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

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August 2014

**Abstract**

We develop a model of the joint capital structure decisions of banks and their borrowers. Our model simultaneously solves the outstanding puzzles of high bank leverage and low firm leverage. Strikingly high bank leverage of 85% or higher emerges naturally from the interplay between two sets of forces. First, seniority and diversification reduce bank asset volatility by an order of magnitude relative to that of their borrowers. Second, previously unstudied supply chain effects mean that highly levered financial intermediaries can offer the lowest interest rates. Low asset volatility enables banks to take on high leverage safely; supply chain effects compel them to do so. Low firm leverage arises because borrowers internalize the systematic risk costs they impose on their lenders. This presents a potential answer to the long-standing theoretical corporate finance puzzle of low firm leverage.

*We thank Anat Admati, Malcolm Baker, Efraim Benmelech, Arvind Krishnamurthy, Ulrike Malmendier, Egor Matveyev, Marcus Opp, Francisco Perez-Gonzalez, Steve Schaefer, Antoinette Schoar, and Xiaolan Zhang for helpful discussions and comments. We are also grateful to seminar participants at the NBER, the Bank of Canada, the Cheung Kong Graduate School of Business, ESSEC, Imperial College, the Trans-Atlantic Doctoral Conference, Tsinghua University, the University of Zurich, and the Stanford University Graduate School of Business. Will Gornall thanks the SSHRC for its support. Gornall: gornall@stanford.edu; Strebulaev: istrebulaev@stanford.edu.

# 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 banking and that limiting it will inhibit credit access and impede economic growth.[1] This paper builds a quantitative model of banking that explains bank capital structure decisions and sheds light on fundamental questions about the nature of banking.

There is disagreement on the causes and effects of high bank leverage; however, there is no disagreement that banks and other financial institutions are indeed highly indebted. The average leverage of U.S. banks, measured as the ratio of debt to assets, has been in the range of 87%–95% over the past 80 years.[2] 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. The dramatic difference in financial structure between financial institutions and non-financial corporations is puzzling. In addition, the leverage of non-financials itself is substantially less than most corporate finance models predict, which gave rise to a voluminous literature on the so-called "low leverage puzzle".[3]

In this paper, we explain both the gap and the low leverage of non-financials 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. Because this framework is built on commonly calibrated models, it naturally lends itself to quantitative analysis. 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 85% while firms choose leverage of only 30%, both close to real-world values. We also find that mechanisms that explain the gap are central to our understanding of how financial institutions work.

[1] The Bank of England's recent attempts to tighten capital regulation led it to be described as the "capital Taliban" by a member of parliament who argued stronger regulation would starve businesses of loans. Refer to the Financial Times (http://www.ft.com/cms/s/0/a6367d06-f377-11e2-942f-00144feabdc0.html) for the full story.

[2] Authors' estimates based on historical Federal Deposit Insurance Corporation data, which are publicly available from http://www2.fdic.gov/hsob/HSOBRpt.asp.

[3] For example, see Goldstein, Ju, and Leland (2001); Morellec (2004); and Strebulaev (2007).

High bank leverage is feasible because bank assets are an order of magnitude less volatile than the assets of their borrowers. Even when lending to firms with asset volatility of 40%, the bank has asset volatility of only 2.6%. This result is very general. Even for conservative parameters, we find the volatility of a pool of bank loans is at least seven times lower than the volatility of the assets that back those loans. We show that this dramatic risk reduction is driven primarily by banks' status as senior creditors. Banks' status as senior creditors allows them to carry high debt without correspondingly high default risk.

While low asset volatility allows banks to pursue high leverage with relative safety, our supply chain mechanisms compel them to do so. Banks provide financing to other agents but in doing so they incur their own financing costs. High bank leverage reduces these costs and allows debt benefits to be more effectively transported down this financing supply chain. The essence of the supply chain effects is that debt benefits originate only at the bank level. This is driven by a fundamental asymmetry between final users of financing ("downstream" borrowers) and those that act as intermediaries passing financing along ("upstream" borrowers). Even if the downstream borrowers have extremely low leverage, upstream borrowers – banks – still lever up, generate debt benefits, and pass those benefits downstream. However, if the upstream borrowers have similarly low leverage, no benefits are generated that can be passed along and, as a result, the downstream borrowers also pursue low leverage.

Beyond its effect on bank leverage, this financing supply chain leads to strategic interaction between bank and borrower debt decisions: bank leverage and firm leverage can act as both strategic substitutes and strategic complements. The strategic substitution effect arises because of bank distress costs. 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 pass this cost on to their borrowers. The borrowers respond by taking on less debt, effectively shielding banks by making their loan portfolio safer. In the opposite scenario, where banks have low leverage, these systemic risk costs are lessened and bank borrowers take on more debt.

The strategic complementarity effect arises from the link between the benefits of debt for banks and those for borrowers. Banks pass their own debt benefits, such as tax benefits, downstream to their borrowers by charging lower loan interest rates. In a competitive banking 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.

Our supply chain effects are general enough to apply to many of the other bank financing frictions identified in the literature. Like Harding, Liang, and Ross (2007), we use the tax benefits and bankruptcy costs framework of Kraus and Litzenberger (1973). However, the risk reduction and supply chain mechanisms we identify are much more general and play a similar role in the presence of other incentives to issue debt our other classes of borrowers. Section 6 shows that bank leverage remains high under a DeAngelo and Stulz (2013) style liquidity benefit to debt or under models such as Baker and Wurgler (2013) or Allen and Carletti (2013) where debt and equity are discounted differently. These alternative, rather than tax originating, debt benefits are also passed down the financing supply chain. Although there are other, agency-conflict induced mechanisms for high bank leverage, such as the leverage ratchet effect proposed by Admati, DeMarzo, Hellwig, and Pfleiderer (2013b), we show that high bank leverage can arise even without such an explicit conflict.

Tax benefits alone make it privately optimal for banks to take on high levels of debt. However, tax benefits to debt are a transfer and do not obviously create value. Our results suggest that equalizing the tax treatment of debt and equity would reduce systemic risk and make the financial system less prone to crises. Such equalizing could be simpler and more effective at reducing risk than other proposals for financial regulation.

Our analysis yields a number of empirical predictions. First, better diversified banks, such as national banks, will have higher leverage and less asset volatility than less diversified banks, such as local banks. Second, borrowers with more systemic risk will pay higher interest rates than otherwise similar borrowers with less systemic risk. In a similar vein, loans with more seniority, say first versus second mortgages, will be held by more levered banks. The framework can also be extended to consider deposit insurance, bailouts, and bank capital requirements – the pillars of modern regulation. In a companion paper, Gornall and Strebulaev (2014) explore how these pillars impact bank capital structure and bank risk-taking incentives. They also show that the analysis can be used by regulators to quantify the impact of their actions.

A variety of mechanisms justify bank existence and many of those could be incorporated into our framework. We build upon a venerable banking literature (see Thakor (2013) for a comprehensive review, including influential early contributions, such as Diamond and Dybvig (1983)). Acharya, Mehran, Schuermann, and Thakor (2011), Acharya, Mehran, and Thakor (2013), Allen and Carletti (2013), DeAngelo and Stulz (2013), Diamond and Rajan (2000), Harding, Liang, and Ross (2006), Shleifer and Vishny (2010), and Sundaresan and Wang (2014) investigate bank optimal capital structures. The efficacy and design of bank regulation have been recently examined by Admati, DeMarzo, Hellwig, and Pfleiderer (2013a), Admati, DeMarzo, Hellwig, and Pfleiderer (2013b), Bulow and Klemperer (2013), Hanson, Kashyap, and Stein (2011), and Harris, Opp, and Opp (2014). Bruno and Shin (2013) explore the transmission of financial conditions across borders by also utilizing a Vasicek-style model. A number of recent empirical studies, including Berger and Bouwman (2013), Berger, DeYoung, Flannery, Lee, and Öztekin (2008), Bhattacharya and Purnanandam (2011), Kisin and Manela (2013), Schandlbauer (2013), and Schepens (2013) have enriched our understanding of banking.

The rest of the paper is structured as follows. In Sections 2 and 3, we develop and discuss a supply chain model of bank and firm financing. In Section 4, we list and justify our parameter assumptions. In Section 5, we present the quantitative results on bank and firm leverage. In Section 6, we consider other debt benefits, bank bargaining power, and bond markets. Concluding remarks are given in Section 7.

# 2 A Supply Chain Model of Financing

In this section, we blend a structural model of bank portfolio returns with the trade-off theory of capital structure. Section 2.1 outlines a model of bank capital structure 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. Section 2.2 sets up a model of a firm that is subject to trade-off frictions and issues Merton (1974) style debt. Section 2.3 links the bank with the firm to derive a unified model of the financing supply chain.

The Vasicek model we use for bank assets has been widely used by financial regulators. Notably, it underlies the Internal Ratings-Based (IRB) Approach to capital regulation the Basel Committee on

Banking Supervision (BCBS) lays out in Basel II and Basel III.[4] This means our model of capital structure decision-making can be readily applied to the existing capital regulation framework.

Banks hold a variety of assets and we develop two different approaches to address this. Section 2.1 details a model of bank capital structure where the bank lends to borrowers with fixed leverage. Sections 2.2 and 2.3 make the borrowers' capital structures endogenous. We use the first approach to model mortgage loans and the second approach to model loans to corporate borrowers. Together, these models allow us to explore the capital structure decisions of a bank that lends only to firms, only through mortgages, or to both households and firms.

### 2.1 Capital Structure of Banks

Consider a bank with a portfolio of loans. These loans could be, for example, mortgages or loans to firms, encompassing the two most important assets on most bank balance sheets. Each loan $i$ is collateralized by an asset that pays a one-off cash flow of $A^i$ at the loan's maturity at time $T$. 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 $\mu$ and standard deviation $\sigma$. 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 borrower defaults and ownership of the collateral passes to the bank. The bank recovers $(1 - \alpha_A)A^i$, where $\alpha_A$ is the proportional bankruptcy cost incurred on defaulted bank loans.

Taking the default and repayment cases together, the bank's payoff from any loan $i$, $B^i$, is given by

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

[4] See paragraph 272 of BIS (2004) and paragraph 2.102 of BCBS (2013), respectively.

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 loan $i$'s collateral in terms of these shocks:

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

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

The bank's realized portfolio value per loan, $B$, is the average of the payoffs (2) from each of the bank's loans:[5]

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

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 borrowers 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.[6]

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 $\Phi$ is the cumulative distribution function of the standard normal.

[5] We model loan recoveries directly, from collateral value, which enables us to price debt consistently. This differs from most applications of the Vasicek (2002) model, which take recovery in default as fixed and model only the portion of loans that default.

[6] 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.

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 underlie the trade-off theory of capital structure that is commonly applied to non-financial firms.

A profitable bank owes corporate income tax and can reduce this tax expense by deducting the interest payments on its debt. Banks are assumed to have access to competitive debt markets, and the bank's debt is thus fairly priced. 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.

The bank's profit depends on the initial cost of its loans. Loans are priced with a spread, such that a loan's time zero value, $V_{AD}$, is

$$V_{AD} = e^{-(r_f+\delta)T}\mathbb{E}\left[B^i\right], \tag{6}$$

where $\delta$ is a fixed spread the bank charges and $r_f$ is the instantaneous risk-free rate. The spread $\delta$ depends on competition in the banking sector. For example, in a perfectly competitive banking industry, $\delta$ is such that the banks earn zero profit in expectation.

The bank pays corporate income tax at rate $\tau$ 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, $R_B - V_{BD}$.[7] Thus, the bank faces a tax obligation of $\tau\left(B - V_{AD} - (R_B - V_{BD})\right)$, provided this number is positive.[8] The total free cash flow available to the bank's debt and equity holders is the after-tax value of the bank's portfolio:

$$B - \tau \max\Big\{0, \underbrace{B - V_{AD}}_{\text{Tax base}} - \underbrace{(R_B - V_{BD})}_{\text{Tax benefit}}\Big\}. \tag{7}$$

[7]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.

[8]In this asymmetric tax system, the bank pays tax on its profit but does not get a tax rebate on its losses. A tax system where the bank partially or fully recovers a tax rebate on losses could easily be introduced into this model and would produce similar results.

Debt introduces the possibility of financial distress. The bank defaults if this free cash flow is less than the amount the bank owes 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

$$B - \tau \max\{0, B - V_{AD} - (R_B - V_{BD})\} < R_B. \tag{8}$$

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

$$B < R_B. \tag{9}$$

The bank defaults if, and only if, its portfolio value at time $T$ 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 the proportional bankruptcy costs of $\alpha_B$.

Discounting the resulting cash flows to time 0, the bank's equity value, $V_{BE}$, and debt value, $V_{BD}$, are given by

$$V_{BE} = e^{-Tr_f}\mathbb{E}\left[(B - \tau \max\{0, B - V_{AD} - R_B + V_{BD}\} - R_B)\,\mathbb{I}\left[B \geq R_B\right]\right] \quad \text{and} \tag{10}$$

$$V_{BD} = e^{-Tr_f}\mathbb{E}\left[R_B \mathbb{I}\left[B \geq R_B\right] + (1 - \alpha_B) B \mathbb{I}\left[B < R_B\right]\right]. \tag{11}$$

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

$$V_B = V_{BD} + V_{BE} = e^{-Tr_f}\mathbb{E}\Bigg[\underbrace{(1-\tau)B}_{\text{Unlevered value}} + \underbrace{\tau \min\{B, V_{AD} + R_B - V_{BD}\}}_{\text{Tax shield}} - \underbrace{\alpha_B B \mathbb{I}\left[B < R_B\right]}_{\text{Bankruptcy costs}}\Bigg]. \tag{12}$$

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.

## 2.2 Capital Structure of Non-Financial Firms

We model the capital structure decisions of non-financial firms by adding firm-level tax and bankruptcy costs to the Merton (1974) model of risky corporate debt.[9] This allows us to endogenize the loan variables that we took as exogenous in the previous section.

[9] The Merton model, which is the foundation of the contingent claims framework, underlies modeling of corporate financial decisions and pricing of default-risky assets (e.g., Leland (1994)).

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

$$\log F^i \sim N\left(-\frac{1}{2}T\sigma^2, T\sigma^2\right). \tag{13}$$

The firm pays corporate income tax at a linear rate $\tau$ on this cash flow and so faces a total tax burden of $\tau F^i$. 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

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

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

$$F^i - \tau \max\left\{0, F^i - (R_F - V_{FD})\right\} < R_F. \tag{15}$$

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

$$F^i < C_F = R_F + \frac{\tau}{1-\tau}V_{FD}, \tag{16}$$

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 $\alpha_F$, so that the firm's creditors receive $(1-\alpha_F)(1-\tau)F^i$ in default.[10] Discounting the expectation of these cash flows, the firm's time-0 equity and debt values can be written as

$$V_{FE} = e^{-Tr_f}\mathbb{E}\left[\left(F^i - \tau\max\left\{0, F^i - R_F + V_{FD}\right\} - R_F\right)\mathbb{I}\left[F^i \geq C_F\right]\right] \quad \text{and} \tag{17}$$

$$V_{FD} = e^{-Tr_f}\mathbb{E}\left[R_F\mathbb{I}\left[F^i \geq C_F\right] + (1-\tau)(1-\alpha_F)F^i\mathbb{I}\left[F^i < C_F\right]\right]. \tag{18}$$

[10] 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:

$$V_F = e^{-Tr_f}\mathbb{E}\Bigg[\underbrace{1-\tau}_{\text{Unlevered value}} + \underbrace{\tau\left(R_F - V_{FD}\right)\mathbb{I}\left[F^i \geq C_F\right]}_{\text{Tax shield}} - \underbrace{\alpha_F(1-\tau)F^i\mathbb{I}\left[F^i < C_F\right]}_{\text{Bankruptcy costs}}\Bigg]. \tag{19}$$

A firm subject to these financing frictions chooses a promised repayment, $R_F$, that maximizes the firm's time-0 value. Because the non-financial and financial sectors of the economy face the same frictions, Expression (19) of the firm's value and Expression (12) of the bank's value are very similar.[11]

## 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 can 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-sized firms, this is less realistic for large firms that can choose between debt markets and banks. In Section 6, we extend the model to include firms' 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 all firms pursue identical financing policy.[12] 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

$$B^i = R_F\mathbb{I}\left[F^i \geq C_F\right] + (1-\alpha_F)(1-\tau)F^i\mathbb{I}\left[F^i < C_F\right], \tag{20}$$

with the other bank value equations being similarly adjusted.

[11] The slight structural difference between Expressions (12) and (19) 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.

[12] 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.

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 spread the bank charges in equilibrium, $\delta$, is such that the proceeds of the firm's debt issuance, $V_{FD}$, are exactly equal to the value the firm's loan adds to the bank. For the ex-ante identical borrowers, this implies that $V_{FD} = V_B = V_{BE} + V_{BD}$. In other words, banks and firms set their capital structures to maximize their joint value, $V_F = V_{FE} + V_B$. Intuitively, if banks compete, a bank that offers different terms would fail to maximize firm value and be competed out of business, as other banks would be able to offer better financing terms. Any bank surplus, therefore, gets passed down to firms in the form of lower interest rates and other better financing terms. On the other hand, if the bank is a monopolist, the bank captures all the firm's value above the firm's reservation price. In either case, while the division of surplus depends on the bargaining power of banks and their borrowers, banks only offer contracts that maximize the combined value. (In Section 6, we extend the model to the general distribution of surplus between firms and banks.)

Given competitive banks, the total firm value at date 0 is thus the sum of the value of the firm's equity (17) and the value the firm's loan contributes to the bank (12):

$$
\begin{aligned}
V_F = e^{-Tr_f}\mathbb{E}\Bigg[ & \underbrace{1-\tau}_{\text{Unlevered value}} - \underbrace{\alpha_F(1-\tau)F^i\mathbb{I}\left[F^i < C_F\right]}_{\text{Firm bankruptcy costs}} - \underbrace{\alpha_B B\mathbb{I}\left[B < R_B\right]}_{\text{Bank bankruptcy costs}} \\
& + \underbrace{\tau\left(R_F - V_{FD}\right)\mathbb{I}\left[F^i \geq C_F\right]}_{\text{Firm tax shield}} - \underbrace{\tau \max\left\{0, B - V_{FD} - R_B + V_{BD}\right\}}_{\text{Bank tax costs and tax shield}}\Bigg]. \qquad (21)
\end{aligned}
$$

The financing frictions driving the policies of both banks and firms are present in this combined value. Under our model, the capital structure parameters, $R_F$ and $R_B$, are chosen to maximize the total firm value $V_F$.

# 3 Driving Economic Forces

The confluence of several economic mechanisms drives the capital structure decisions of banks and borrowers, as well as the fragility of the resulting system. We divide these mechanisms into two classes. First, there are two risk-mitigating mechanisms, namely diversification and seniority. A *diversification* effect, due to the bank's risk pooling, and a *seniority* effect, due to the bank's status as a senior creditor, reduce bank asset risk and allow the bank to have high leverage without high default risk. Second, two supply chain mechanisms push banks to taking high leverage through the bank's strategic interaction with its borrowers.

### 3.1 Diversification and Seniority

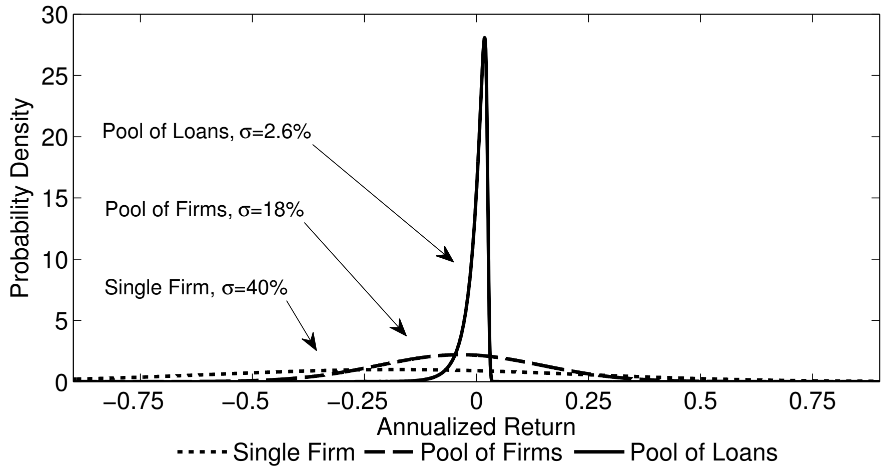
Diversification and seniority make the bank's asset volatility as much as *fifteen* times less than its borrowers'. Even in conservative scenarios, these effects reduce the bank's asset volatility by an order of magnitude. Figure 1 and Table 2a use the returns on corporate obligations to illustrate how diversity and seniority can lead to such a dramatic reduction in risk. The diversification effect alone significantly reduces the spread of returns, while diversification and seniority together dramatically reduce portfolio volatility. Diversification reduces volatility by half, seniority cuts volatility by a factor of three, with both effects together leading to a fifteen-fold decrease in volatility. The upshot is that while diversification is an important driving force, it is the seniority and the joint effect of seniority and diversification that produce such a dramatic effect. Similar results hold for mortgages, as shown in Table 2b. What can explain such surprising magnitudes? Given the importance of this risk reduction, we devote the rest of this section to the economics of these effects.

The diversification effect arises because banks lend to a large number of borrowers and experience aggregate returns that are less volatile than the returns on any single loan. Table 2 shows that for both the pool of houses and the pool of firms 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 borrowers 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 (the Diamond (1984) case).

The seniority effect arises from the priority of bank loans in a borrower's capital structure. Banks are generally senior creditors and as such are paid first in bankruptcy. In the case of corporate borrowers, large firms also finance themselves in the bond market and small firms also finance themselves using trade credit, with bank debt typically being senior to both types of obligation. In the case of mortgages,

**Figure 1: Impact of Seniority and Diversification on Distribution of Returns**

Figure 1 shows the probability density function of returns on a single firm's assets (dotted), a diversified portfolio of firms (dashed), and a diversified portfolio of loans to those same firms (solid). For this illustration, we set the firm's repayment, $R_F$, to produce 25% firm leverage and we model firm performance using the assumptions in Section 4.1.



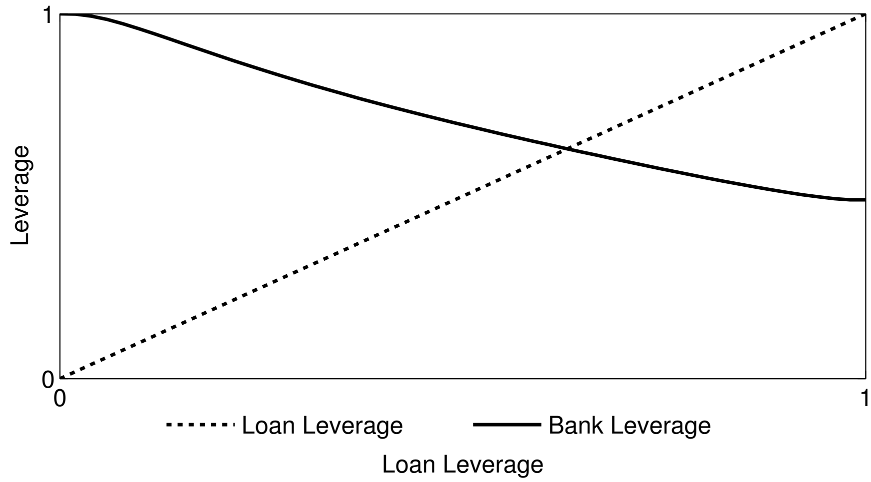

banks are secured creditors with first claim on the borrower's house. This seniority is critical, because it means a bank will not suffer losses unless its borrowers perform very poorly.[13] Correspondingly, for a bank to experience financial distress, a significant fraction of its borrowers must suffer significant financial hardship. This allows the banks to pursue high leverage without high default risk. Some intuition can be grasped by analyzing Figure 2, which shows how bank leverage responds to exogenous variation in firm leverage, where leverage is defined as the ratio of debt to total value. As firm leverage decreases, and firm debt becomes senior to a larger tranche of firm equity, bank leverage increases correspondingly. Similar results would hold for a bank lending only through mortgages with varying leverage. Section 6 explores this mechanism in further detail by introducing junior bond debt into a firm's capital structure.

A synergy between the seniority and diversification effects doubles the strength of their combined effect. This synergy arises from a subtle mechanism whereby seniority potentiates diversification. Any asset volatility a bank experiences can only come from those loans in a bank's portfolio that fail. Even in bad states of the world, many borrowers experience positive idiosyncratic shocks and will therefore

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

**Figure 2: Optimal Bank Leverage for Given Firm Leverage**

Figure 2 illustrates how varying firm leverage (dotted) impacts bank leverage (solid).




not default. As these loans do not contribute to the bank's asset volatility, seniority implies that systematic risk is only coming through on a portion of the bank's portfolio. This dramatically reduces the bank's asset volatility.

These effects mean that a bank can lend to risky borrowers and still have a safe portfolio. A loan to a firm with leverage of 25% and asset volatility of 40% produces an annual bank asset volatility of just 2.6%, much lower than the volatility of the borrower firms. Running the same calculation for mortgages with 80% loan to value ratio gives an asset volatility of 2.3%. These volatilities are empirically reasonable. For example, Ronn and Verma (1986) and Hassan, Karels, and Peterson (1994) find bank asset volatility ranging from 0.9% to 2.3% using different methodologies and bases.

Figure 1 also shows how seniority changes the shape of the asset return distribution. Seniority gives bank assets a highly negative skew and fat left tails. Models of bank capital that rely on the normal distribution could thus substantially underestimate bank default risk.

## 3.2 Supply Chain Effects

A financing "supply chain" arises because households and firms borrow from banks and those banks, in turn, borrow from debt markets. Both firms and banks get tax benefits from debt.[14] The consequences of this interest tax shield for non-financial firms 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 a firm's interest tax shield to have an ambiguous effect on total tax:

$$V_F = e^{-Tr_f}\mathbb{E}\Bigg[\underbrace{1-\tau}_{\text{Unlevered value}} - \underbrace{\alpha_F(1-\tau)F^i\mathbb{I}\left[F^i < C_F\right]}_{\text{Firm bankruptcy costs}} - \underbrace{\alpha_B B\mathbb{I}\left[B < R_B\right]}_{\text{Bank bankruptcy costs}} \\ + \underbrace{\tau(V_{FD} - (1-\alpha_F)(1-\tau)F^i)\mathbb{I}\left[F^i < C_F\right]}_{\text{Tax benefit of loan losses}} + \underbrace{\tau\min\left\{R_B - V_{BD}, B - V_{FD}\right\}}_{\text{Bank interest tax shield}}\Bigg]. \tag{22}$$

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.

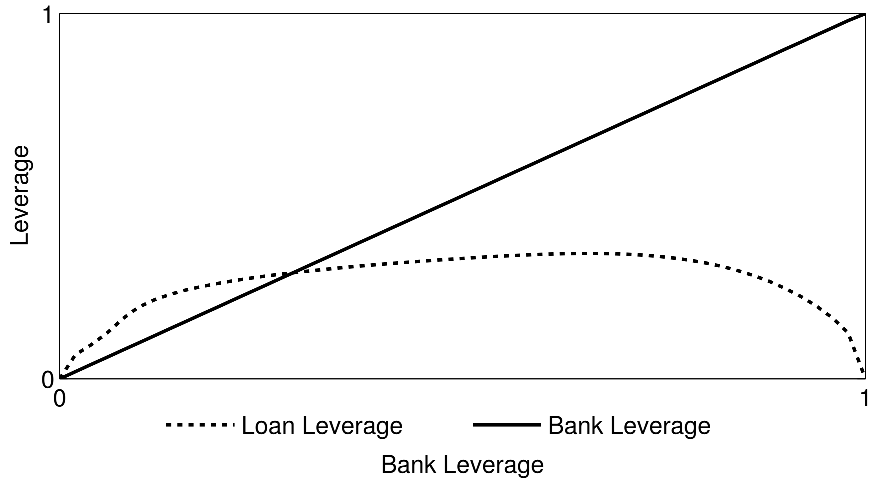
The observation that debt benefits originate only at the bank level is much more generic and is driven by the fundamental asymmetry between final users of financing ("downstream" borrowers) and those that act as intermediaries passing financing along ("upstream" borrowers). Even if the downstream borrowers – firms – have extremely low leverage, it is still optimal for the upstream borrowers – banks – to lever up, generate debt benefits, and pass those benefits downstream. However, if the upstream borrowers have similarly low leverage, no benefits are generated that can be passed along and, as a result, the downstream borrowers also do not lever up. The same logic would apply to a relationship between a firm and its supplier that acts as a trade creditor.

This supply chain mechanism is fundamentally similar to the impact personal tax exerts on corporate debt tax benefits. 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, downstream borrowers cannot capture the full tax benefits of debt because of

[14] Households get a tax benefit from mortgage interest in some countries, including the United States. A similar intuition holds for such a mortgage interest tax deduction.

**Figure 3: Optimal Firm Leverage for Given Bank Leverage**

Figure 3 illustrates how varying bank leverage (solid) impacts firm leverage (dotted).




the tax costs debt imposes on upstream debt holders. The supply chain intuition also shows that, while traditional models of capital structure (as well as contingent-claim models of credit risk) do not specify the identity of debt buyers, they cannot be banks or similar institutions, as these institutions would impose their own financing frictions.

The strategic link between bank and borrower financing decisions means that these decisions can be both *strategic complements* and *strategic substitutes.* Figure 3 highlights these interactions by showing how firm leverage responds to exogenous variation in bank leverage.

The strategic complementarity effect arises because 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 (22), 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. 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 far left in Figure 3. 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. 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. For relatively low bank leverage, this strategic complementarity effect dominates, which reduces the total indebtedness of the economy.

The strategic substitution effect arises because lower bank leverage reduces the risk of bank failure and therefore expected bank distress costs. This effect decreases firm borrowing costs and allows a firm to increase its 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 tax benefits are marginally important). This 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 loss. This instability translates into higher firm borrowing costs, which will reduce a firm's debt issuance. Effectively, a firm builds up a safety cushion to protect its bank. On the far right of Figure 3, a fully levered bank means the firm chooses not to borrow.

# 4 Benchmark Parameter Values

Our framework is a combination of the Vasicek (2002) model used by bank regulators and the trade-off model used in the corporate finance literature. These are both widely used and commonly calibrated models, thus we can readily quantify our results.

We model a bank as having three types of asset: (1) residential mortgages, (2) corporate debt, and (3) risk-free assets such as government bonds or cash. Based on FDIC data, our benchmark case is a bank whose assets are 60% residential mortgages, 20% corporate debt, and 20% risk-free government securities. This simplified model excludes many bank assets such as retail exposure, commercial real estate, and farmland loans. However, the framework can easily include any other asset class as well as be applied to a specific bank. Our goal here is not to exactly match bank assets; rather, it is to explore the capital structure results using a plausible bank.

## 4.1 Benchmark Parameter Values for Firms

Our benchmark parameter values for corporate debt are based on empirically motivated proxies. Because many parameters of interest are challenging to estimate with good precision, we conduct extensive comparative statics exercises. For the reader's convenience, Table 1 summarizes the assumption laid out in this section.

We set the benchmark value of our firm asset correlation parameter, $\rho_F$, to 0.2.[15] This is similar to the values assumed by regulators. The Basel II (and Basel III) IRB Approach sets its loan-specific correlation parameter, $\hat{\rho}$, to between 0.12 and 0.24 based on the following formula:

$$\hat{\rho} = 0.12\ \frac{1 - e^{-50PD}}{1 - e^{-50}} + 0.24\ \left(1 - \frac{1 - e^{-50PD}}{1 - e^{-50}}\right), \tag{23}$$

where $PD$ is the loan default probability (see paragraph 272 of BCBS (2004) for more details).[16] Our value of 0.2 is also similar to 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 small- and medium-sized enterprises in Europe.

We set annual firm asset volatility, $\sigma_F$, to 0.4, a value 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. While public corporate debt typically has a maturity of 7–15 years at origination, bank debt is of shorter duration. For example, the loans studied by Roberts and Sufi (2009) have an average time to maturity of 4 years and the BCBS (2002) prescribes a time to maturity of 2.5 years (see paragraph 279). To be consistent with our later treatment of mortgages, we assume a time to maturity, $T$, of 5 years. Time to maturity is important primarily because of its impact on total volatility, $\sigma\sqrt{T}$, and so by using a longer time to maturity we are increasing the volatility of loan collateral. This will tend to reduce both bank and firm leverage. We perform additional robustness checks using $T = 2.5$. We also set the risk-free rate, $r_f$, to 0.025.

Following estimates suggesting that the effective tax rate U.S. companies pay is less than the statutory federal corporate tax rate of 0.35, 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, 2000)). Djankov et al. (2010) show similar rates apply globally. We set firm distress costs, $\alpha_F$, at 0.1. This assumption is likely conservative. Some recent estimates, such as Davydenko, Strebulaev, and Zhao (2012), find that, conditional on experiencing distress, large firms incur sizable total distress costs of 20%–30% of asset value at the time of distress

[15]We use the subscripts $F$ and $A$ to denote parameters related to firms and residential mortgages, respectively.

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

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) and Bennett and Unal (2008) find direct bank bankruptcy costs equal to 8–10% of assets and total losses on assets in default of 16–30%. We set bank distress costs, $\alpha_B$, to 0.2 which generates an empirically reasonable loss on assets in default of 25%. Because distress costs are an important driver in our model, we conduct extensive robustness tests with respect to these parameters.

### 4.2 Benchmark Parameter Values for Mortgage Loans

The most popular form of mortgage loan in the U.S. is a 30-year, fixed rate mortgage with a loan to value ratio at origination of about 80% (e.g., Bokhari, Torous, and Wheaton (2013)). This type of mortgage features equal monthly payments and a gradually amortizing loan principal. The loan could go into delinquency or default at any time up to its maturity or it could be refinanced at the borrower's choice. Default and refinancing decisions depend not only on the value of the underlying house, but also on interest rates and the borrower's personal situation.

These complications make modeling mortgages notoriously difficult. We therefore abstract from them and study the "skeleton" of mortgages using the model in Section 2.1. Our goal is to provide a simple account of how adding mortgages affects bank capital structure decisions and the consequences of those decisions. Our model could be extended to a fuller mortgage risk model such as that of Campbell and Cocco (2011). Below, we summarize not only our parameter assumptions but also the extent to which these assumptions likely need to be modified in a more realistic mortgage model.

We model mortgages as 5-year term loans. Although mortgages typically have much longer maturities, we use $T = 5$ because empirical evidence suggests that mortgage defaults peak in the first 5 years and there is no refinancing risk for banks under the assumption of constant interest rates (e.g. Westerback et al. (2011) and Figure 1.8 of International Monetary Fund (2008)). Our benchmark case uses an 80% of loan to value ratio at origination, which maps to a repayment of $R_A = 0.8e^{-Tr_f}$. Our model assumes that the full principal is to be repaid at maturity. In practice, amortization reduces the principal outstanding and leads to seasoned, older mortgages with lower loan to value ratios making up a significant portion of a bank's portfolio. Excluding the run-up to the recent financial crisis, the average loan to value of outstanding mortgages is normally closer to 60% (e.g. p. 22 of Bullard

(2012)). The seasoning effect would make bank mortgage portfolios less risky than in our model, as seasoned mortgages have better risk characteristics.

We assume that a firm defaults strategically and reneges on its debt whenever its value is below the promised repayment. A household, on the other hand, is more likely to default as a result of liquidity issues than for strategic reasons. Empirically, the majority of underwater homeowners do not default, even if they are deep underwater (e.g., Figure 3 of Krainer and LeRoy (2010) or Amromin and Paulson (2010)). At the same time, some households default even though they have positive equity in the house. We approximate this behavior by assuming half of all the mortgages that are underwater at maturity default and other mortgages do not. The cost of foreclosure, $\alpha_A$, is assumed to be 0.25. This matches empirical studies such as the one by Qi and Yang (2009) who find an average loss of 25% for defaulting mortgages, where the house value is equal to the mortgage debt.

We use $\sigma_A = 0.25$ for house price volatility. This is roughly in line with the levels suggested by Zhou and Haurin (2010), who find volatility ranging from 13-25%. The Basel regulation contains no guidance on house price volatility. We assume that the correlation between the price movements of different houses in a bank's mortgage portfolio is $\rho_A = 0.2$.[17] The Basel regulation assigns a lower value of 0.15. We use a higher value of 0.2 in order to match the recent U.S. experience of higher correlation (e.g., Cotter, Gabriel, and Roll (2011)). To see how these assumptions perform over the long run, it is useful to conduct a long-term volatility exercise. Our values of $\sigma_A = 0.25$ and $\rho_A = 0.2$ produce a 5-year index volatility of 25% which is close to the 21% 5-year volatility of Case-Shiller index. A 2008-style housing crisis with a 40% 5-year house price decline occurs approximately once per century under our model which again matches the Case-Shiller index.

Beyond the characteristics of mortgage loans, it is important to comment on how banks hold mortgages. Guarantees and securitization are defining features of the U.S. mortgage market. More than half of U.S. mortgages are guaranteed by government-sponsored enterprises, such as Fannie Mae or Freddie Mac, or by government agencies, such as the Federal Housing Administration or the Department of Veteran's Affairs (e.g., Congressional Budget Office (2010)). The majority of these guaranteed mortgages, along with many mortgages that lack such guarantees, are then packaged into mortgage-

[17]Like the Basel IRB Framework, our analysis implicitly uses a single factor model. This means that house prices co-move with firm asset values as both are exposed to the bank risk factor. Our framework can be easily extended to include multiple factors.

backed securities and sold. If the bank takes the securitized or guaranteed mortgages off its balance sheet, the model needs no adjustment. If these structures remain on a bank's balance sheet, they can alter that bank's risk. Guarantees can dramatically reduce bank risk as the credit risk is borne by the guarantor. Securitizations can reduce or concentrate risk, depending on their structure and the risk the bank chooses to retain. Our model assumes that the bank retains no interest in any securitizations and no guaranteed assets; however, the model could be extended to cover a richer case.

## 5 Debt and Default for Banks and Borrowers

Highly levered banks arise from our base case parameter assumptions, as well as plausible parameter variations. Table 3 shows the capital structure and default risk implications of our model for a variety of parameter values. The first two columns consider a firm borrowing from a bank and show the firm market leverage ratio, $V_{FD}/(V_{FE}+V_{FD})$, and the associated annual firm default probability. The next two columns show the capital structure and default rate of the bank, where the bank's market leverage ratio is given by $V_{BD}/(V_{BE}+V_{BD})$.[18] For comparison, the final two columns show the capital structure and default probability of a firm that issues bonds in the public market and does not borrow from the bank. Two results immediately stand out.

First, bank leverage is indeed very high. Our benchmark case yields banks with 85% leverage, a value that would be extremely high for a non-financial firm (indeed, a non-financial firm with such leverage would almost automatically be regarded as in distress) but in line with the empirical evidence on the capital structure of financial firms. For example, Federal Deposit Insurance Corporation (FDIC) data shows that aggregate bank book leverage has been 87%–95% for the past 80 years.[19] Furthermore, all of the parameter variations in Table 3 produce high bank leverage. As discussed in Section 3, this result is driven by the confluence of seniority and diversification effects which dramatically reduces bank risk and allows banks to afford high leverage. A good illustration of the relative safety of banks

[18] A zero profit bank has equal book and market values for both bank equity and bank assets. Section 6 explores profitable banks and shows similar results.

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

is that in our base case, banks have an annual default rate of only 0.08%. The historical U.S. bank failure rate is higher,[20] at 0.25%.[21]

Second, firm leverage is an empirically reasonable 30%. Many standard corporate finance models cannot explain the low levels of firm leverage seen in practice. This low leverage puzzle has sprung its own stream of research (e.g., Leland (1994, 1998); Goldstein, Ju, and Leland (2001); Morellec (2004); Ju, Parrino, Poteshman, and Weisbach (2005); Strebulaev (2007)). Supply chain frictions provide a natural solution to this puzzle. A firm borrowing through a financial intermediary bears some of that intermediary's capital structure costs and, as a result, borrows less. For the benchmark parameter estimates, our model produces firm leverage of 30%, in line with the average quasi-market leverage ratio of 25%–30% for U.S. public firms between 1962 and 2009 (e.g., Strebulaev and Yang (2013)). For comparison, when we exclude supply chain frictions in the public debt market case, firm borrowing jumps from 30% to 51%. This is again in line with empirical evidence, such as Faulkender and Wang (2006), who show that among firms with positive debt, those with bond market access have higher leverage (28.5%) than those without (20.5%).

Bank leverage ends up being 55% higher than firm leverage. This sizable gap arises for three reasons. First, a firm does not enjoy the same diversification and seniority protections that banks do. Second, a firm borrowing through a bank bears that bank's default costs, and so borrows less to protect the bank (the strategic substitution effect). Finally, the borrowing firm captures only some of the tax benefits of debt as the rest are lost through the bank's tax costs – the financing supply chain is not completely frictionless. Together, these forces simultaneously explain high bank leverage and low firm leverage.

Beyond our base case bank, bank leverage is high for a variety of borrowers and types of loans, as illustrated by Table 4. Higher borrower leverage results in lower bank leverage, but the bank still pursues high leverage for variety of portfolio compositions.

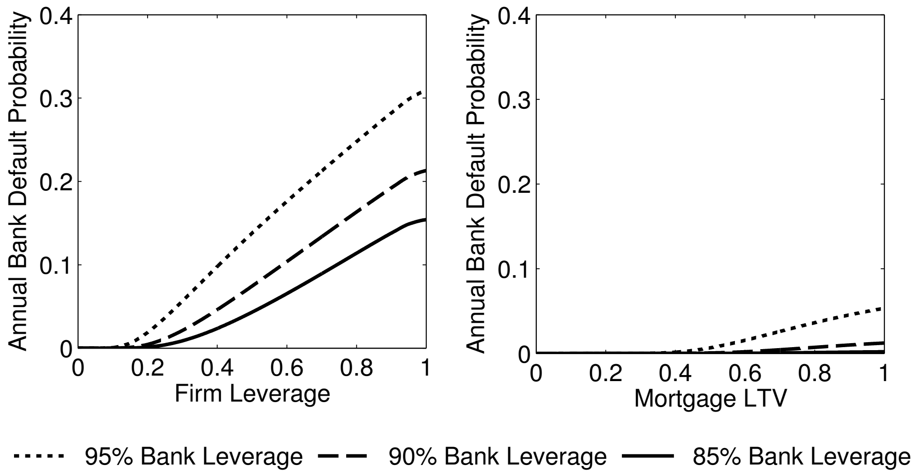
If bank leverage cannot adjust in response to borrower leverage, bank defaults become more common. Figure 4 holds bank leverage fixed and looks at how borrower leverage impacts bank default proba-

[20] Our current model abstracts from volatile interest rates that can also cause bank defaults.

[21] Authors estimates based on FDIC data, which are publicly available from http://www2.fdic.gov/hsob/. In Table CB02, the FDIC reports 2,429 commercial bank failures out of 968,458 bank-year observations for the period of 1934 to 2013.

**Figure 4: Impact of Borrower Leverage on Bank Default Rates**

Figure 4 shows how varying leverage impacts bank default rates for banks with fixed capital structures. The left plot shows results for firms modeled using the parameters in Section 4.1. The right plot shows results for mortgages modeled using the parameters in Section 4.2.

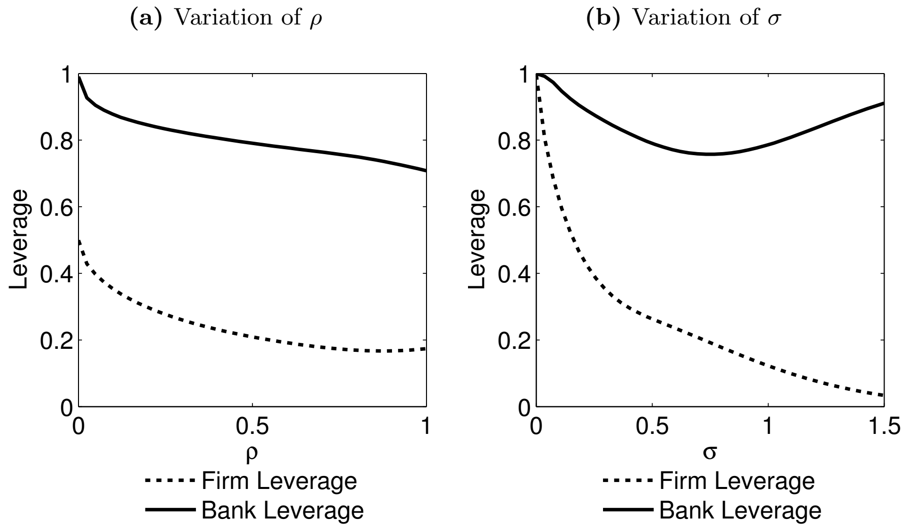



bilities. Holding bank leverage fixed at 85% and increasing firm leverage from 30% to 60% causes the 1-year default probability of a bank that lends to firms to increase sevenfold, from 0.90% to 6.55%. Holding bank leverage at 90% and increasing mortgage loan to value ratios from 80% to 100% similarly causes the default probability of an all-mortgage bank to increase to from 0.10% to 1.22%. Both high firm leverage and high bank leverage are associated with more frequent bank defaults. As a potential illustration, the run-up to the recent financial crisis was associated with a dramatic increase in the leverage of households. Banks that failed to model such an increase in leverage would have been extremely vulnerable to systemic shocks due to their unexpectedly inadequate seniority.

The benchmark model assumes that banks and firms face the same marginal tax rate. In reality, as banks have lower earnings volatility than firms, banks would have less losses to carry forward and therefore face a higher marginal tax rate. This results in even higher bank leverage. For example, if banks face a marginal tax rate of 0.3 instead of the 0.25 faced by firms, bank leverage increases by 1.8% to 86% and firm leverage falls by 3.7% to 26%. This observation calls for better estimates of effective marginal tax rates faced by financial institutions.

**Figure 5: Impact of Systematic Risk and Volatility on Leverage**

Figure 5 shows how varying systematic risk (5a) and collateral volatility (5b) impacts the leverage of banks (solid) and firms (dotted). The bank is modeled using the parameters in Section 4.




## 5.1 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 5a. Low systematic risk leads to highly levered banks and firms because better diversified exposures reduce 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 correlation between firms implies banks need to hold more equity and charge higher interest rates, which reduces 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's equity as a second set of dikes, further inland.[22] 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 $\rho$. We find that this comparison between the flood-preventing dike system and bank-failure-preventing leverage system works rather well in explaining the intuition behind our framework. For most of the values of systematic risk, the "dike" system works well and banks rarely default.

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 $\rho$ 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 5a, this effect eventually causes firms to lower their equity buffer, as it is no longer effective.

In interpreting the parameter $\rho$, one needs to keep in mind that it can vary both with the nature of the bank and with macroeconomic conditions. For a national bank, $\rho$ would be the exposure of a bank's portfolio firms to systematic shocks. For a regional bank, $\rho$ 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. To the extent that asset comovement increases during recessions, poor macroeconomic conditions would be associated with higher $\rho$.

[22]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 worst-case scenario, *dromer* (dreamer) dikes provided protection for individual farms or even fields. Refer to Neave and Grosvenor (1954) for more detail.

### 5.2 Impact of Asset Volatility

Figure 5b shows the impact of varying asset volatility, $\sigma$, on bank and firm leverage and default likelihood.[23] Bank leverage decreases with higher volatility. This behavior is well documented in the capital structure literature both theoretically and empirically (e.g., Leland (1994); Adrian and Shin (2010)). As loan portfolios become more volatile, banks decrease their leverage to protect themselves against default. Firm leverage follows a similar pattern.

The right plot of Figure 5b shows the impact of asset volatility on equilibrium default probabilities. As expected, increasing firm asset volatility dramatically increases the firm's default rate. It also increases the bank's default rate, but not to the same degree, due to the bank endogenously decreasing its leverage and to the previously discussed seniority and diversification mechanisms.

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 firm and house price volatility by 50% causes the probability of bank default to surge from 0.08% to 2.79%. Increasing the correlation between assets to $\rho = 0.4$ causes bank defaults to rise to 0.64%. Recessions and economic downturns are often marked by unexpected increases in volatility and correlation, which would lead to substantial systemic risk (e.g., Cotter, Gabriel, and Roll (2011)). Such parameter changes could dramatically increase bank risk or push many banks into distress at the same time. This scenario could be modeled in our framework by introducing parameter uncertainty.

### 5.3 Impact of Taxes and Bankruptcy Costs

If borrower leverage is held constant, trade-off frictions have their expected impact on capital structure. For a bank that lends only through mortgages, increasing tax rates leads to an increase in bank leverage as the value of the tax shield to the bank increases. This matches the results Schandlbauer (2013)

[23]Note that while we vary $\sigma$, 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 Figure 5b.

and Schepens (2013) who use tax changes in U.S. states and in Belgium, respectively, to show that increasing tax rates increases financial institution leverage. Increasing bank or borrower bankruptcy costs has the opposite effect. Higher bank-level bankruptcy costs cause the bank to reduce its leverage to avoid those. Higher borrower-level bankruptcy costs also reduce bank leverage, as higher bankruptcy costs increase bank bankruptcy risk.

If borrower leverage is endogenous, these effect can vary. Higher tax rates cause firms to take on higher leverage. That increases the amount of risk the bank has in its portfolio. Thus, increasing tax rates have an indeterminate effect on bank leverage. Bank-level bankruptcy costs decrease both bank and firm leverage. Borrower-level bankruptcy costs decrease borrower level. Bank leverage decreases for most parameter values; however, very high borrower-level bankruptcy costs can dramatically decrease borrower leverage which causes a corresponding increase in bank leverage. Note that even for very high bank bankruptcy costs, the bank still opts for relatively high debt levels due to the supply chain mechanism and seniority and diversification effects.

# 6 Extensions

In this section, we briefly discuss a number of extensions of our framework. First, we discuss the impact of bailouts, deposit insurance, and capital regulation. Second, we consider alternative mechanisms for debt benefits, other than taxes. Third, we introduce imperfect bank competition and analyze the consequences of bank bargaining power. Fourth, we analyze the introduction of bond markets that compete with banks in the corporate loan market. The upshot is that the main results, both qualitative and quantitative, remain robust to these extensions.

**Bailouts, Deposit Insurance, and Capital Regulation.** Bailouts and deposit insurance create moral hazard for banks and can lead banks to choose more levered capital structures. In a companion paper, Gornall and Strebulaev (2014) discuss how these forms of government subsidy can change bank capital structure and bank risk-taking incentives. They show that sufficiently high levels of deposit insurance (above 92% of bank liabilities) or sufficiently high bailout probabilities (above 62%) can push banks into dramatic risk-seeking strategies. Both of these scenarios are not unlikely in reality and may explain banks' desire to pursue high-risk strategies, for example in the run up to the financial crisis of 2007–2009. As the companion paper shows, one way for banks to hike risk-taking is to increase the correlation of their loan portfolio.

**Alternative Debt Benefits.** Tax benefits drive the debt decisions of banks and firms in the preceding sections. Appendix A considers other debt benefits. Namely, we consider a DeAngelo and Stulz (2013) style liquidity provision benefit and a Baker and Wurgler (2013) style reduced discount rate for debt. Replacing the tax benefit of debt with either of these frictions produces similar results. Again, we see banks with high leverage because, as explained in Section 3, even a small benefit to debt will cause banks to pursue high leverage. Applying the aforementioned frictions, we see bank leverage that ranges from 82% to 100%.

**Bank Bargaining Power.** The previous sections use zero profit banks for simplicity; however, this assumption can easily be relaxed. Appendix B explores the effect of exogenously varying the spread banks charge. We see that increasing bank bargaining power also increases bank leverage. Banks that are more profitable pay tax in more states of the world and get greater tax benefits from debt issuance. This means our zero profit assumption leads us to slightly underestimate bank leverage.

**Bond Markets.** Appendix C adds junior bond holders to our model of financing. Adding junior bond holders means that banks are more senior. This reduces the riskiness of bank portfolios and allows banks to pursue even higher leverage. Firm leverage increases as firm borrowing now imposes less systemic risk on banks. Bank leverage also increases, although only slightly, as corporate debt makes up only a small part of the bank's portfolio.

# 7 Conclusion

In this paper, we propose a novel framework to model the joint debt decisions of banks and their borrowers. This framework combines a model bank regulators use to assess risk with a model academics use to explain capital structure decisions. Our structure can be used to model quantitatively bank and firm capital structure decisions in a realistic fashion.

Banks are diversified senior creditors, which reduces their risk and allows them to take on high leverage. The bank's borrowers respond to this high leverage by reducing own their borrowing, partially explaining low corporate leverage. Our benchmark parameters give rise to banks with leverage of 85% and firms with leverage of 30%, not dissimilar to what we observe empirically. These results have resolved two standing puzzles at the same time: why banks are so highly levered and why non-financial firms dislike financing themselves with debt.

The mechanisms that we have uncovered are generic and can be used, for example, further to study the impact of government regulations on financial decisions of private agents. Obviously, we have just scratched the surface of these issues. Regulators, academics, and practitioners continue to have a discussion on bank capital structure, systemic risk, and capital regulation. The framework we present is rich and flexible enough to address many of their unanswered questions.

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## Table 1: Benchmark Parameter Values

Table 1 summarizes the parameter assumptions listed and explained in Section 4.

| Model | | |
|---|---|---|
| Risk free rate | $r_f$ | 0.025 |
| Time to loan maturity | $T$ | 5 |
| Linear tax rate | $\tau$ | 0.25 |

| Bank | | |
|---|---|---|
| Portfolio value | $B$ | Loans |
| Loan mix | | 60% residential mortgages,<br>20% corporate debt,<br>20% risk free assets |
| Bank's debt repayment | $R_B$ | endogenous |
| Bankruptcy cost | $\alpha_B$ | 0.2 |

| Corporate Loan | | |
|---|---|---|
| Loan collateral | $F$ | Firm assets |
| Asset volatility | $\sigma_F$ | 0.4 |
| Correlation | $\rho_F$ | 0.2 |
| Loan repayment | $R_F$ | endogenous |
| Bankruptcy cost | $\alpha_F$ | 0.1 |

| Residential Mortgage | | |
|---|---|---|
| Loan collateral | $A$ | Residential property |
| Asset volatility | $\sigma_A$ | 0.25 |
| Correlation | $\rho_A$ | 0.2 |
| Loan repayment | $R_A$ | $0.8e^{-Tr_F}$ |
| Bankruptcy cost | $\alpha_A$ | 0.25 |

## Table 2: Impact of Seniority and Diversification

Table 2 reports how diversification and seniority impact the annualized standard deviation of log-returns. Table 2a looks at how these forces affect loans to firms; Table 2b looks at how these forces affect mortgages. The columns correspond to four types of exposure: a single asset, a diversified pool of assets, a loan collateralized by a single asset, and a diversified portfolio of such loans, respectively. Redundant values are omitted.

### (a) Impact of Seniority and Diversification on Corporate Debt

This table plots the impact of diversification and seniority on the volatility of corporate claims. Our base case sets borrower leverage at 25% and correlation between borrowers at $\rho = 0.2$. Firms are modeled using the parameters in Section 4.1.

| | Single Firm | Pool of Firms | Single Loan | Pool of Loans |
|---|---|---|---|---|
| Base Case | 40.00% | 17.89% | 11.48% | 2.57% |
| $\rho = 0.1$ | | 12.65% | | 1.69% |
| $\rho = 0.4$ | | 25.30% | | 4.24% |
| Leverage of 15% | | | 5.69% | 0.96% |
| Leverage of 35% | | | 17.23% | 4.49% |

### (b) Impact of Seniority and Diversification for Mortgages

This table plots the impact of diversification and seniority on the volatility of mortgage claims. Our base case sets the mortgage loan to value (LTV) ratio at 80% and correlation between house prices at $\rho = 0.2$. House prices and mortgage defaults are modeled using the parameters in Section 4.2.

| | Single House | Pool of Houses | Single Mortgage | Pool of Mortgages |
|---|---|---|---|---|
| Diversified | No | Yes | No | Yes |
| Senior | No | No | Yes | Yes |
| Base Case | 25.00% | 11.18% | 12.98% | 2.32% |
| $\rho = 0.1$ | | 7.91% | | 1.60% |
| $\rho = 0.4$ | | 15.81% | | 3.42% |
| LTV of 60% | | | 8.74% | 1.48% |
| LTV of 100% | | | 16.61% | 2.89% |

**Table 3: Capital Structure of Banks and Firms**

Table 3 reports the bank and firm leverage and default rates for varying parameters. The bank is modeled as described in Section 4.

| | Firms Borrow Through Bank (Section 2.3) | | | | Firms Issue Bonds (Section 2.2) | |
|---|---|---|---|---|---|---|
| | Firm | | Bank | | Firm | |
| | Leverage | Def. Rate | Leverage | Def. Rate | Leverage | Def. Rate |
| Base Case | 29.73% | 4.95% | 84.52% | 0.08% | 50.81% | 13.10% |
| $\rho = 0.1$ | 35.31% | 6.82% | 87.71% | 0.05% | 50.81% | 13.10% |
| $\rho = 0.4$ | 23.13% | 3.04% | 80.59% | 0.12% | 50.81% | 13.10% |
| $\sigma = 0.2$ | 61.68% | 0.51% | 95.35% | 0.03% | 65.57% | 0.93% |
| $\sigma = 0.8$ | 26.31% | 7.74% | 79.03% | 0.08% | 48.59% | 18.01% |
| $\tau = 0.1$ | 16.11% | 1.47% | 84.97% | 0.02% | 20.91% | 2.57% |
| $\tau = 0.35$ | 38.36% | 7.79% | 82.57% | 0.13% | 61.77% | 18.34% |
| $r_f = 0.01$ | 30.01% | 5.12% | 81.80% | 0.03% | 51.34% | 13.46% |
| $r_f = 0.05$ | 29.83% | 4.87% | 86.70% | 0.18% | 50.21% | 12.65% |
| $T = 1$ | 47.34% | 5.78% | 93.37% | 0.24% | 55.23% | 12.05% |
| $T = 2.5$ | 36.32% | 5.02% | 88.86% | 0.13% | 51.57% | 13.04% |
| $\alpha_F = 0.05$ | 42.50% | 9.46% | 82.08% | 0.09% | 63.86% | 19.68% |
| $\alpha_F = 0.2$ | 19.97% | 2.24% | 87.19% | 0.07% | 30.53% | 5.25% |
| $\alpha_B = 0.1$ | 30.41% | 5.17% | 86.30% | 0.18% | 50.81% | 13.10% |
| $\alpha_B = 0.4$ | 29.15% | 4.77% | 82.96% | 0.04% | 50.81% | 13.10% |

**Table 4: Bank Leverage for Banks with Varying Portfolios**

Table 4 reports how bank leverage and default rates vary with differing bank portfolios. The first row is our benchmark bank as described in Section 4. The later rows consider banks that hold only loans to firms (with varying leverage) or only mortgages (with varying loan to value ratios (LTV)). The first pair of columns uses our benchmark parameter assumptions. The second set of columns uses $T = 2.5$ as the maturity assumption.

| | Base Case | | $T = 2.5$ | |
|---|---|---|---|---|
| | Leverage | Default Rate | Leverage | Default Rate |
| Diversified Bank | 84.52% | 0.08% | 88.86% | 0.13% |
| Bank Lending only to Firms | | | | |
| Leverage of 15% | 90.24% | 0.11% | 98.20% | 0.05% |
| Leverage of 25% | 81.17% | 0.19% | 93.44% | 0.14% |
| Leverage of 35% | 73.06% | 0.26% | 86.54% | 0.26% |
| Leverage of 55% | 59.51% | 0.35% | 73.81% | 0.43% |
| Leverage of 75% | 48.82% | 0.37% | 61.52% | 0.52% |
| Bank Lending only via Mortgages | | | | |
| LTV of 60% | 87.72% | 0.07% | 92.85% | 0.10% |
| LTV of 70% | 85.61% | 0.07% | 90.09% | 0.12% |
| LTV of 80% | 84.08% | 0.07% | 87.78% | 0.12% |
| LTV of 90% | 83.04% | 0.06% | 86.10% | 0.12% |
| LTV of 100% | 82.41% | 0.06% | 85.05% | 0.10% |