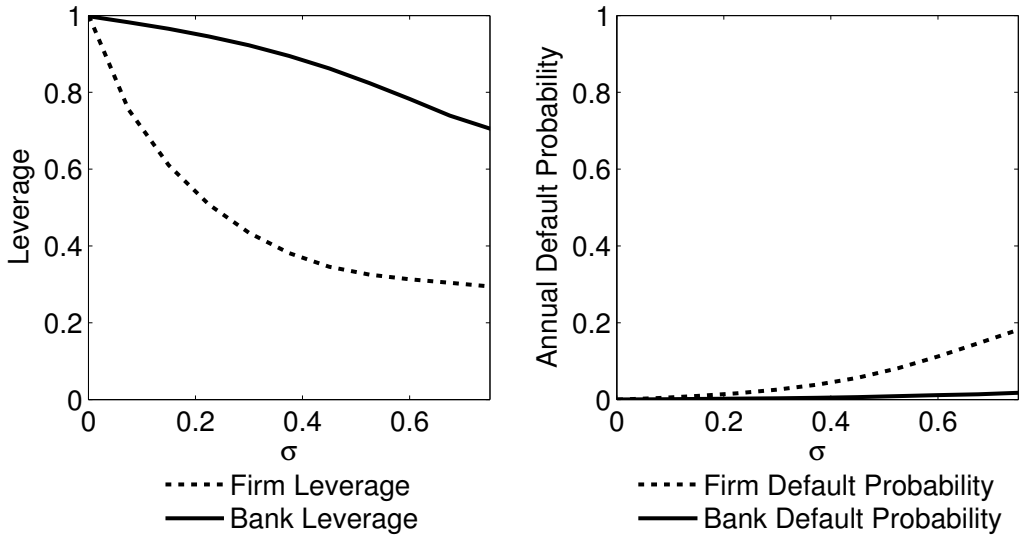
As the level of systematic risk increases further, a marginal dollar of bank equity capital becomes less and less effective at guarding against default. If risk is systematic, it is more efficient for firms to increase their equity buffers than for the bank to increase its equity buffer by the same amount. One way to visualize this is to imagine a system of dikes guarding against flood, with firm equity serving as the first set of dikes and the bank equity as a second set of dikes, further inland.[16] If the first dike is likely to fail catastrophically with multiple breaches, the second dike is unlikely to be of much help – the best way to protect against such flooding is to make the first dike stronger and higher. Such a scenario is akin to an economy where firms have large systematic exposure. It is better to increase firm equity and raise the first dike than to increase bank equity and raise the second dike. If instead, breaches in the first dike are expected to be isolated and quickly repaired, a second dike could provide valuable protection. This case corresponds to more moderate levels of ρ. We find that this comparison between the flood-preventing dike system and bank-failure-preventing leverage system works rather well in explaining the intuition of our framework. For most of the values of systematic risk, the "dike" system works well and banks rarely default.

[14]Factors other than trade-off considerations likely influence firms with very low leverage. Strebulaev and Yang (2013) report that the average leverage of public firms in the U.S. with the leverage above the 5% leverage ratio threshold is 37%.

[15]Static trade-off models of capital structure typically result in much higher leverage. In these models, debt is issued as a perpetuity, while in our case tax benefits effectively accumulate over a relatively short period of time. Thus, our modeling of debt maturity is closer to dynamic capital structure models that produce much lower leverage.

[16]For example, the historic Dutch dike system included redundancy to improve safety. Large *waker* (watcher) dikes took the first impact of the waves; if they crumbled, *slaper* (sleeper) dikes provided a second line of defense; in the worse case scenario *dromer* (dreamer) dikes provided protection for individual farms or even fields. Refer to Neave and Grosvenor (1954) for more detail.

Figure 6: Impact of Firm Asset Volatility on Leverage and Default Rates



This figure shows how varying asset volatility σ impacts the leverage and annual default probabilities of banks (solid) and firms (dotted). The parameter values are $r_f = 0.05,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

For large values of systematic risk, trouble hits many firms in the economy at the same time. The bank's loans move together and the bank gets minimal diversification benefit. As such, the optimal way to prevent bank failure is to lower the fragility of the downstream elements – the firms. For levels of ρ near 1, firm performance is almost perfectly correlated and the bank's portfolio is thus extremely volatile. Low firm leverage becomes less effective at preventing bank defaults because bank asset volatility is so high. The same effect eventually reduces the marginal benefit firms get from an extra dollar of equity. As can be seen in Figure 5, this effect eventually causes firms to lower their equity buffer as such a buffer is no longer effective.

4.4 Impact of Asset Volatility

Figure 6 shows the impact of varying asset volatility σ on bank and firm leverage and default likelihood.[17] Bank leverage decreases with higher volatility. This behavior is well documented in the capital structure literature both theoretically and empirically (e.g. Leland (1994) and Adrian and Shin (2010).) As loan portfolios become more volatile, banks decrease their leverage to better protect against default. Firm leverage follows a similar pattern.

[17]Note that while we vary σ, we are interested in the impact of total volatility, $\sigma\sqrt{T}$. The primary impact of varying T is through its impact on total volatility; therefore, a chart that shows leverage and default probabilities as T varied would be qualitatively similar to 6.

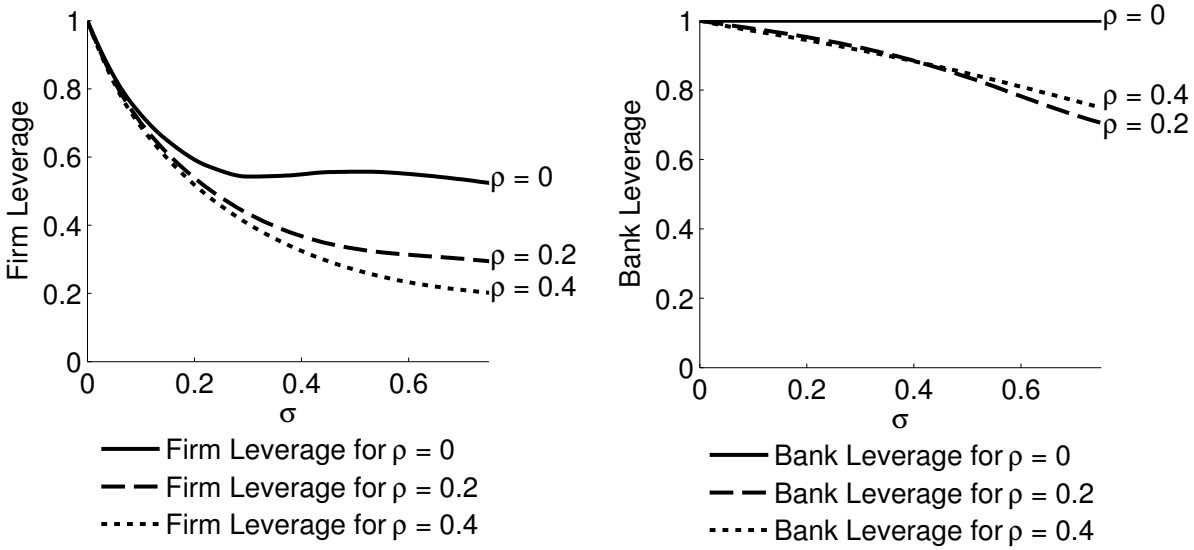
A companion Figure 7 shows the impact of varying asset volatility on leverage for three different values of systematic risk, ρ=0, 0.2, and 0.4. As before, we see that increasing firms with more systematic risk borrow less. Also visible apparent is the non-convex path of firm leverage as σ varies. This pattern is most visible for $\rho = 0$, because the effect of bank leverage is removed, but exist for every ρ as the result of three competing factors. First, as volatility increases, the equity buffer needed to prevent default for a given systematic shock increases. This causes a decrease in leverage for both banks and firms. Second, high volatility increases the cost of avoiding default for any given shock. Firms and banks respond by protecting against fewer shocks. This pushes leverage and default probabilities upward. This effect is stronger for firms than banks because firm assets are much more volatile than a bank's diversified portfolio. Third, increasing volatility increases the value of equity relative to debt due to the call option nature of equity. The patterns in firm leverage are a result of the juxtaposition of these effects: The first effect is strongest for low volatility; the second for intermediate volatility, and the third for high volatility.

Both figures suggest that asset volatility affects bank and firm leverage through several pathways, including the value of tax benefits and the relative optionality of debt and equity market values. Importantly, for all the values of asset volatility, bank leverage remains substantially above firm leverage.

The right plot of Figure 6 shows the impact of asset volatility on equilibrium default probabilities. As expected, increasing firm asset volatility dramatically increases the firm default rate. Firm asset volatility also increases bank default rate, but not to the same degree, both due to the previously discussed seniority and diversification mechanisms and due to bank's endogenously decreasing their leverage.

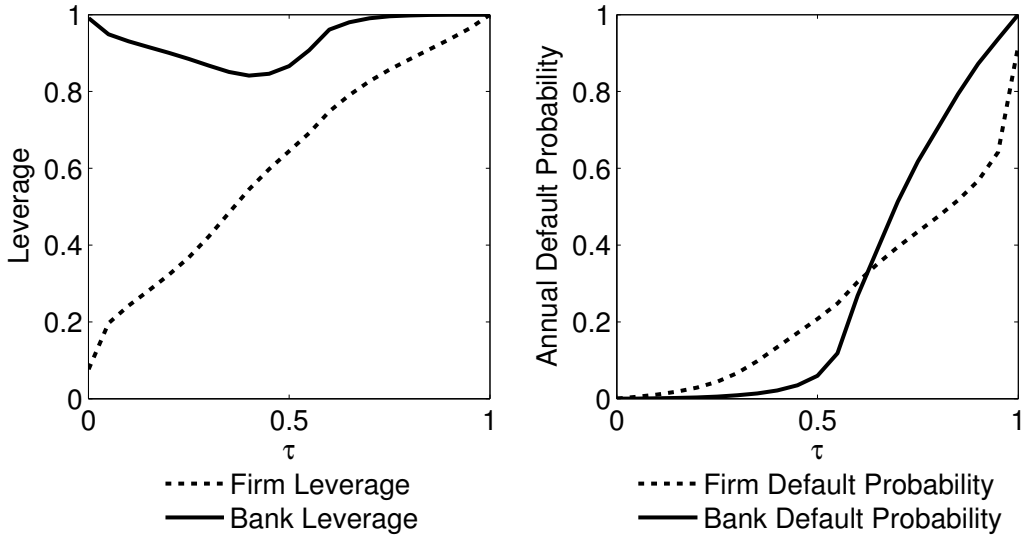
Although outside the current model, we can also comment on the effects of unexpected increases in systematic risk and volatility. After banks and firms optimally choose their leverage, and assuming there are frictions that prevent leverage adjustments, increases in systematic risk or volatility can dramatically increase bank default risk. For example, increasing asset volatility by 50% from $\sigma = 0.4$ to 0.6 raises the probability of bank default increases by an order of magnitude, from 0.53% to 15.30%. Increasing the correlation between firms to $\rho = 0.4$ causes bank defaults to triple to 1.82%. Recessions and economic downturns are often marked by unexpected increases in volatility and correlation which would lead to substantial systemic risk. Such parameter changes could dramatically increase bank risk or push many banks into distress at the same time. While outside the current model, this scenario could be added by introducing the parameter uncertainty.

Figure 7: Impact of Volatility and Systematic Risk on Leverage



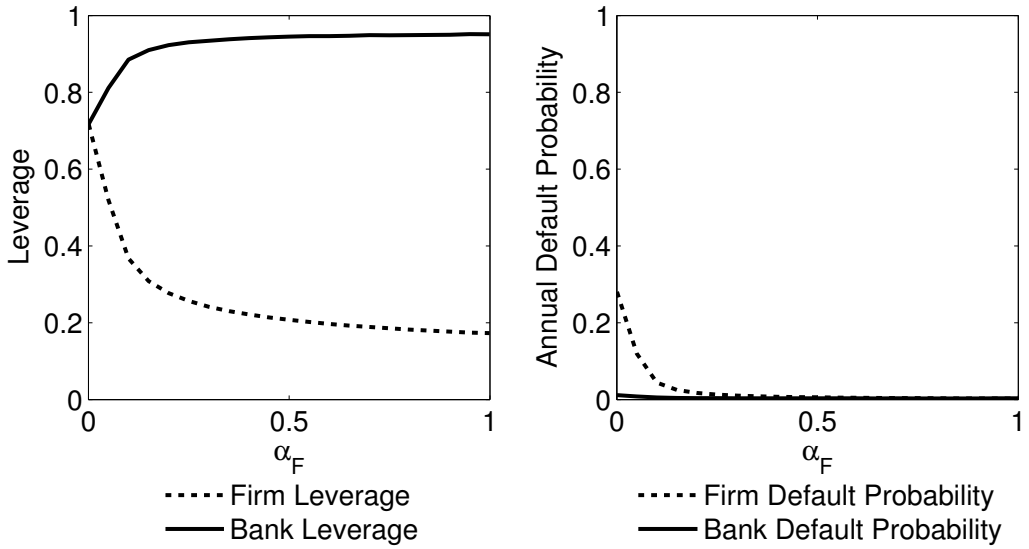
This figure shows how varying σ impacts firm (left plot) and bank (right plot) leverage at different levels of systematic risk ρ. The parameter values are $r_f = 0.05,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1$.

Figure 8: Impact of Tax Rates on Leverage and Default Rates



This figure shows how varying tax rates τ impacts the leverage and annual default probabilities of banks (solid) and firms (dotted). The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

Figure 9: Impact of Firm Bankruptcy Costs on Leverage and Default Rates



This figure shows how varying firm default costs α_F impacts the leverage and annual default probabilities of banks (solid) and firms (dotted). The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_B = 0.1,\ T = 2.5$.

4.5 Impact of Corporate Tax

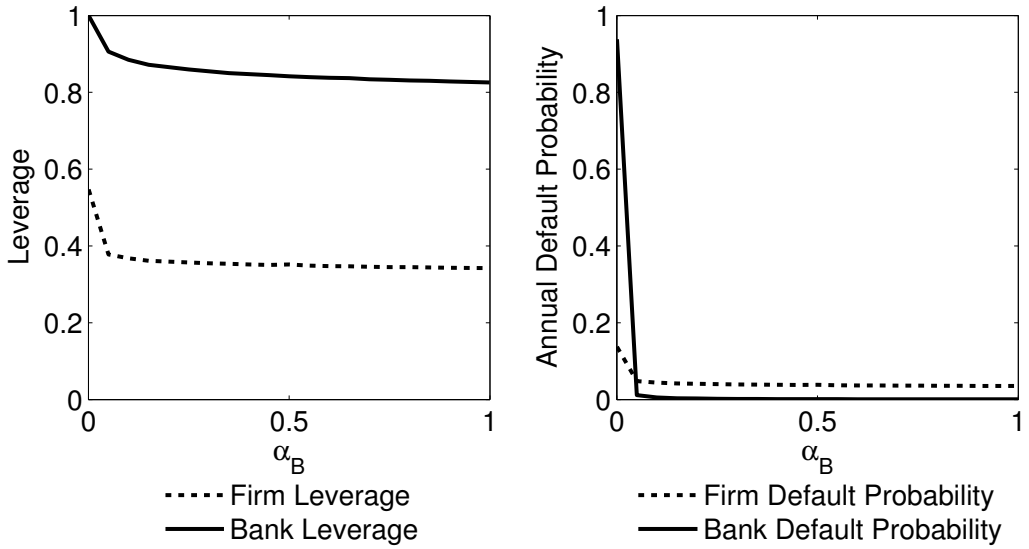
Higher corporate tax rates increase firm leverage and have a nonmonotonic effect on bank leverage, as illustrated by Figure 8. When tax rates are very low, neither banks nor firms get significant tax benefits which pushes firm leverage to zero. However, as firm leverage tends to zero bank bankruptcy costs decrease much faster than firm bankruptcy costs. Thus, when tax benefits are very low (but strictly above zero), firms have low leverage and banks have high leverage. While banks get little benefit from this high leverage, firm defaults are so rare that banks face almost no cost for their indebtedness.

As tax rates rise from zero, firm leverage increases because firms issue more debt to take advantage of the increased tax benefits. The tax benefit of debt also increases for banks; however, higher firm leverage means bank portfolios are riskier which pushes bank leverage down through the substitution effect. Initially, the substitution effect dominates. As τ tends to one, the tax effect dominates and bank leverage increases until the bank is fully levered.

4.6 Impact of Bankruptcy Costs

As shown in Figure 9, increasing the distress costs firms face decreases firm leverage but, surprisingly, *increases* bank leverage. This second effect arises because the substitution effect overwhelms the

Figure 10: Impact of Bank Bankruptcy Costs on Leverage and Default Rates



This figure shows how varying bank default costs α_B impacts the leverage and annual default probabilities of banks (solid) and firms (dotted). The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_F = 0.1,\ T = 2.5$.

impact of firm bankruptcy costs on bank risk. High firm default costs reduce creditor recovery, but the corresponding decrease in firm leverage means bank portfolio volatility actually decreases. This decreased portfolio volatility causes banks to increase their leverage.

Higher bank default costs, on the other hand, reduce both bank and firm leverage, as Figure 10 illustrates. As bank default costs increase, banks reduce their leverage to increase their equity buffer and better protect against financial distress. This impairs their ability to pass the tax benefits of debt to firms and increases the interst rates firms pay, in turn reducing firm leverage. Note that the joint effect of the supply chain mechanism and diversification ensures that even for very high bank bankruptcy costs banks still opt for relatively high debt levels. Bank portfolios are safe and banks choose high leverage even when they internalize high bankruptcy costs.

5 Moral Hazard and Leverage

Government interventions such as bailouts and deposit insurance subsidize financial distress. We find that bailouts and deposit insurance can have a substantial impact, not only on bank behavior but also on the capital structure decisions of the non-financial sector. Expectations of government support not only provide banks with bad incentives, but they change the way banks price risk which pushes firms toward higher leverage. In Section 6, we extend this analysis to incorporate bank capital regulation.

5.1 Deposit Insurance

Government-backed deposit insurance schemes protect bank depositors from the costs of bank failure. In the U.S., the FDIC is a deposit insurance scheme explicitly guaranteed by the federal government that all deposit-taking institutions participate in. As we show in this section, deposit insurance can distort bank and firm capital structure decisions in the same way as bailouts.

Let D be the amount of insured depositors a bank has at date 0. We assume that insured deposits make up a constant portion of the bank's liabilities, $D = \gamma V_{BD}$.[18] Because insured depositors are guaranteed to receive their investment back, their debt is risk-free and at time T they are owed De^{Tr_f} by the bank.

The class of insured depositors can be thought of as a separate class of debt. The payout to the residual debt holders (uninsured depositors and other creditors) is $R_B - De^{Tr_f}$ if the bank survives and $\max\left\{0, (1-\alpha_B)B - De^{Tr_f}\right\}$ if the bank defaults. The value of the residual debt holders' claim at date 0 is

$$\begin{aligned}(1-\gamma)V_{BD} &= e^{-Tr_f}(R_B - De^{Tr_f})\mathbb{P}\left[B \geq R_B\right] \\ &\quad + e^{-Tr_f}\mathbb{E}\left[\max\left\{0, \left((1-\alpha_B)B - De^{Tr_f}\right)\right\}\mathbb{I}\left[B < R_B\right]\right]. \end{aligned} \tag{23}$$

Adding this to the value of insured deposits, the total value of the bank's debt is

$$\begin{aligned}V_{BD} &= \underbrace{e^{-Tr_f}R_B\mathbb{P}\left[B \geq R_B\right] + e^{-Tr_f}\mathbb{E}\left[(1-\alpha_B)\mathbb{I}\left[B < R_B\right]\right]}_{\text{Debt value without deposit insurance}} \\ &\quad + \underbrace{e^{-Tr_f}\mathbb{E}\left[\max\left\{0, De^{Tr_f} - (1-\alpha_B)B\right\}\right]}_{\text{Value of deposit insurance}}. \end{aligned} \tag{24}$$

Figure 11 shows the impact of varying the amount of insured deposits on the leverage and default likelihood of banks and firms. Two results can be gleaned from the figures. First, moderate levels of insured deposits cause only slight changes in bank capital structure. Deposit insurance is essentially a deep out of the money put option on the bank's portfolio value. Section 3 shows that bank portfolio volatility is low, which means this put option has little value because losses large enough to trigger deposit insurance are unlikely. As with the deductibles seen in personal insurance markets, forcing the claimant (the bank) to pay the first dollar of losses (using equity and uninsured debt) dramatically reduces moral hazard. Another way to view this effect is to view the bank's equity as a deductible. These same factors cause deposit insurance to have little impact on firms' financial strategies.

Second, high levels of insured deposits cause banks to pursue high risk strategies. If the bank receives a subsidy on losses in the form of a generous deposit insurance scheme, that bank pursues a high-leverage

[18] Assuming D is proportional to the bank's assets produces similar results.

strategy. For our benchmark parameters, the bank switches to a risk-seeking strategy that exploits the government guarantee when insured deposits make up more than 94% of its liabilities. Empirical evidence supports the idea that some banks pursue a risky strategy and others pursue safer strategies. Lambert, Noth, and Schüwer (2012) find that while a plausibly exogenous increase in loan risk causes well capitalized banks to increase their capital buffers and shift into less risky loans, poorly capitalized banks are less likely to follow this path. Note that this analysis need not hold for parameters that make bank volatility very large. For example, increasing σ to 0.6 and ρ to 0.3 decreases the critical level of deposit insurance to 80%. Section 6.4 provides a more detailed analysis of the impact of parameter variation.

According to FDIC data for Q1 2013, the median bank in the U.S. has insured deposits equal to 79% of liabilities, with a 75th percentile bank having insured deposits equal to 85% of liabilities.[19] 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 bank 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.

5.2 Bailouts

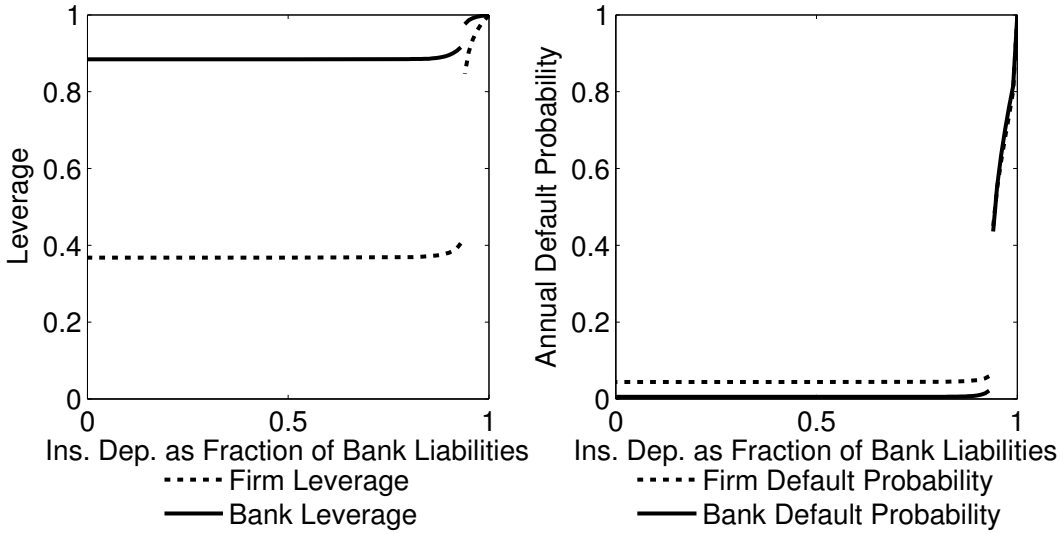
Bailouts of financial institutions can take many forms. At their root is a transfer of taxpayer funds to support the assets or honor liabilities of a weakened financial institution.[20] While taxpayers often receive securities as compensation for this transfer, these securities are generally worth less than the transfer, at least at the time of the bailout.

We consider two types of bailouts that shaped a number of recent interventions. First, the government can guarantee a financial institution's debt. Second, the government buy a financial institution's equity at a below-market valuation. In either case, what is important for the ex-ante capital structure decisions is ex-ante expectations of such bailouts by private decision-makers.

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

[20] Some bailouts are accomplished through means other than an explicit transfer, or promise thereof, of taxpayer funds. Coercion of private companies (e.g. Long Term Capital Management), printing to buy bank assets (aspects of quantitative easing), or waiver of traditional competition laws (Lloyds-HBOS merger) can also aid failing banks and have a similar effect on bank capital structure as they are all subsidize poor performance.

Figure 11: Impact of an Insured Deposit Base Proportional to Liabilities on Leverage and Default Rates



This figure shows how insured deposits impact the leverage and annual default probabilities of banks (solid) and firms (dotted). The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

5.2.1 Debt Guarantees

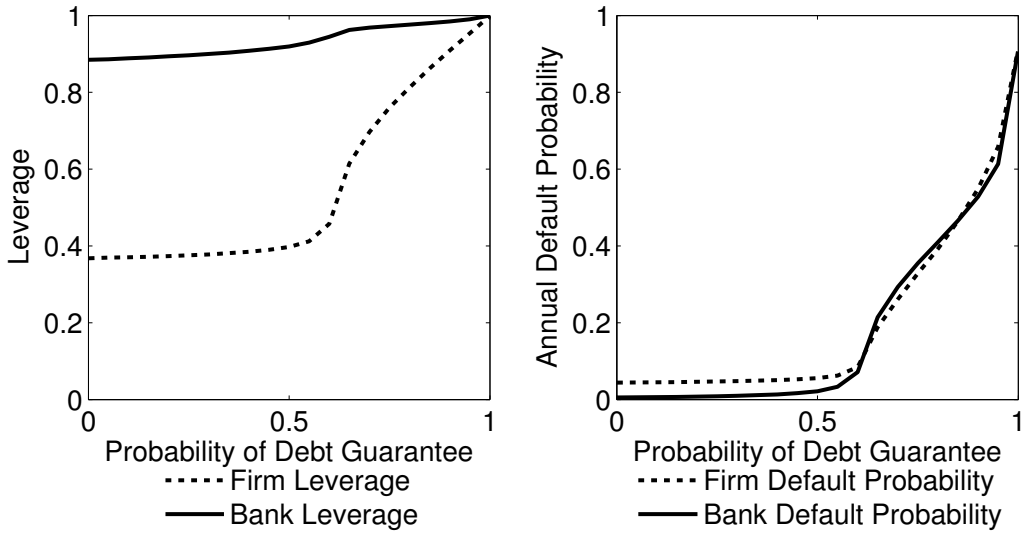
At the time a bank issues debt, market participants may expect that if the bank finds itself in distress and unable to fulfill its debt obligations, the government will step in and guarantee the failing bank's debt. This response may be contingent upon macroeconomic, macrofinancial, and political concerns. Abstracting beyond those considerations, suppose that the market's expectation is that with some probability, θ, the government will step in and guarantee a failing bank's debt; otherwise that bank will be allowed to fail.

If the government intervenes, the defaulting bank's creditors recover the full value of their initial investment, V_{BD}, and are also paid the interest at risk-free interest of r_f. Note that the bailout still results in creditors' losses relative to the non-default state, because $R_B < V_{BD}e^{Tr_f}$. The bank's date-0 debt value still increases because the possibility of a bailout increases the expected recovery in default. The value of a bank's debt when there is a θ probability of a government guarantee is then

$$V_{BD} = e^{-Tr_f} R_B \mathbb{P}\left[B \geq R_B\right] + e^{-Tr_f} \mathbb{E}\left[\theta V_{BD} e^{Tr_f} + (1-\theta)(1-\tau)(1-\alpha_B) B \mathbb{I}\left[B < R_B\right]\right]. \qquad (25)$$

Guaranteeing debt creates moral hazard for the bank at the time of a capital structure decision, because all the ex-post benefits of a bailout are internalized by the bank equity holders in the presence

Figure 12: Impact of Debt Guarantee Expectations on Leverage and Default Rates



This figure shows how debt guarantees impact the leverage and annual default probabilities of banks (solid) and firms (dotted). The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

of competitive capital markets. The bank is subsidized in the states of the world where it defaults, and thus is incentivized to increase its leverage in order to take advantage of those subsidies. Figure 12 illustrates how bank leverage increases as bailouts become more likely. Banks are less worried about default if the government bears some of their bankruptcy costs. Firm leverage also increases as bank bankruptcy costs become less material and banks are able to pass along the tax benefits of debt more effectively. If bailouts are seen as very likely (above about a 60% probability for our benchmark set of parameters), banks suffer extreme moral hazard. At this point, as the gains from taxpayer-subsidized gambling overwhelm the gains from legitimate lending, and banks choose to pursue extremely high leverage and lend to very risky firms.

Table 4 shows that bank default risk quadruples from the baseline if the probability of a bailout is 50%. If the probability rises to 75%, the likelihood of bank default increases by a factor of seventy and the bank shifts to a risk seeking strategy with very frequent defaults.

5.2.2 Equity Injections

Alternatively, market participants may expect a bailout in the form of a purchase of a bank's equity at an above market price. This form of bailout was frequently employed by regulators during the recent financial crisis. For example, a number of U.S. financial institutions, such as Citigroup and Bank of America, participated in the TARP program, in which the government purchased common

and preferred equity from troubled institutions. The Royal Bank of Scotland in the U.K. received a massive injections of equity in dire circumstances and is still majority owned, at the time of writing, by the U.K. government.

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 is solvent after receiving the cash. In our notation, suppose that when $R_B > B > R_B - \nu$ the government steps in with probability θ and gives the bank equity holders the tax-free amount of ν in exchange for m portion of the bank's equity.[21]

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

As the bank's original equity holders benefit from bailouts, the possibility of bailouts changes the bank's time-0 equity value (9) to

$$\begin{aligned} V_{BE} = {} & e^{-Tr_f}\mathbb{E}\left[\left(B - \tau \max\left\{0, B - V_{FD} - R_B + V_{BD} - R_B\right\}\right)\mathbb{I}\left[B \geq R_B\right]\right] \\ & + e^{-Tr_f}\theta(1-m)\mathbb{E}\left[\left(\nu + B - R_B\right)\mathbb{I}\left[R_B > B > R_B - \nu\right]\right]. \end{aligned} \tag{26}$$

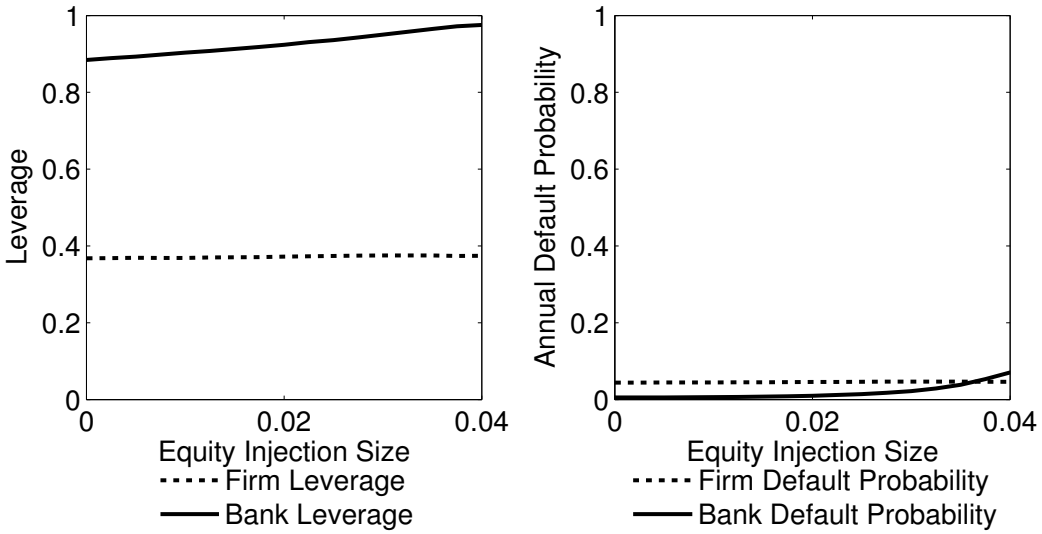
The bank's creditors also benefit as they are now fully repaid in some states of the world where the bank would have defaulted. The bank's debt value formula is adjusted to reflect the reduced bankruptcy risk:

$$\begin{aligned} V_{BD} = {} & e^{-Tr_f}R_B\mathbb{P}\left[B \geq R_B\right] + e^{-Tr_f}\mathbb{E}\left[(1-\alpha_B)B\mathbb{I}\left[B < R_B\right]\right] \\ & + e^{-Tr_f}\theta\mathbb{E}\left[\left(R_B - (1-\alpha_B)B\right)\mathbb{I}\left[R_B > B \geq R_B - \nu\right]\right]. \end{aligned} \tag{27}$$

This form of bailout also creates moral hazard. Figure 13 illustrates the leverage in the economy as the size of the equity injection varies from 0 to 0.04. 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 88% to 98%. 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

[21] To prevent degenerate strategies, we assume the bank will not receive an equity injection if the amount it has promised its creditors R_B is greater than the R_F it would receive from borrowers in the best state of the world.

Figure 13: Impact of Equity Injection Expectations on Leverage and Default Rates



This figure shows how the size of a potential equity injection, ν, impacts the leverage and annual default probabilities of banks (solid) and firms (dotted). The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5,\ \theta = 0.5,\ m = 0.5$.

bailouts causes the bank to take so much additional risk that the bank's default likelihood actually increases, despite the bank being saved 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.

To summarize, both the bailouts we have considered generate moral hazard for financial institutions. Small interventions have only a very small effect on risk taking, but if bailout expectations get high enough banks shift to destructive risk seeking strategies.

6 Capital Regulation

Capital regulation that restricts bank financing is a key weapon regulators use to combat excessive risk taking. Preventing banks from issuing excessive debt reduces banks' incentive to risk-shift and insulates bank creditors from loss. Capital regulation policies, their cost and impact have been at the center of recent debates by both practitioners and academics. We find that capital regulation reduces bank leverage, but it can increase firm leverage by changing the way banks price risk. The overall efficiency impact of capital regulations is thus unclear.

While capital regulation takes many forms, the international standards laid out in Basel II framework and those proposed in its successor Basel III form widely accepted benchmarks. Basel II and its

successor give banks a choice of what regulatory standard to work under. Smaller and less sophisticated banks can use what is known as the Standardized Approach that uses simple risk weights for different types of assets. Larger banks may also apply what is known as the Internal Ratings-Based Approach, where a bank's equity requirements are calculated using outputs from the bank's own models. In the following sections, we apply these two regulatory approaches to our model and examine how effectively these regulations combat the incentive problems introduced by bailouts and deposit insurance. These regulatory structures are complicated and so, for our purposes, we focus on equity standards and use simplified models.

6.1 Basel Capital Regulation: Standardized Approach

Under the Standardized Approach of the Basel II and III frameworks, bank need to hold equity capital equal to a constant fraction of their risk-weighted assets. This section discusses the impact of such exogenous limits on bank leverage. We model this type of limit by forcing the bank to have equity capital above some h portion of the bank's asset value, so that

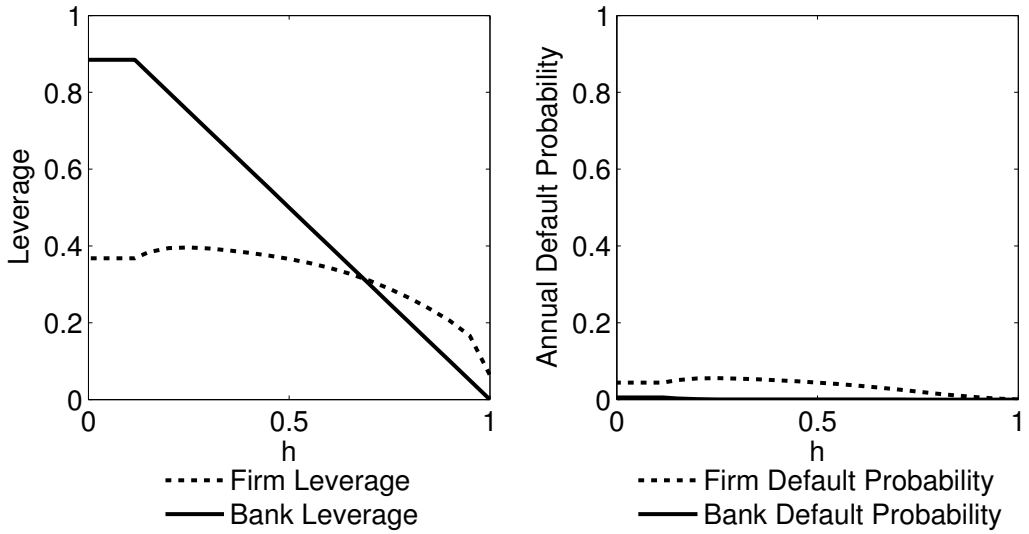
$$V_{BE} \geq hV_B. \tag{28}$$

We set h to 0.08, so that a bank needs to hold eight cents of equity capital for every dollar of assets, based off the Standardized Approach in Basel II and III.

There are several important caveats. First, capital regulation is usually defined in terms of the book value of assets and the book value of equity. Under our model, the time-zero book value and market value are equal as the bank is zero profit. Second, different assets have different risk weightings. Unrated corporate debt has a risk weighting of 100%, so we focus on that as a class. Rated corporate debt can fall into several buckets, and so the effects in this section would be within bucket effects that push corporate debt to be as risky as possible while falling in a given bucket. Finally, we model the Standardized Approach using an equity ratio of 0.08; however, the Basel II and Basel III frameworks are much more complicated. Banks face multiple capital requirements which can be satisfied using a multitude of securities. Depending on one's intent, a more appropriate number could be anywhere from 0.025, the common equity mandate from Basel II, to 0.13, the maximum mandate from Basel III with full capital conservation and countercyclical capital buffers. We focus on $h = 0.08$ for simplicity and later explore effects of varying h.

Figure 14 illustrates the impact of imposing bank leverage limits. As in Section 3, bank and firm leverage act as strategic substitutes for moderate capital regulation (relatively low values of h.) Limiting bank leverage causes banks to borrow less, but paradoxically causes firms to borrow more. This effect arises because firms borrowing from a leverage-constrained bank pay lower incremental costs for systematic risk and face incentives to become riskier. Our analysis suggests that this effect dominates over the levels of capital regulation seen in practice. Capital regulation causes the real sector of the

Figure 14: Impact of Bank Leverage Limits on Leverage and Default Rates



This figure shows how capital regulation that mandates an equity capital to asset ratio above h impacts the leverage and annual default probabilities of banks (solid) and firms (dotted). The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

economy to borrow more and become riskier, as witnessed by higher default probability of firms. When capital regulation standard are sufficiently tight, i.e. when h is high, bank and firm leverage act as strategic complements as low-levered banks are unable to pass along the tax benefits of debt. Note capital regulation has an ambiguous effect on firm leverage, but always increases firm borrowing costs because constrained banks are less efficient at passing down debt benefits.

Lax capital regulation makes firms less stable, which in its turn has an impact on banks. The plausible analogue of this that we can observe in practice is that a bank subject to capital regulations may find it in its interests to circumvent the regulation by making riskier loans as a back door way to increase its leverage. These capital restrictions distort bank lending preferences, which may cause a non-trivial spill over into the real economy.

Our leverage limit of $h = 0.08$ does not bind for a bank not subject to moral hazard, but it can reduce the risk taking associated with deposit insurance and bailouts as shown in Columns 3 and 4 of Table 5. Setting h to at least 0.08 mitigates the risk-seeking strategies of the flavor discussed in Sections 5.2 and 5.1. Forcing banks to maintain an equity buffer reduces the bank's ability to exploit government bailouts. However, Table 5 shows that banks still experiance extreme moral hazard when 95% of their liabilities come from insured deposits, a situation we earlier argued was very reasonable. Further, this form of capital regulation causes banks to make riskier loans, especially in the presence of bailouts.

Summing up, simple leverage limits may be ineffective, insofar as they encourage banks to make risky loans and change the structure of borrowing in the real economy. In Section 6.4, we explore another path the banks may take to increase leverage – hiking up the correlation risk of their loan portfolio.

6.2 Basel Capital Regulation: Internal Ratings-Based Approach

Simple leverage limits may push banks toward risky lending. One countermeasure is to better risk weigh assets. Basel II and III include this type of capital regulation as an option for banks.[22] The risk-weighting formulas the regulatory framework uses is based on the Vasicek structure that underlies our analysis. Banks are required to maintain equity capital in excess of a formula-imposed floor. This floor, $K\ V_{FD}$, is the value of the bank's assets multiplied by an exposure-based risk weighting K, which is calculated as

$$K = \left[LGD * \Phi \left(\sqrt{\frac{1}{1-\hat{\rho}}} \Phi^{-1}(PD) + \sqrt{\frac{\hat{\rho}}{1-\hat{\rho}}}\ \Phi^{-1}(0.999) \right) - LGD \times PD \right]\ \frac{1+(T-2.5)b}{1-1.5b}, \quad (29)$$

where PD is the default probability, LGD is loss given default, $\hat{\rho}$ is the imputed correlation given by Equation (22), and b, the maturity adjustment, is calculated as

$$b = (0.11852 - 0.05478 * \ln(PD))^2. \quad (30)$$

The formulas in Equations (29) and (30) are copied from paragraph 102 in the current Basel III proposal from the Basel Committee on Banking Supervision (2013).[23] We calculate proxies for PD and LGD from our model.[24]

As with the Standardized approach, this form of capital regulation is not binding for our base case parameters – if banks pay their own default costs, their without-regulation debt levels satisfy this form of capital regulation. The real effect of this type of capital regulation is in preventing the moral hazard induced by government interventions, as the last two columns of Table 5 show. Without capital regulation, banks increase their leverage in order to benefit from the effective put option the

[22]The U.S. implementation of Basel III requires the largest banks use this approach in addition to the Standardized Approach. See the Report by Office of the Comptroller of the Currency and the Board of Governors of the Federal Reserve System (2013) for more details on the U.S. implementation of Basel III.

[23]There are two flavors of the Basel Internal Ratings-Based Approach - Foundation and Advanced. Under the Foundation Internal Ratings-Based Approach, parameters such as loss given default and maturity are given by the Basel Committee on Banking Supervision. The use of these prescribed values (a maturity of 2.5 and, for unsecured exposures, a loss given default of 45%) may be optional or mandatory depending on the national regulator. See Basel Committee on Banking Supervision (2002) for more detail. In the interests of space, we apply the Advanced Approach for our analysis – the Foundation Approach yields similar values.

[24]For simplicity, we calculate the loss given default and the probability of default using the pricing measure rather than the real world measure. Real world values, as are used in regulation, would loosen the capital requirements and reduce bank equity requirements; however, this effect is small for our parameters and reasonable equity risk premia.

government provides with deposit insurance or bailouts. In the unregulated case, banks respond to very high levels of deposit insurance or bailouts by taking on more leverage and defaulting more frequently. Note that, as detailed in Sections 5.1 and 5.2, such strategies are only profitable in the presence of very large government interventions.

6.3 Efficiency Cost of Capital Regulation

Capital regulation can substantially reduce moral hazard; however, any interference with bank financial structure reduces the efficiency of the banking sector and increases the interest rates charged to borrowing firms. This section looks at the trade off between removing inefficient moral hazard and the cost of capital regulation.

We find that capital regulation slightly increases the interest rates paid by borrower firms: Increasing equity capital requirements by one percentage point increases firm interest rates by at most 1.5 basis points, as illustrated in Figure 15. This estimate is almost an order of magnitude lower than that produced by analysis such as Basel Committee on Banking Supervision (2010) that assume bank return on equity is fixed and exogenous.[25] This suggests that strengthening capital regulation may not be as costly as sometimes argued. For example, recent attempts by regulators to tighten capital regulation led them to be described as the "capital Taliban" with the implication that such changes would starve businesses of loans.[26] Our model does not support this conclusion, at least in the long run.

Table 6 gives a more detailed breakdown of the costs of financial frictions with and without capital regulation. In addition to a no-regulation case (column 1), we consider two regulatory setups: a simple leverage limit as in the Basel Standardized Approach (2 and 3) and a Vasicek-model based limit as in the Basel Internal Ratings-Based Approach (4 and 5). For each of these approaches, we consider the current regulation and a hypothetical regulation with a doubled equity requirement.

Panel A looks at the effect of regulation on a bank without bailouts or deposit insurance. Four patterns are apparent. First, the cost of bank bankruptcies is substantially smaller than the cost of firm bankruptcies, because firms fail much more frequently than banks and correspondingly firm failures destroy more value. Second, capital regulation may actually *increase* the total value destroyed in bankruptcy. Simple leverage limits on banks, as in the Basel Standardized Approach, cause firms to increase their leverage through the substitution effect. For our parameters, this effect is strong enough to dominate the benefit of safer banks. Note that both this and the first point take into account only the private costs of bank bankruptcy and ignore the potentially much larger social costs of bank

[25] Such approaches ignore the fundamental effects of bank leverage on the cost of equity as implied by Modigliani and Miller (1958). Admati, DeMarzo, Hellwig, and Pfleiderer (2011) provide an extensive discussion of this error in the context of bank regulation.

[26] Refer to Parker, Goff, and Rigby (2013) for the full story.

failure. Finally, the overall cost of capital regulation is relatively small, as in Figure 15. Doubling the strength of current regulation would reduce the firm return on assets by at most four basis points.[27]

Panel B repeats this analysis on a bank subject to bailouts and deposit insurance. Specifically, we consider a bank with an insured deposit base equal to 85% of its liabilities, subject to a debt guarantee with a 25% probability, and with a 50% probability of receiving an equity injection of 1% of total assets in exchange for 50% of the ex post bank's equity value, as described in Sections 5.1, 5.2.1, and 5.2.2, respectively. Adding moral hazard means that all forms capital regulation now bind; however, capital regulation is not especially valuable as the bank's moral hazard is not especially strong. The total value of debt guarantees, equity injections, and deposit insurance we described is relatively small compared to tax benefits.

Note that this analysis only considers the private costs of bank failure. The social costs of failed banks may be much greater and may show higher value in capital regulation. However, our analysis suggests that, at least from the bank's perspecitve, the value of tax benefits may be much larger than the value of deposit insurance or bailouts. If the regulators want banks to reduce risks in an efficient manner, eliminating the distortions created by the tax benefit of debt may be of more importance than reforming too-big-to-fail or deposit insurance.

6.4 Systematic Risk as a Choice Variable

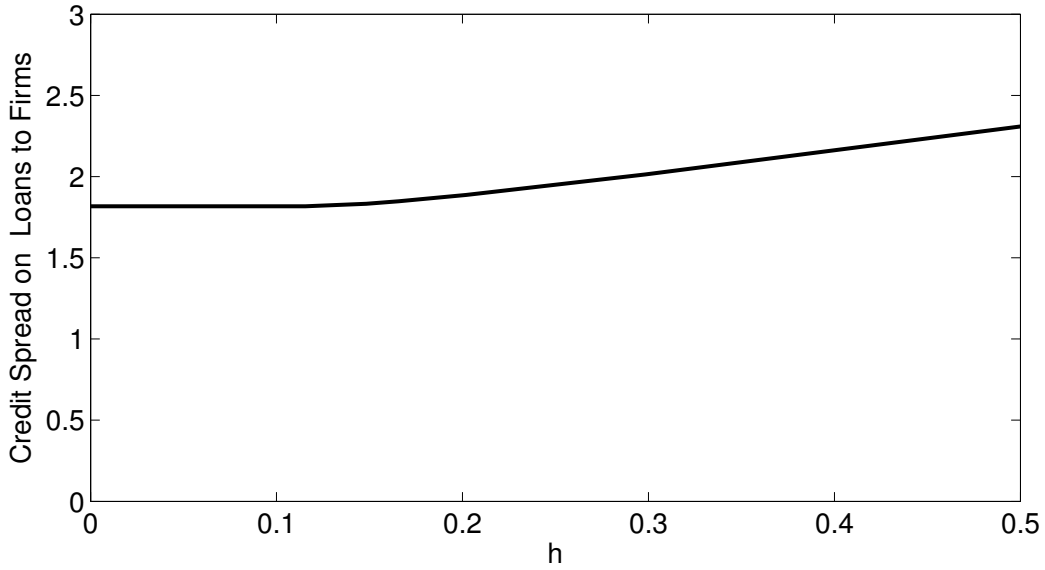
The Basel IRB Approach is effective at preventing bank failure in our model partially because the bank's portfolio value is modeled using the assumptions that underlie the IRB framework. In the real world, substantial model risk exists. Banks faced with binding capital regulation may try to find back doors to increase their risk.[28] Under our base model, backs subject to leverage limits accomplish this by lending to riskier firms. In this section, we examine the impact of allowing banks to directly increasing the risk of the underlying bank portfolio by manipulating their systematic exposure.

So far, the level of systematic risk, ρ, has been kept exogenous. In reality banks can choose not only the riskiness of individual loans but also their exposure to systematic risk. This might be achieved by increasing exposure to borrowers with high systematic risk or simply similar risk. The Basel IRB framework assesses correlation based simply on default probability, as in Equation (22), and so would not prevent this type of manipulation. Increasing the systematic risk increases the bank's asset volatility. Outside of our model, banks could similarly increase their portfolio volatility through the

[27] The difference between the four basis point figure here and the 1.5 basis point per percentage figure arises from two sources. First, the impact on return on investment is lower than the impact on credit spreads because the denominator of the former is assets and the denominator of the later is debt. Second, the marginal cost of capital regulation is increasing as additional bank equity capital increases tax costs at a constant rate and decreases bank default costs at a decreasing rate.

[28] Acharya and Richardson (2009) suggest the pursuit of such back doors was one of the causes of the financial crisis.

Figure 15: Impact of Capital Regulation on Bank Loan Credit Spreads



This figure shows how capital regulation impacts the credit spreads firms pay when borrowing from banks . Spreads are calculated as the excess of the interest rate a firm pays over the risk free rate. We fix firm borrowing, with firms always pledging 29% of their expected cash flows (this makes firm borrowing optimal in the no-regulation case). The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

use of financial derivatives, off balance sheet assets, or other risk exposures. Increasing the bank's risk makes the bank more likely to fail and the financial system more fragile, but it also increases the payoff of the gambling strategy by more effectively exploiting subsidies such as deposit insurance and bailouts.

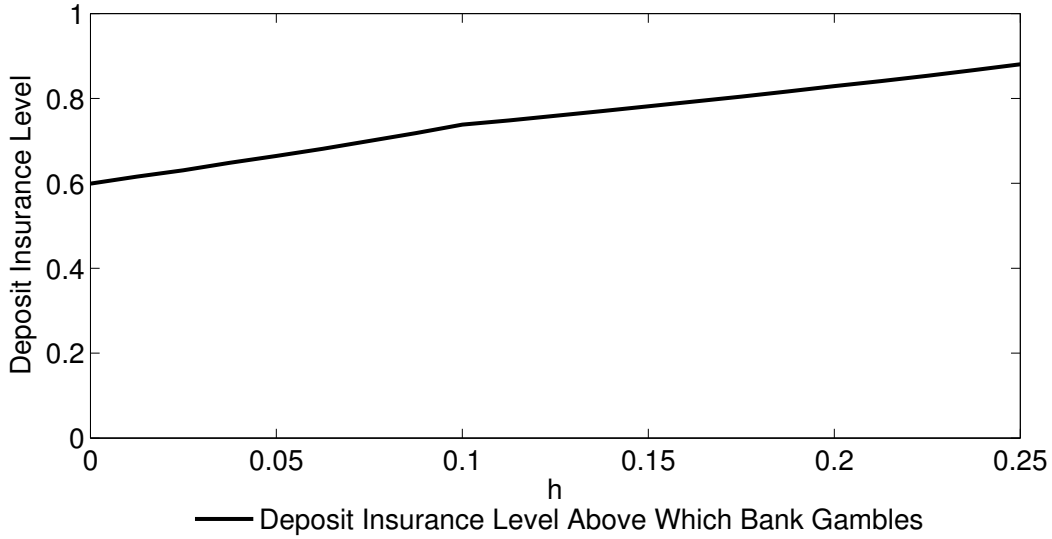
To consider an important example, suppose banks can choose between two types of portfolio risk. They can either make perfectly diversified loans with $\rho = 0$ or make perfectly correlated loans with $\rho = 1$. Of course, it represents a rather extreme case, but in the absence of readily available empirical data it would illustrate well the type of behavior and risks that can arise in our framework. Anecdotal evidence from the recent financial crisis indicates that financial institutions can easily become overexposed to systematic risk if they wish to do so.

Giving banks the option to increase systematic risk dramatically increases the moral hazard posed by bailouts or deposit insurance, which makes capital regulation much more important. Figures 16 and 17 show how capital regulation impacts a bank's choice between the $\rho = 0$ safe strategy and the $\rho = 1$ gambling strategy. Tight capital regulation helps mitigate the additional moral hazard and makes banks less willing to gamble. While capital regulation reduces the payoffs of both the safe and gambling strategies, it reduces the payoff of the gambling strategy much more and so makes the bank less likely to choose the gambling strategy. A bank financed almost-entirely by equity would not purse the gambling strategy even if all liabilities were insured. As capital regulation is eased, banks pursue the gambling strategy more often. In the extreme, when there is no capital regulation, banks choose the gambling strategy if more than 74% of their liabilities are insured deposits or the bank has a 24% chance of receiving a debt guarantee in the event of failure.

An equity capital requirement of $h = 0.08$, as in our model of the Basel Standardized Approach, means that the bank gambles if insured deposits make up more than 71% of liabilities or the chance of a bank debt is guarantee is greater than 30%. Given the average level of deposit insurance is well above that and there is arguably a high chance of government bailouts, current capital regulation may be insufficient, at least to the extent that banks can manipulate their risk. Unreported, when we implement the same approach using the Vasicek-style IRB capital regulation we get similar results with less severe moral hazard. The efficiency cost analysis from the previous section suggests doubling current equity requirements would not be especially costly and our figures suggest this would substantially bank incentives to gamble.

Beyond the level of capital regulation, Figures 16 and 17 show that moral hazard is increasing in the degree of bailouts and deposit insurance. To prevent misbehavior, banks with more moral hazard need tighter capital regulation. Banks funded primarily with insured deposits should be subject to stricter equity requirements, as should banks that are implicitly too-big-to-fail. These banks have stronger incentives to misbehave, and capital requirements that take this into account could increase efficiency.

Figure 16: Impact of Deposit Insurance on Bank Gambling for Varying Capital Regulation



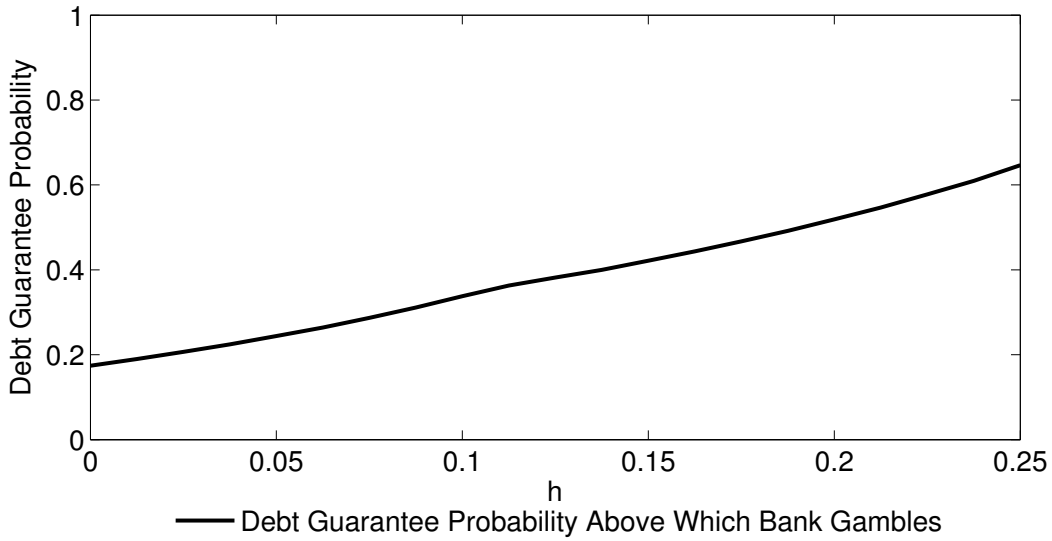
This figure shows how capital regulation impacts a bank's choice to gamble in response to deposit insurance. The solid line marks the level of deposit insurance (as a portion of bank liabilities) that makes a bank indifferent between the safe and gambling strategies. For levels of deposit insurance above the line, the bank chooses the $\rho = 1$ gambling strategy. For levels of deposit insurance below the line, the bank chooses the $\rho = 0$ safe strategy. The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

Basel III includes additional capital requirements for systemically important financial institutions, our analysis suggests banks funded primarily by deposits should be subject to similar regulation.[29]

Other parameters also influence a bank's choice of strategy. For example, Figure 18 shows the impact of asset volatility on bank strategy choice in the presence of deposit insurance. When volatility is very high, even small amounts of insured deposits cause the bank to gamble. As before, adding capital regulation reduces the relative benefit of gambling and causes the bank to gamble only for higher levels of deposit insurance. However, banks still have an incentive to gamble for high levels of volatility. In reality, asset volatility is time varying and likely higher in recessions, so banks are would be more likely to gamble in worse states of the economy. This suggests that current forms of capital regulation are likely insufficient to curb these incentives, especially during recessions.

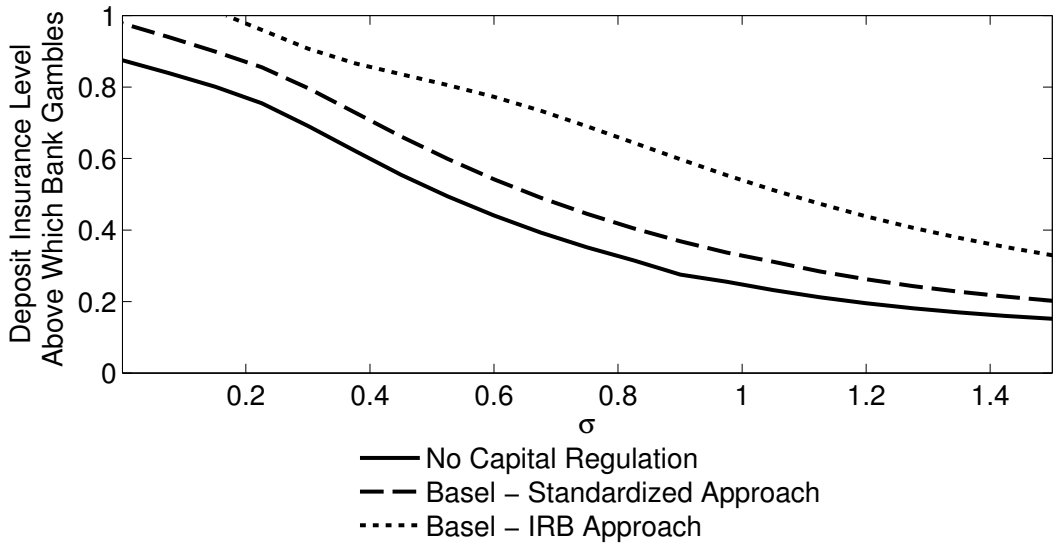
[29]Refer to Basel Committee on Banking Supervision (2011) for more details on additional capital requirements for systemically important financial institutions.

Figure 17: Impact of Debt Guarantee Expectations on Bank Gambling for Varying Capital Regulation



This figure shows how capital regulation impacts a bank's choice to gamble in response to debt guarantees. The solid line marks the probability of debt guarantee that makes a bank indifferent between the safe and gambling strategies. For debt guarantee probabilities above the line, the bank chooses the $\rho = 1$ gambling strategy. For debt guarantee probabilities below the line, the bank chooses the $\rho = 0$ safe strategy. The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

Figure 18: Impact of Deposit Insurance on Bank Gambling for Varying Volatility



This figure shows how volatility impacts a bank's choice to gamble in response to deposit insurance. The solid line shows the level of deposit insurance (as a portion of bank liabilities) that makes a bank indifferent between the safe and gambling strategies with no capital regulation. The dotted and dashed lines show the same under the Basel II Standardized Approach and Internal Ratings-Based (IRB) Approach, respectively. The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

7 Bank Bargaining Power

Our benchmark model assumes the banking industry is perfectly competitive, while in reality banks are extremely profitable. This section explores how changing the division of surplus between firms and banks impacts financial decisions. We find that altering the bargaining power and hence profitability of banks has only a small impact on our results.

Let π be the excess of a levered firm's value (21) over a comparable unlevered firm's value:

$$\pi = V_F - (1-\tau)e^{-Tr_f}. \tag{31}$$

This can be thought of as the total net benefit of debt in the economy. Of course, π is a function, through V_F, of firm and bank debt issuance.

Suppose the bank has bargaining power ω and can therefore capture an ω fraction of the time-0 surplus. A perfectly competitive bank is associated with $\omega = 0$, while a bank that has full bargaining power that captures all the surplus is associated with $\omega = 1$. Changing the bank's bargaining power changes V_{FD}, which affects the total surplus.

The last two rows of Table 4 show that giving banks more bargaining power marginally increases bank leverage. Banks with higher bargaining power are more profitable and face larger tax bills that push them towards more borrowing. Firm leverage also increases, as firms have higher interest tax deductions. The size of the effect is small. In the base case, bank leverage increases from 88.4% for a perfectly competitive bank to 89.9% for a bank that captures all the surplus. The effect is small because the economic mechanisms we have identified are largely independent of the recipient of the profits. Moving profits from firms to banks simply moves the incidence of taxes up the financing supply chain from firms to banks. Net tax benefit creation is only impacted at the margin and financial structure therefore changes minimally.

8 Bond Markets

Banks are not the only sources of debt financing for firms. Trade credit and public debt also play an important role. This section explores the implications of a richer firm financing structure, concentrating on corporate bond financing. Intuitively, the most important economic mechanism in play is the seniority of bank financing. Banks are typically senior creditors and take losses only after other creditors are wiped out, if the absolute priority rule (APR) is adhered to. Thus, effectively, we assume the seniority of bank debt and explore how adding junior debt into the picture changes bank and firm financing and default patterns.

In the base model, where firms borrow only from banks, R_F denotes the firm's debt obligation to the bank. With multiple sources of funding, we use R_F as the total debt repayment promised by the firm, and R_L as the amount the firm agrees to repay to the bank. The remaining $R_F - R_L$ of the firm's repayment is promised to the firm's bondholders. If the firm is solvent at loan maturity, i.e. if $F^i \geq C_F$, the bank and the firm's bondholders are repaid in full. Otherwise, the firm defaults. In default, the bank's seniority and the APR mean it is paid first:

$$\min\left\{R_L, (1-\alpha_F)(1-\tau)F^i\right\}. \tag{32}$$

The firm's bondholders get the residual value, if any, that remains after the firm's bank debt is paid:

$$(1-\alpha_F)(1-\tau)F^i - \min\left\{R_L, (1-\alpha_F)(1-\tau)F^i\right\}. \tag{33}$$

The payoff to the bank from a single loan is derived in a similar way as in the benchmark model, with Equation (2) adjusted by taking into account the bank's added seniority:

$$B^i = R_L \mathbb{I}\left[F^i \geq C_F\right] + \min\left\{R_L, (1-\alpha_F)(1-\tau)F^i\right\}\mathbb{I}\left[F^i < C_F\right]. \tag{34}$$

The bank's equity and debt values are then still given by Equations (9) and (10).

The value of the firm's bond issuance, V_M, is the discounted payoff of the residual debt claim:

$$V_M = e^{-Tr_f}(R_F - R_L)\mathbb{P}\left[F^i \geq C_F\right] + e^{-Tr_f}\mathbb{E}\left[\max\left\{0, (1-\alpha_F)(1-\tau)F^i - R_L\right\}\mathbb{I}\left[F^i < C_F\right]\right]. \tag{35}$$

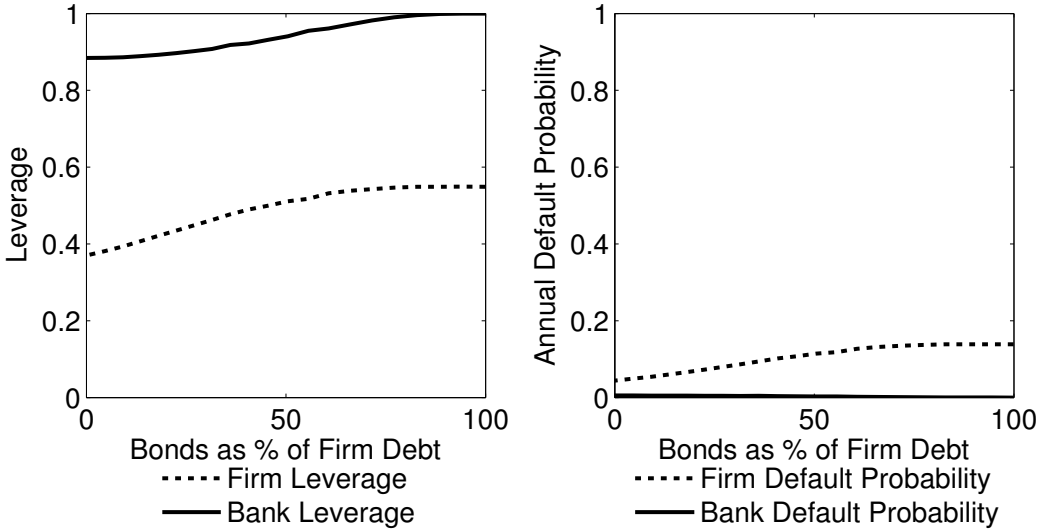
The firm's total debt value V_{FD} is the sum of the proceeds of the firm's bond issuance and the value the firm's loan contributes to the bank:

$$V_{FD} = V_M + V_{BE} + V_{BD}. \tag{36}$$

Consider a firm that chooses its debt to equity ratio but has a fixed debt structure with a fixed ratio of bonds to bank loans. Figure 19 shows how varying firm debt structure impacts the financial system. As firms rely more on bond financing, banks increase their leverage. Despite this, the bank's default rate decreases because of the seniority effect. Junior bondholders absorb the first round of the firm's losses which gives the bank an additional buffer, or creates an additional dike, against losses. This seniority makes the bank's loan portfolio safer and allows it to increase its leverage and enjoy a lower chance of default. For the base case parameters, as Table 7 demonstrates, if the firm relies equally on bond and bank financing, banks increase their leverage from 88% to 93%. At the same time, because the strategic substitution effect is weakened and the strategic complement effect is strengthened, firms increase their leverage from 37% to 50%.

Table 7 also shows the impact of government interventions for the case of mixed financing of firms. Adding public market debt as a junior claimant makes bank assets less volatile and reduces the impact

Figure 19: Impact of Firm Debt Financing Mix on Firm and Bank Leverage



This figure looks at the capital structure of firms and banks in an economy where firms that raise debt financing must raise a given portion of it through banks. The parameter values are $r_f = 0.05,\ \sigma = 0.4,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

of bailouts and deposit insurance on bank leverage and lending decisions. Junior debt makes the bank's loan portfolio very safe. The IRB capital regulation takes this into account and doesn't bind, the more primitive leverage limit does and forces the already-safe bank to hold excessive equity which reduces firm borrowing slightly due to reduced tax benefits.[30]

9 Discussion: What Is Missing?

Perhaps the greatest advantage of our framework is that it can be readily used by policy makers and academic researchers alike to quantify the impact of various regulatory measures on both the financial and real sectors of the economy. Because of this, it is particularly important to mention several extensions to our framework that would add further realism, but which are outside the scope of the present paper.

Our model uses constant and commonly known parameters; however, Bhamra, Kuehn, and Strebulaev (2010) and other authors have shown that the time variation of parameters can be crucial, especially variation of those parameters related to macroeconomic risk. For example, if volatility unexpectedly increases, the incentives of firms and banks alike change and thus the effectiveness of time-invariant

[30]Note that the Standardized Approach in Basel II and III provides risk weights for rated corporate exposure. Firms with public market debt will generally be rated which could reduce the bank's capital requirements.

capital regulation. Considering such parameter variation would be an important extension. In addition, most parameters are imperfectly known and learned over time by market participants (including firm and banks.) The impact of this learning on financial decisions and the systemic fragility is another issue this model could be extended to explore.

Banks lend only to firms in our model. In many countries, including the U.S., lending against real estate collateral, both residential and commercial, make up a larger fraction of bank assets. Our mechanisms are generic enough to apply to mortgages and any other bank assets, but it would be important to quantify their impact. Further, we assumed that all firms are ex-ante homogeneous. Realistically, banks deal with heterogenous firms and the shape of the distribution of firm leverage may have a non-trivial impact on our results. Modeling firm investment decisions more directly would add a further layer of richness.

Tax benefits drive the debt decisions of banks and firms in our model. These are inherently private benefits as they are a transfer from taxpayers to private agents. Thus, eliminating the tax deductability of interest, or equalizing the tax treatment of debt and equity in some other way, would remove all the wasteful distortions we have considered. However, the economic mechanisms we consider (strategic substitution and complementarity effects, diversification and seniority) are more general and should play a similar role with other incentives to issue debt, both of private and social origin, are present. Thus, our framework can be applied in the presence of other frictions that drive the wedge between bank equity and bank debt.

Another key question is the timing of bank defaults. In our model, banks can default only at the time-T maturity of their assets. In reality, banks are subject to runs which may mean that the bank equity holders and debt holders bear less loss in the event of a bank failure than in our model. Conversely, aggressive regulators may intervene early and force bank investors to bear more losses. Extending the model in this direction might shed light on the trade-offs between early and late intervention.

Finally, and perhaps most importantly, we have considered only the private costs and benefits of defaults, interventions, and taxes. The externalities imposed by bank failure, particularly systemic bank failure, are more important considerations when setting policy. A more detailed analysis could extend our framework to multiple banks in order to examine how bank incentives impact systemic risk.

blue]LATER: WG/ILYA: Comment from Steve: Vasicek model assumes normal distribution, which does not produce sufficiently fat tails. Hedge funds and banks, in reality, use (or at least it is written they use) other distributions, such as Student t and mixture of normal (of the same mean but different volatilities). It would be curious to see perhaps how this might change the numerical outcomes of our model (of course, will require numerical analysis)

10 Concluding Remarks

This paper proposes a novel framework to model joint debt decisions of banks and borrowers. Our framework combines the models used by bank regulators with the models used to explain capital structure in corporate finance. This structure allows us, or policy makers, to easily explore the quantitative impact of government interventions such as deposit insurance, bailouts, and capital regulation.

We find that bank and borrower financial decisions are intertwined through a number of mechanisms. Costly bank distress means high bank leverage pushes firm leverage down and vice versa. At the same time, highly levered banks are better able to pass along the tax benefits of debt, raising the debt of both banks and firms. These two supply chain mechanisms are accentuated by bank's ability to diversify and bank debt being senior to equity and commonly senior to other forms of debt. High bank leverage and low firm leverage emerge naturally from this strategic interaction. In our base case, firm leverage is 37%, while bank leverage is 88%, not dissimilar to what we observe empirically.

Our model allows us to quantify the impact of deposit insurance and bailouts on bank risk taking. We find that small probabilities of bailouts and moderate levels of deposit insurance have only marginal effects on bank risk taking, but there is a tipping point beyond which expectations of intervention lead banks to take on dramatically more risk. Many U.S. banks have enough insured deposit insurance to suffer such extreme moral hazard.

Capital regulation can be effective at reducing moral hazard but is subject to substantial model risk. By inappropriately capturing borrower risk, some forms of capital regulation can make banks misprice risk and lead to excessive borrower defaults. Capital regulation that is subject to gaming, as we argue Basel may be, is ineffective at preventing moral hazard.

Strong, targeted capital regulation increases efficiency. Banks funded primarily with insured deposits or banks that are defacto too-big-to-fail should face tighter capital regulation. We calculate the costs of capital regulation as modest – increasing bank equity requirement by 1% increases borrower cost by 1.5 basis points – which suggests capital regulation could be substantially strengthened without undue economic harm. Current capital requirements may be insufficient, we find that a 16% equity requirement using a Basel-style Advanced IRB formula produces substantial efficiency gains by reducing bank defaults and forcing banks to better price systemic risk.

Obviously, we have just scratched the surface of these issues. Our framework is rich and flexible enough that it can be used to model and understand many further questions about the bank financing and capital regulation.

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Table 1: Payoffs to Debt and Equity Holders Under Various Models

Section 2.1: Model with Banks

Condition	Bank Equity Holder Payoff	Bank Creditor Payoff
$B \geq R_B$	$B - R_B - \tau \max\{0, B - V_{FD} - (R_B - V_{BD})\}$	R_B
$B < R_B$	0	$(1 - \alpha_B)B$

Section 2.2: Model with Firms

Condition	Firm Equity Holder Payoff	Firm Creditor Payoff
$F^i \geq C_F$	$F^i - R_F - \tau \max\{0, F^i - (R_F - V_{FD})\}$	R_F
$F^i < C_F$	0	$(1 - \tau)(1 - \alpha_F)F^i$

Section 2.3: Model with Banks and Firms (Bank payoffs are the contribution of firm i to that payoff)

Condition	Firm Equity Holder Payoff	Bank Equity Holder Payoff	Bank Creditor Payoff
$F^i \geq C_F$, $B \geq R_B$	$F^i - R_F - \tau \max\{0, F^i - (R_F - V_{FD})\}$	$R_F - R_B$ $-\tau \max\{0, B - V_{FD} - (R_B - V_{BD})\}$	R_B
$F^i < C_F$, $B \geq R_B$	0	$(1 - \tau)(1 - \alpha_F)F^i - R_B$ $-\tau \max\{0, B - V_{FD} - (R_B - V_{BD})\}$	R_B
$F^i \geq C_F$, $B^i < R_B$	$F^i - R_F - \tau \max\{0, F^i - (R_F - V_{FD})\}$	0	$(1 - \alpha_B)R_F$
$F^i < C_F$, $B^i < R_B$	0	0	$(1 - \tau)(1 - \alpha_F)(1 - \alpha_B)F^i$

Table 2: Impact of Seniority and Diversification on Return Moments

This table reports how diversification and seniority impact the standard deviation and skewness of returns. The four pairs of columns correspond to four types of exposure: a single firm's assets, a diversified pool of such assets, a loan to a single firm, and a diversified portfolio of such loans, respectively. Redundant values are omitted for clarity. Our base case sets firm borrowing at $C_F = 0.4$ and correlation at $\rho = 0.2$ with the other parameters as described in Section 4.2.

	Single Firm		Pool of Assets		Single Loan		Pool of Loans	
	σ	γ_1	σ	γ_1	σ	γ_1	σ	γ_1
Base Case	0.291	0.785	0.129	0.341	0.056	-4.410	0.014	-2.437
$\rho = 0.1$			0.091	0.240			0.009	-1.647
$\rho = 0.4$			0.183	0.486			0.022	-3.599
$C_F = 0.3$					0.032	-7.254	0.006	-3.415
$C_F = 0.5$					0.079	-3.076	0.022	-1.877

Table 3: Capital Structure of Banks and Firms

This table reports the optimal leverage levels for the models in Sections 2.2 and 2.3 over varying parameters. The benchmark set of parameters is $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

	Firm Borrows Through Bank (Section 2.3)				Firm Issues Bonds (Section 2.2)	
	Firm		Bank		Firm	
	Leverage	Def. Rate	Leverage	Def. Rate	Leverage	Def. Rate
Base Case	0.3681	4.42%	0.8844	0.53%	0.5495	13.90%
$\rho = 0.1$	0.4097	6.11%	0.8987	0.32%	0.5495	13.90%
$\rho = 0.4$	0.3246	2.96%	0.8831	1.00%	0.5495	13.90%
$\sigma = 0.2$	0.5387	1.38%	0.9525	0.21%	0.5932	2.72%
$\sigma = 0.8$	0.2866	20.45%	0.6914	2.16%	0.5135	39.34%
$\tau = 0.1$	0.2419	1.08%	0.9310	0.09%	0.2772	1.78%
$\tau = 0.35$	0.4841	9.75%	0.8506	1.37%	0.7084	26.77%
$r_f = 0.025$	0.3123	2.66%	0.8949	0.21%	0.5399	13.43%
$r_f = 0.1$	0.4134	6.08%	0.8886	1.24%	0.5591	14.23%
$T = 1$	0.4151	2.24%	0.9497	0.19%	0.4825	5.27%
$T = 5$	0.3435	5.68%	0.8329	1.09%	0.5429	13.50%
$\alpha_F = 0.05$	0.5188	11.94%	0.8114	0.82%	0.7172	27.96%
$\alpha_F = 0.2$	0.2768	1.71%	0.9231	0.38%	0.3424	3.50%
$\alpha_B = 0.05$	0.3778	4.78%	0.9059	1.14%	0.5495	13.90%
$\alpha_B = 0.2$	0.3594	4.10%	0.8653	0.26%	0.5495	13.90%

Table 4: Capital Structure of Banks and Firms Under Extensions

This table reports the optimal leverage levels under several extensions to the model of Section 2.3. The benchmark set of parameters is $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

	Firm		Bank	
	Leverage	Default Rate	Leverage	Default Rate
Base Case	0.3681	4.42%	0.8844	0.53%
Section 5.1: Insured Deposits with Value γV_{BD}				
$\gamma = 0.85$	0.3714	4.54%	0.8862	0.59%
$\gamma = 0.9$	0.3806	4.90%	0.8950	0.89%
$\gamma = 0.95$	0.9051	55.04%	0.9862	55.49%
Section 5.2.1: Bailout of Debt Holders with Probability θ				
$\theta = 0.25$	0.3774	4.77%	0.8964	0.87%
$\theta = 0.5$	0.3978	5.60%	0.9203	2.22%
$\theta = 0.75$	0.7582	32.57%	0.9726	35.41%
Section 5.2.2: Equity Injection of Size υ with Probability 0.5				
$\upsilon = 0.01$	0.3689	4.44%	0.9033	0.63%
$\upsilon = 0.02$	0.3721	4.56%	0.9237	1.00%
$\upsilon = 0.04$	0.3743	4.62%	0.9757	7.05%
Section 6.1: Capital Regulation with Bank Equity $\geq hV_B$				
$h = 0.3$	0.3933	5.46%	0.7000	0.01%
$h = 0.2$	0.3944	5.48%	0.8000	0.10%
Section 7: Bank Bargaining Power of ω				
$\omega = 0.5$	0.3645	4.39%	0.8941	0.56%
$\omega = 1$	0.3620	4.38%	0.8989	0.58%

Table 5: Default Probabilities with Regulation and Government Intervention

This table reports the default probabilities of banks and firms in an economy subject to government interventions and Basel style capital regulation: either the Standardized Approach as in Section 6.1 or Internal Ratings-Based (IRB) Approach as in Section 6.2. The benchmark set of parameters is $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

	No Regulation		Basel: Standardized		Basel: IRB	
	Firm	Bank	Firm	Bank	Firm	Bank
Base Case	4.42%	0.53%	4.41%	0.54%	4.41%	0.54%
Section 5.1: Insured Deposits with Value γV_{BD}						
$\gamma = 0.85$	4.55%	0.60%	4.55%	0.60%	4.55%	0.60%
$\gamma = 0.9$	4.90%	0.89%	4.90%	0.88%	4.87%	0.75%
$\gamma = 0.95$	55.04%	55.49%	24.93%	14.55%	5.39%	0.80%
Section 5.2.1: Bailout of Debt Holders with Probability θ						
$\theta = 0.25$	4.77%	0.87%	4.70%	0.85%	4.69%	0.73%
$\theta = 0.5$	5.60%	2.22%	5.58%	2.16%	5.08%	0.77%
$\theta = 0.75$	32.57%	35.41%	23.23%	13.60%	5.45%	0.80%
Section 5.2.2: Equity Injection of Size υ with Probability 0.5						
$\upsilon = 0.01$	4.44%	0.63%	4.46%	0.63%	4.51%	0.49%
$\upsilon = 0.02$	4.56%	1.00%	4.60%	0.91%	4.96%	0.45%
$\upsilon = 0.04$	4.62%	7.05%	6.11%	1.39%	5.09%	0.40%

Table 6: Efficiency Cost of Capital Regulation

This table reports the costs and benefits associated with defaults and government policy. Values are reported in annual basis points of unlevered firm value. Panels A and B show results for, respectively, a bank without bailouts or deposit insurance and a bank with a 25% probability of a debt guarantee, insured deposits making up 85% of its liabilities and an equity injection with $\nu = 0.01, m = 0.5, \theta = 0.5$. The first column gives results without regulation. The second and fourth columns provide results under the Basel Standardized Approach and Internal Ratings-Based Approach, respectively; the third and fifth columns redo that analysis after doubling the equity capital requirements of those regulations. All cases are calculated using $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

Panel A: Bank without Deposit Insurance or Bailouts

	No Regulation	Basel Standardized		Basel IRB	
		Base	Doubled	Base	Doubled
Bankruptcy Costs	17.78	17.78	20.38	17.78	13.58
Firm Default Costs	16.12	16.12	19.64	16.12	13.48
Bank Default Costs	1.66	1.66	0.74	1.66	0.09
Tax Benefits of Debt	47.99	47.99	50.03	47.99	41.52
Private Value from Financing	30.21	30.21	29.65	30.21	27.94

Panel B: Bank with Deposit Insurance and Bailouts

	No Regulation	Basel Standardized		Basel IRB	
		Base	Doubled	Base	Doubled
Bankruptcy Costs	24.92	25.08	23.99	20.54	13.63
Firm Default Costs	19.70	20.24	23.21	18.80	13.57
Bank Default Costs	5.22	4.84	0.78	1.74	0.06
Subsidies to Debt	57.09	57.23	54.19	52.09	41.63
Tax Benefits of Debt	54.10	54.44	53.69	51.06	41.59
Deposit Insurance	0.77	0.74	0.15	0.28	0.01
Debt Guarantees	1.81	1.69	0.28	0.61	0.02
Equity Injections	0.40	0.37	0.06	0.14	0.01
Private Value from Financing	32.17	32.15	30.19	31.55	28.00

Table 7: Capital Structure of Banks and Firms when Firms Have Mixed Financing

This table reports the optimal leverage levels and the resulting firm values over varying parameters for a firm that derives 50% of its debt financing from bank debt and 50% from bond issuance. The benchmark set of parameters is $r_f = 0.05,\ \sigma = 0.4,\ \rho = 0.2,\ \tau = 0.25,\ \alpha_F = \alpha_B = 0.1,\ T = 2.5$.

	Firm		Bank	
	Leverage	Default Rate	Leverage	Default Rate
Base Case	0.5006	10.80%	0.9313	0.33%
$\rho = 0.1$	0.5149	11.66%	0.9479	0.16%
$\rho = 0.4$	0.4817	9.70%	0.9181	0.69%
$\sigma = 0.2$	0.5911	2.66%	0.9976	0.01%
$\sigma = 0.8$	0.3939	29.30%	0.7102	1.84%
$\tau = 0.1$	0.2722	1.66%	0.9814	0.02%
$\tau = 0.35$	0.6284	19.57%	0.8959	0.91%
$r_f = 0.025$	0.4747	9.41%	0.9321	0.19%
$r_f = 0.1$	0.5142	11.32%	0.9404	0.64%
$T = 1$	0.4825	5.27%	0.9943	0.03%
$T = 5$	0.4552	9.69%	0.8680	0.81%
$\alpha_F = 0.05$	0.6562	22.14%	0.8764	0.54%
$\alpha_F = 0.2$	0.3290	3.08%	0.9695	0.15%
$\alpha_B = 0.05$	0.5037	10.97%	0.9440	0.62%
$\alpha_B = 0.2$	0.4959	10.52%	0.9185	0.17%
Section 5.1: Insured Deposits with Value γV_{BD}				
$\gamma = 0.85$	0.4998	10.75%	0.9317	0.33%
$\gamma = 0.9$	0.5025	10.91%	0.9354	0.41%
$\gamma = 0.95$	0.5112	11.43%	0.9531	1.07%
Section 5.2.1: Bailout of Debt Holders with Probability θ				
$\theta = 0.25$	0.5024	10.90%	0.9381	0.46%
$\theta = 0.5$	0.5070	11.18%	0.9485	0.80%
$\theta = 0.75$	0.5244	12.26%	0.9707	3.06%
Section 6.1: Capital Regulation				
Standardized	0.4805	9.63%	0.9200	0.13%
IRB	0.5006	10.80%	0.9313	0.33%