Bank Profitability and Risk-Taking

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1 August 2017*

Abstract

Traditional theory suggests that more profitable banks have lower risk-taking incentives. Then why did many profitable banks make risky investments before the 2008 crisis, realizing substantial losses? We offer a model of bank risk-taking that helps explain such pre-crisis evidence. In our setup, banks are endowed with a core business, and can borrow to make risky investments alongside it. A more profitable core business enables a bank to borrow more and take risk on a larger scale, offsetting lower incentives to take risk of fixed size. Therefore, more profitable banks may have higher risk-taking incentives. The framework offers implications for financial regulation and monetary policy.

Keywords: Banks; Risk-Taking; Bank Capital; Repo Markets; Crises.

JEL Classifications: G21, G24, G28.

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1 Introduction

The 2008 crisis revealed a surprising amount of risk-taking in otherwise very profitable financial institutions. For example, UBS in Switzerland had prior to the crisis a unique wealth management franchise with a stable return on allocated capital in excess of 30% (UBS, 2007). It rapidly, over just two years, accumulated a large portfolio of credit default swaps (CDS), lost over \$50 billion in 2008, and had to be rescued. Washington Mutual, once called "The Walmart of Banking," had profitable consumer and small business operations. It became prior to the crisis one of the most aggressive mortgage lenders, lost \$22 billion on subprime exposures, and was liquidated. The insurance company AIG was one of only three AAA-rated companies in the U.S. It started selling CDS protection on senior tranches of asset-backed securities in 2005 and lost over \$100 billion – 10% of assets – in 2008 (AIG, 2008), wiping out shareholder equity and inducing a bailout. Similar investments-related disasters occurred in many other well-established financial institutions in the U.S. and Europe.

Significant risk-taking in profitable financial institutions seems to contradict the traditional predictions of corporate finance models. Shareholders are protected by limited liability and have incentives to take risk to maximize their option-like payoff (Jensen and Meckling, 1976). But the risk-taking incentives should be lower in more profitable firms, because their shareholders stand to lose more value if downside risks realize (Keeley, 1990). Therefore, it is puzzling why some of the world's most profitable financial institutions chose to become exposed to risky market-based instruments on such a large scale. Understanding this contradiction seems critical both from the perspective of bank management and governance, and for systemic risk regulation, as otherwise we might be missing an important determinant of bank risk-taking.

This paper offers a model of bank risk-taking that is consistent with the decision of profitable banks to take risk. Our starting observation is that in Jensen and Meckling-type models, firms choose the risk of a portfolio that has a fixed (exogenous) size. Yet bank risk-taking in the run-up to the crisis took a different form. Banks used their implicit equity—the profitability of their 'core business'—to lever up and engage in risky 'side activities' (often market-based investments) alongside their core business. Thus, banks chose not just the risk of their assets, but also the size of the exposure.[1]

The main point of our argument is that, in the presence of a leverage constraint, a more profitable core business enables a bank to borrow more and take risk in 'side activities' on a larger scale. Larger scale makes opportunistic risk-taking more attractive. This indirect scale effect can offset the traditional direct effect where a more profitable bank has lower incentives to take risk of fixed size. As a result, banks with a more profitable core business may have higher, not lower, risk-taking incentives. Put differently, our analysis highlights the banks' ability – not only the incentives – to take risk. A profitable core business gives banks the ability to take risk in side activities on a particularly large scale. With an exceeding scale of risk-taking, even very profitable banks may choose to take risk.[2]

The model's comparative statics fit well with the stylized patterns of bank risk-taking prior to the crisis.[3] We show that profitable banks are more likely to take risk when bank leverage constraints are less binding (when it is easier to lever up, all else equal). Loose leverage constraints may stem from a better institutional environment with more protection of creditor rights. This

[1] Examples of a core business include a wealth management franchise for UBS, or retail relationships for Washington Mutual. Examples of risky side activities are accumulating senior tranches of asset-backed securities (Gorton, 2010), selling protection on senior tranches of asset-backed securities through CDS contracts (Acharya and Richardson, 2009), undiversified exposures to housing (Shin, 2009), etc.

[2] An interesting illustration to the scale-related effect in bank risk-taking is that prior to the crisis UBS ran the largest trading floor by physical size in the world (103,000 sq.ft., the size of two football fields). We posit that a bank with a weaker core business might have been unable to support such a massive non-core operation. Indeed, as of 2014, the UBS trading floor is "almost empty" ("Empty Floors Fray Traders' Nerves," *Wall Street Journal*, July 14, 2014).

[3] In motivating our theoretical analysis, we interpret the pre-crisis risk-taking by profitable financial institutions in the most direct manner: that those institutions chose to take that risk. Besides this direct interpretation, there are three alternative explanations for risk-taking by profitable financial institutions. First, some institutions might be profitable because they take risk, i.e. there is reverse causality. However, this interpretation is inconsistent with our motivating examples: the high profits of UBS and AIG came from the relatively safe parts of their business (wealth management or traditional insurance), and not from the risky market-based parts of their business. Second, the financial institutions might have faced uncertainty: insufficient information about the risk they were taking. Still, to the extent that the institutions understood that there was some risk, the implications of the traditional theory are similar: profitable banks, averse to downside risk realizations, should be less tolerant of uncertainty. In fact, when agents respond to uncertainty with min-max preferences (so-called 'Knightian uncertainty' – based on worst case beliefs, cf. Pritzker, 2013), the unknown risk is effectively over-emphasized and profitable institutions should be particularly averse to it. Third, the risk could have been fully unanticipated (Gennaioli et al., 2012). But this interpretation contradicts the evidence that mortgage originators knew of the risks (Demyanyuk and van Hemert, 2011) and that those risks were – at least in part – priced (Demiroglu and James, 2012). So it seems difficult to argue that the troubled large institutions were fully unaware of potential risks. For these reasons, we believe that our initial interpretation is credible enough to motivate deeper theoretical analysis of why profitable financial institutions might have incentives to take risk.

helps explain why most banks affected by the crisis were those in advanced economies.[4] Profitable banks are also more likely to take risk when the funding for their side activities (market-based investments) is senior to the funding for their core business. This highlights the role of repo funding in contributing to pre-crisis vulnerabilities (Gorton and Metrick, 2012; Acharya and Öncü, 2013).

The model offers itself to a number of extensions. In one extension, we allow banks to exert effort to increase the profitability (or, equivalently, reduce the risk) of its core business. We find that a bank may strategically combine high effort in the core business with opportunistic side activities. The reason is that a more profitable core business expands the bank's borrowing capacity and enables it to engage in risky investments on a larger scale. The literature has often associated the seeming inconsistency of combining a prudent core business with risky side activities with a "clash of cultures" between conservative bankers and risk-loving traders (Froot and Stein, 1998). We explain it based purely on shareholder value maximization.

In another extension, we consider the effects of monetary policy on bank risk-taking. Loose monetary policy reduces a bank's cost of funding, increasing its profitability. We show that this has two, opposite effects on bank risk-taking in the core business versus that in side activities. Higher profitability reduces bank risk-taking in the core business, because shareholders internalize more of the downside risk realizations. However, higher profitability also loosens a bank' leverage constraint and thus boosts bank incentives for large-scale risk-taking in side activities. The finding of a differential effect of monetary policy on bank risk-taking in the core business versus that in side activities offers a new angle to the debate on the impact of monetary policy on bank risk-taking (see e.g., Dell'Ariccia et al., 2014, 2017; and Jiménez et al., 2014).

The paper relates to the literature on the link between bank profitability and risk-taking. Profitability is a static concept, its dynamic counterparts are bank franchise value or charter value. The accepted first-order effect is that higher profitability reduces bank risk-taking incentives (Keeley,

[4] The international economics literature documents that better institutions may enable countries to accumulate more liabilities (Mendoza et al., 2009), often leading to more severe crises (Giannonne et al., 2011; Gourinchas et al., 2011; Gennaioli et al., 2014). Similarly, in our model, banks in countries with better protection of creditor rights can lever up more easily, facilitating risk-taking. In the banking literature, the link between institutional environment, creditor rights, and bank risk was examined by Laeven (2001), La Porta et al. (2003), and Boyd and Hakenes (2014).

1990; Demsetz et al., 1996; Repullo, 2004; among others). But some papers caution that the relationship is more complex. First, banks may take risk in order to generate profits (e.g., to satisfy higher capital requirements, see Blum, 1999; Hellmann et al., 2000; Matutes and Vives, 2000). Second, profitability allows banks to build up capital, which makes capital requirements less binding, enabling banks to more easily absorb occasional losses and thus permitting risk-taking (Calem and Rob, 1999; Perotti et al., 2011). Our model proposes a novel effect, closely linked to the pre-crisis experience, where a more profitable core business enables banks to increase their leverage and take risk on a larger scale.

The mechanism of our paper, which operates through leverage-driven asset growth, is consistent with the evidence in Adrian and Shin (2014) that financial intermediaries, particularly those active in financial markets, tend to increase leverage and expand assets during financial cycle upturns. Further, Fahlenbrach et al. (2016) show that rapid asset expansions are associated with increased bank risk. More broadly, the notion that easier access to funds (in our case, as a result of higher profitability) can induce opportunistic investments is resembling of Jensen (1986) free cash flow and Myers and Rajan (1998) 'paradox of liquidity' insights.

The framework of our model, which builds on the interaction between a bank's core business and its side activities, is similar to that of Boot and Ratnovski (2016). However, as such an interaction is a wide-ranging issue, the questions addressed in our paper are very different. Boot and Ratnovski study how the opportunistic misallocation of capital from core banking to "trading" might render the bank unable to serve its relationship customers. This paper examines how a bank's core profits can be used to increase leverage and take risk in side activities.

The paper is structured as follows. Section 2 sets up the model. Section 3 solves the baseline model and shows why banks with higher profitability may take more risk. Section 4 endogenizes the cost of bank funding. Section 5 offers extensions, discussing in particular the interaction of bank risk-taking and monetary policy. Section 6 outlines empirical and policy implications. Section 7 concludes. The proofs are in the Appendix.

2 The model

Consider a bank that operates in a risk-neutral economy with three dates $(0, 1, 2)$ and no discounting. The bank is owner-managed, has no initial capital, and maximizes its expected profit.

Projects The bank has four investment opportunities:

1. The bank is endowed with a relationships-based "core" project. Thanks to an endowment of private information about the bank's existing customers, the core project is profitable (due to information rents; Petersen and Rajan, 1995) but not scalable (due to adverse selection in the market for new customers, Dell'Ariccia and Marquez, 2006; or the difficulty in processing large amounts of soft information, Stein, 2002). For 1 unit invested at date 0, the core project produces $R > 1$ at date 2. Since the size of the core project is normalized to 1, R is also the profitability of the core project: a ratio of profit to project size. (For simplicity we abstract from risk in the core project in the main model. This does not affect the results. A risky core project is analyzed in Section 5.1.)

2-3. The bank may in addition engage in "side activities" – market-based investments. Market-based investments are scalable but less profitable (due to smaller if any information rents). There are two available side investments. *A safe market-based investment* (such as treasury securities) for each unit invested at date 1 produces $1 + \varepsilon$ ($\varepsilon > 0$) at date 2. *A risky market-based investment* (such as asset-backed securities that lose value in a crisis) for each unit invested at date 1 produces at date 2: $1 + \alpha$ ($\alpha > \varepsilon$) with probability p, $p < 1$, but 0 with probability $1 - p$. We denote the endogenous scale of the market-based investment X. The fact that the scale of the market-based investment is endogenous allows us to generate predictions that are different from traditional risk-shifting models.

Note that the side investments are initiated after the core project: at date 1 rather than at date 0. This reflects the fact that they are undertaken alongside the bank's pre-existing, long-term business. We will use this sequential timing assumption to rationalize why bank debt is not fully priced at the margin, which is a necessary condition for risk-shifting with the endogenous cost of bank funding (in Section 4). The bank's project choice is not verifiable, so the bank cannot pre-commit at date 0 to the scale or the type of its future side activities.

4. Finally, the banker can 'abscond'. Immediately after date 1 the owner-manager can convert the bank's assets into private benefits, leaving nothing to creditors. The manager runs the bank normally when:

$$\Pi \geq b(1+X), \tag{1}$$

where Π is the bank's profit when assets are employed for normal use, and $b(1+X)$ is the initial value of assets $1+X$ multiplied by the conversion factor b ($0 < b < 1$) of assets into private benefits. The parameter b can reflect the quality of institutional environment (e.g., creditor rights), with lower b for better institutions. While the returns R, ε, and α (those obtained in the normal course of bank business) are fully pledgeable to outside investors, the private benefits received during absconding are not pledgeable. In our model, the absconding event is out-of-equilibrium: the creditors do not provide funding if they expect the bank to abscond. The expression (1) therefore defines the bank's leverage constraint: its maximal balance sheet size as a $1/b$ multiplier of equity (Holmstrom and Tirole, 1998).[5]

Parametrization We set the parameter space so as to analyze the bank's incentives to opportunistically choose a risky rather than a safe market-based investment. We assume that the risky market-based investment has a lower NPV than the safe market-based investment:

$$p(1+\alpha) - 1 < \varepsilon, \tag{2}$$

[5] The restriction that firms can borrow only up to a multiple of their net worth is standard in corporate finance models. For banks it can be thought of as an economic capital requirement (Allen et al., 2011). The payoff to moral hazard $b(1+X)$ can represent savings on abstaining from the owner-manager's effort; payoff to absconding, looting, or cash diversion (Calomiris and Kahn, 1991; Akerlof and Romer, 1993; Hart, 1995; Burkart and Ellingsen, 2004; Martin and Parigi, 2013; Boyd and Hakenes, 2014); and more generally results from the limits on the pledgeability of revenues (Holmstrom and Tirole, 1998; Gennaioli et al., 2014).

but once the cost of funding is sunk the expected return to the banker from the risky investment is higher than that from the safe investment, creating risk-shifting incentives:[6]

$$p\alpha > \varepsilon. \tag{3}$$

We also assume that:

$$R - 1 \geq b, \tag{4}$$

so that the leverage constraint (1) is not binding when the bank engages only in the core project, but:

$$\varepsilon < p\alpha < b, \tag{5}$$

so that the leverage constraint becomes more binding when the bank expands market-based investments. The conditions (4) and (5) can be interpreted as that the core project gives the bank spare borrowing capacity, which the bank then uses for side investments.[7]

Funding The bank funds itself with debt. It attracts 1 unit of funds for the core project at date 0 against the interest rate r_0, and X units of funds for market-based investments at date 1 against the interest rate r_1. We call the two groups of creditors "date 0" and "date 1" creditors, respectively.

The creditors are repaid in full at date 2 if the bank is solvent: the payoff from projects exceeds

[6] Of course, some risky market-based investments may be more profitable than safe investments or indeed traditional bank lending (think of successful hedge fund-like strategies). But in our setup we focus on bank incentives to opportunistically undertake unproductive risky investments. The setup with binary risky return resembles 'carry trade' strategies that were common in the run-up to the crisis and generated a small positive return most of the time, but catastrophic losses with a small probability (Acharya et al., 2009).

[7] Banks' traditional lending is indeed usually more profitable than their marked-based investments. In 2000-2014, the average bank net interest margin was 3% (NY Fed, 2015) and the average cost of bank funding 2.5% (according to the Federal Home Loan Bank of San Francisco Cost of Funds Index), making the gross return on lending 5.5%. In the same period, the average gross return on banks' trading assets and securities was substantially lower: less than 2%. The assumption on the relative profitability of traditional vs. market-based bank activities is also consistent with the observation that traditional banks (with relationship rents and a fixed customer base) are often not credit-constrained, while market-based activities require a substantial equity commitment (as obtained through partnerships in early investment banking, or from full partners in hedge funds). A b higher than that in (4), $b > R - 1$, would make the bank unable to raise funds even for its core activity (creditors' participation constraint would never be satisfied). A b lower than that in (5), $b < p\alpha$, would enable the bank to undertake market-based investments on an infinite scale (a bank's leverage constraint would never be binding).

the total amount owed. If the bank is insolvent, which may happen when the risky market-based investment returns 0, the bank goes bankrupt and the value of its assets – the core project's payoff R – is distributed to the two groups of creditors according to their relative seniority. The relative seniority of date 1 creditors is given by a parameter θ: the share of their initial investment that they reclaim in bankruptcy. That is, in bankruptcy, date 1 creditors are repaid θX and date 0 creditors $R - \theta X$, where:

$$0 < \theta < \min\{R/X, 1\}. \tag{6}$$

A higher θ implies more senior date 1 creditors. We treat θ as an exogenous parameter. We show separately (in Section 4) that if the bank was able to choose θ after date 0 debt was attracted, and θ was non-contractible *ex ante*, the bank would always select the highest possible θ, so as to reduce the cost of date 1 debt. Therefore one can interpret the exogenous θ as the maximum seniority of date 1 debt that is feasible under contractual arrangements available to the bank and its date 1 creditors. For example, the more of date 1 debt can be attracted as repos, the higher is θ.[8]

To generate risk-shifting, we need to impose that some bank debt is not priced at the margin. We do that in two alternative ways. In Section 3, we present a simplified model with an exogenous interest rate charged by date 0 creditors: $r_0 = 0$. This allows us to obtain a simple closed-form solution, and demonstrate the economics behind our results most directly. (The setup with an exogenous $r_0 = 0$ can be rationalized with deposit insurance.) In Section 4, we solve the model with a fully endogenous cost of funding. There, the friction that prevents bank debt from being priced at the margin is that the bank cannot commit to date 0 creditors to the type of the market-based investment that it will undertake at date 1. (Here we use the sequential timing assumption that the market-based investments are initiated alongside a pre-existing core project.) Should the bank attract senior date 1 debt to fund a risky market-based investment, that would dilute the pre-existing date 0 debt (similar to Brunnermeier and Oehmke, 2013). While that expected dilution is priced in date 0 debt *ex ante*, the actual *ex post* risk choice is not, making date 0 debt not priced at the margin. We keep date 1 debt always priced at the margin;[9] our results would become stronger

[8] Our specification is consistent with θX of date 1 funding being provided through repos (i.e. senior, with protected principal investment), and the remaining as junior debt. Choosing alternative specifications for describing the creditors' relative seniority would not qualitatively affect our results.

[9] When the bank's date 1 risk-taking strategy is contemporaneously observable but not verifiable, it can be priced

if it was not.

The timeline is summarized in Figure 1.

3 Solution with an exogenous r_0

This section solves the model with an exogenous interest rate charged by date 0 creditors: $r_0 = 0$. This enables us to present a closed-form solution, and does not affect the economics of the model. In principle, the assumption of a risk-inelastic r_0 can be rationalized when date 0 creditors are protected by deposit insurance with risk-insensitive premia.[10] Section 4 considers a model with a fully endogenous r_0 and confirms that our results hold.

We solve the model backwards. First, we derive bank profits conditional on a bank's strategy. Next, we establish the profit-maximizing bank strategy. Finally, we show how the bank's strategy (i.e., the decision on whether to engage in risk-shifting) depends on its profitability, and on debt seniority arrangements.

3.1 Bank payoffs

Safe market-based investment When, alongside the core project, the bank makes a safe market-based investment, its profit is:

$$\Pi_{Safe} = (R - 1) + \varepsilon X, \tag{7}$$

where $R - 1$ is the return on the core project, and εX is the return on the safe investment, both net of repayment to creditors. Here $r_0 = 0$ by assumption, and $r_1 = 0$ because the bank with a safe market-based investment never fails. (Note that $\Pi_{Safe} > R - 1$, so making a safe market-based investment always dominates making no market-based investment at all.)

at the margin in date 1 but not date 0 debt interest rates.

[10] See Laeven (2002) for a discussion of bank deposit insurance modalities. Boyd et al. (1998) and Freixas et al. (2007) analyze mispriced safety net as a source of bank risk-shifting.

Risky market-based investment Now consider the bank's profit when it makes a risky market-based investment. Recall that the risky market-based investment has a lower NPV than the safe market-based investment. Accordingly, the bank will only make the risky investment when it can shift the downside risk realizations to its creditors. For a small-scale market-based investment, $X < R - 1$, that is impossible: even when the risky investment returns 0, the bank's return on the core project R exceeds the total amount owed to creditors $1 + X$, so the shareholders internalize the downside. A bank's expected profit from such a small-scale risky investment is:

$$\Pi_{Risky}^{X<R-1} = R - 1 + p(1 + \alpha)X - X, \tag{8}$$

where R is the return on the core project, 1 is the amount borrowed for the core project, $p(1+\alpha)X$ is the expected return on the risky project, and X is the amount borrowed for the risky investment. From (2), $\Pi_{Risky}^{X<R-1} < \Pi_{Safe}$: a bank's profit from a small-scale risky market-based investment is always lower than that from a safe investment.

Therefore, the bank would only make a risky market-based investment when the investment's scale is large enough, $X > R - 1$. Then, the bank's expected profit is:

$$\Pi_{Risky} = p\left(R - 1 + (\alpha - r_1)\, X\right), \tag{9}$$

where p is the probability of success of the risky investment, $R - 1$ is the return on the core project, and $(\alpha - r_1)\, X$ is the return to the bank on the risky investment, both net of repayment to creditors. With additional probability $1 - p$ the risky investment fails, the bank cannot repay the creditors in full, and its profit is zero.[11] The interest rate r_1 is obtained from the break-even condition of date 1 creditors:

$$p(1 + r_1)X + (1 - p)\theta X = X, \tag{10}$$

where $(1 + r_1)X$ is the repayment to date 1 creditors when the risky investment succeeds and the

[11] The face value of bank debt is $1 + X$; the actual promised repayment to the creditors is larger than that because date 1 debt interest rate is positive. When the market-based investment produces 0, the only bank asset is the gross return on the core project, R. Then, $X > R - 1$ implies that $R < 1 + X$: the bank has negative equity and cannot repay its creditors in full.

bank is solvent (with probability p), θX is the repayment when the risky investment fails and the bank goes bankrupt (with probability $1-p$), and X is the date 1 creditors' investment into the bank. From (10):

$$r_1 = \frac{(1-p)(1-\theta)}{p}, \tag{11}$$

making the bank's profit (9):

$$\Pi_{Risky} = p\left(R - 1 + \left(\alpha - \frac{(1-p)(1-\theta)}{p}\right)X\right). \tag{12}$$

Combining a safe and a risky investments is never optimal Hypothetically, the bank could make a combination of a safe and a risky market-based investments. However, this is never optimal, because a single investment type always dominates a combination of the two. To see this, assume that the bank divides the total market-based investment X into a combination of a safe X^S and a risky X^R investments, so that $X^S + X^R = X$. Similar to (7), (8), and (9), the bank's profit is:

$$\Pi_{Safe+Risky} = \begin{cases} R - 1 + \varepsilon X^S + (p(1+\alpha)-1)X^R, & \text{if } R - 1 + \varepsilon X^S - X^R \geq 0 \\ p(R - 1 + (\varepsilon - r_1)X^S + (\alpha - r_1)X^R), & \text{otherwise} \end{cases}. \tag{13}$$

The top line in (13) represents the case when the bank is able to repay all creditors in full even when the risky investment fails (therefore, $r_1 = 0$). Then, choosing a safe investment dominates the combination of a safe and a risky ones (from (2)):

$$\Pi_{Safe+Risky} = R - 1 + \varepsilon X^S + (p(1+\alpha)-1)X^R < R - 1 + \varepsilon X = \Pi_{Safe}. \tag{14}$$

The bottom line in (13) represents the case when the bank cannot repay its creditors in full when the risky investment fails (therefore, $r_1 = (1-p)(1-\theta)/p$). Then, choosing a risky market-based investment dominates the combination of a safe and a risky ones (from (3)):

$$\Pi_{Safe+Risky} = p(R - 1 + (\varepsilon - r_1)X^S + (\alpha - r_1)X^R) < p(R - 1 + (\alpha - r_1)X) = \Pi_{Risky}. \tag{15}$$

Therefore, the combination of a safe and a risky market-based investments is never optimal.

3.2 Bank strategy

We showed above that the bank chooses between making a safe market-based investment that obtains profit Π_{Safe} (7) and a risky market-based investment that obtains profit Π_{Risky} (12). We decompose the analysis of that decision into two parts. One part is the bank's *incentives* to take risk. The other part is the bank's *ability* to take enough leverage to make a risky investment worthwhile. We discuss these in turn.

Incentives to make a risky investment The bank has incentives to choose the risky market-based investment over a safe one for $\Pi_{Safe} < \Pi_{Risky}$, corresponding to (use (7) and (12)):

$$X > X_{\min} = \frac{(1-p)\,(R-1)}{p\alpha - \varepsilon - (1-p)(1-\theta)}, \tag{16}$$

when:

$$\theta > \theta_{\min} = 1 - \frac{p\alpha - \varepsilon}{1-p}, \tag{17}$$

and never for a lower θ.[12] (The intuition is that, for $\theta \leq \theta_{\min}$ the cost of date 1 funding is high and consequently the risky market-based investment is less profitable than the safe market-based investment.)

The expression (16) suggests that the risky investment can only dominate the safe investment when it is undertaken at sufficient scale. The intuition is that the benefit to the bank of choosing a risky investment – the extra return to shareholders, $X(p\alpha - \varepsilon)$ – is proportional to the scale of the investment. The cost of making a risky investment – a possible loss of the core project's profits in bank bankruptcy, $(1-p)\,(R-1)$ – is invariant to the scale of the risky investment. Thus the scale of the investment X has to be high enough to make the benefit of the risky investment outweigh its cost.

[12] Note that $X_{\min} > R-1$, where $R-1$ is the minimum scale of the risky investment such the the bank becomes insolvent upon a 0 realization of the risky investment ($X > R-1$ is the constraint that underlies equation (12)). From (2): $(1-p)-p\alpha > -\varepsilon > -\varepsilon-(1-p)(1-\theta)$, implying for the denominator in (16) that: $p\alpha-\varepsilon-(1-p)(1-\theta) < 1-p$, and consequently: $X_{\min} > R-1$.

Ability to obtain leverage for the risky investment The notion of the minimal scale of the risky investment leads us to analyze whether the bank can lever up sufficiently to achieve the scale at which the risky investment dominates the safe investment. The leverage constraint (1) of a bank that makes a risky investment at scale X is:

$$p\left(R-1+\left(\alpha-\frac{(1-p)(1-\theta)}{p}\right)X\right)\geq b(1+X), \tag{18}$$

where the left hand side $p(\cdot)$ is the bank's profit (same as Π_{Risky} in (12)) and the right hand side $b(1+X)$ is the absconding payoff. From (18), the bank has the ability to make a risky investment for scale X with:

$$X\leq X_{\max}=\frac{p\,(R-1)-b}{b-p\alpha+(1-p)(1-\theta)}. \tag{19}$$

In addition, it must hold that $\theta X<R$, because the promised repayment in bankruptcy to date 1 creditors θX cannot exceed the resources available in bankruptcy R (see (6)). Combining (6) and (19) yields an additional restriction:

$$\theta<\theta_{\max}=\frac{R(b-p\alpha+1-p)}{R-b-p}. \tag{20}$$

Expressions (16) and (19) help contrast the effects of profitability on bank risk-taking in traditional models and in our model. Consistent with traditional risk-shifting models, in our model the bank's risk-shifting incentives decline in its higher profitability R holding the size of the investment X fixed. From (16): $\partial X_{\min}/\partial R>0$, so for any given X there exists $\bar{R}(X)$ such that the bank makes a risky investment for $R<\bar{R}(X)$ but a safe one for $R\geq\bar{R}(X)$. The novelty of our framework is that, in contrast to traditional risk-shifting models, we make the size of the investment X endogenous to the bank's profitability R. From (19): $\partial X_{\max}/\partial R>0$, so higher profitability enables the bank to achieve larger scale of the risky investment. Then the question is whether a higher R (which increases the right-hand side in (16)) might allow for an exceedingly higher endogenous X (which increases the left-hand side in (16)), thus offsetting the traditional effect where a higher R diminishes bank risk-taking incentives for a fixed X.[13]

[13] Another effect highlighted by (16) is that the bank is more likely to make the risky investment when the seniority

Figure 2 illustrates the bank's payoffs from different strategies. The bank chooses between a safe and a risky market-based investments, shown with the dashed and the solid lines, respectively. For high enough scale of side investments, $X > X_{\min}$, the risky investment dominates. However the bank is constrained by the leverage constraint, shown with the dotted line, restricting the scale of side investments to $X < X_{\max}$. A change in R affects both $X_{\min}$ and $X_{\max}$.

Bank risk choice To derive the bank's strategy, we restrict the parameter space to $\theta_{\min} < \theta < \theta_{\max}$ (see (17) and (20)) as otherwise the bank never takes risk. We can summarize the bank's strategy as follows:

Lemma 1 *The bank chooses a risky market-based investment when $X_{\min} < X_{\max}$, corresponding to:*

$$b < b^* = \frac{\left(p(\alpha - \varepsilon) - (1-p)(1-\theta)\right)(R-1)}{(1-p)(R-1) + p\alpha - \varepsilon - (1-p)(1-\theta)}. \tag{21}$$

Here exist parameter values such that the intersection between conditions $\theta_{\min} < \theta < \theta_{\max}$ and $b < b^*$ is non-empty. When the bank chooses a risky market-based investment, it does so at its maximum scale $X_{\max}$. For $b \geq b^*$, the bank chooses the safe market-based investment.

Proof. See Appendix. ■

The intuition for Lemma 1 is that an opportunistic risky investment is only attractive at high scale, and thus a bank is more likely to choose it when its leverage constraint is sufficiently loose: b is low (i.e., $b < b^*$). A loose leverage constraint may be a result of a better institutional environment, with more protection of creditor rights. This interpretation is consistent with the fact that banks in advanced economies were on average more leveraged and more exposed to risky financial instruments compared to banks in emerging and developing economies prior to the recent crisis (Claessens et al., 2010). Expression (21) summarizes bank risk-taking strategy as a relation between b and other parameters of the model. We can use it to assess how changes in those other parameters – specifically R and θ – affect bank risk-taking by considering how they impact the threshold value

of new debt θ is higher: $\partial X_{\min}/\partial\theta < 0$. The reason is that a high seniority of date 1 debt reduces the interest rate demanded by date 1 creditors and makes the funding of the risky investment cheaper.

of b, b^*. A higher b^* indicates a wider range of parameter values for which a bank chooses the risky investment, which we interpret as higher risk-taking incentives.

3.3 Determinants of bank risk-taking

For the effect of core profitability R on bank risk-taking, we can demonstrate the following:

Proposition 1 (Bank Profitability and Risk-Taking) *Higher profitability of the bank's core business R expands the range of parameter values for which the bank chooses the risky market-based investment: $\partial b^*/\partial R > 0$, and increases the scale of the risky investment: $\partial X_{\max}/\partial R > 0$.*

Proof. See Appendix. ■

Proposition 1 is our key result. It shows that, in our framework, more profitable banks have higher risk-taking incentives. The reason is that a higher profitability R enables the bank to make the risky investment on a larger scale (higher $X_{\max}$), making risk-taking more attractive. This indirect scale-related effect offsets the traditional direct effect where higher profitability reduces a bank's incentives to take risk of fixed size (higher $X_{\min}$). Proposition 1 sheds light on a possible reason why some profitable banks invested so much in risky financial instruments before the recent crisis. High profitability allowed those banks to take risky side exposures on an exceedingly large scale. The additional profit from risky investments taken at high scale compensated the banks for the risk of a loss of a profitable core business franchise. Figure 3 panel A illustrates the impact of the bank's core profitability R on its risk-taking in side activities.

We now examine the effect of the seniority of date 1 bank funding θ on bank risk-taking. We can demonstrate the following:

Proposition 2 (Debt Seniority and Bank Risk-Taking) *Higher seniority of date 1 debt θ expands the range of parameter values for which the bank chooses the risky market-based investment: $\partial b^*/\partial\theta > 0$, and increases the scale of the risky investment: $\partial X_{\max}/\partial\theta > 0$. Moreover, the effects of core profitability and debt seniority on bank risk-taking are mutually reinforcing: $\partial^2 b^*/\partial R\partial\theta > 0$ and $\partial^2 X_{\max}/\partial R\partial\theta > 0$.*

Proof. See Appendix. ■

Proposition 2 highlights the role of bank funding arrangements in inducing risk-shifting through side activities. When the side activities (market-based investments) are financed with senior funding, this subsidizes new, date 1 creditors at the expense of incumbent, date 0 creditors. The interest rate required by the new creditors declines in their seniority: $\partial r_1/\partial\theta = -(1-p)/p < 0$, making side investments more attractive (lower $X_{\min}$) and enabling the bank to take risk on a larger scale (higher $X_{\max}$). Since the feasible scale of side investments X (on which the seniority-related interest rate subsidy is accrued) increases in R, the effects of higher core profitability and new debt seniority on bank risk-taking are mutually reinforcing. Figure 3 panel B illustrates the impact of new bank debt seniority θ on bank risk-taking.

Recall that this model treats θ as an exogenous parameter. If the bank were able to choose θ after date 0 debt was attracted, and θ were not contractible *ex ante*, the bank would always set the highest possible θ to reduce the cost of date 1 debt and thus increase profits.[14] Indeed, from (12): $\partial\Pi_{Risky}/\partial\theta > 0$. Therefore one can interpret the exogenous θ as the maximum feasible seniority of date 1 debt.

4 Solution with an endogenous r_0

The previous section assumed an exogenous interest rate on date 0 debt, $r_0 = 0$, to obtain a closed-form solution and demonstrate the economics of our model most directly. This section considers an endogenous r_0 set from the date 0 creditors' break-even condition, and verifies that the results of Propositions 1 and 2 hold.[15]

With an endogenous r_0 the solution becomes more complex. The reason is the interaction

[14] The assumption that a bank cannot commit at date 0 to a future θ appears plausible. As Brunnermeier and Oehmke (2013) explain, a bank is usually not able to commit to the future funding strategy because of [unpredictable and] "frequent funding needs, opaque balance sheets, and continuous activity in the commercial paper market."If the bank were able to commit to a low θ, that would reduce (as per Proposition 2) or eliminate (e.g., for $\theta < \theta_{\min}$) bank risk-taking incentives highlighted by this model.

[15] As in Section 3, the market-based investments are initiated alongside the pre-existing core project. Here, this sequential timing assumption creates a friction (i.e., the bank cannot commit to date 0 creditors to the type of the market-based investment that it will undertake at date 1) that prevents date 0 bank debt from being priced at the margin.

between the interest rate charged by date 0 creditors and bank risk-taking. The bank's anticipated risk-taking implies a positive interest rate r_0. In a typical risk-shifting model, a higher interest rate induces borrowers to undertake projects with lower probabilities of success but high payoff in case of success (because higher debt repayments absorb much of the return on moderately profitable projects), i.e. it increases the borrowers' risk-taking incentives (Stiglitz and Weiss, 1981). However, in our model a higher r_0 may have an opposite effect: it may reduce bank risk-taking incentives. The reason is that a higher r_0, in effect, reduces the profitability of the bank's core project and thus constrains the bank's borrowing capacity (similar to an effect of a lower R on $X_{\max}$ in (19)), whereas risk-taking is less attractive at a lower scale.[16] Therefore, in our model there always exists a high enough r_0 that constrains the bank's borrowing capacity sufficiently to prevent risk-taking. But with such a high r_0, date 0 bank creditors would generally obtain positive rents, which is inconsistent with them being competitive. To meaningfully characterize the equilibrium, we assume that date 0 bank creditors set the minimal interest rate so as to at least break even under correctly anticipated bank risk choices.

4.1 Interest rates and bank risk-taking

We consider the mutually consistent combinations of date 0 interest rates and bank risk choices. There are three such possible combinations in our model.

1. A bank makes a safe investment. Assume that date 0 creditors anticipate that the bank will make a safe market-based investment and set $r_0 = 0$. Then, as in the basic model, the bank makes a safe investment for $b \geq b^*$ (see (21)). For $b < b^*$, a bank makes a risky investment in response to $r_0 = 0$, so creditors have to set a positive interest rate.

2. A bank makes a risky investment. Assume that $b < b^*$, so date 0 creditors anticipate that the bank will make a risky market-based investment in response to $r_0 = 0$. Then, they can set the

[16] The idea that higher interest rates may prevent bank risk-taking while low interest rates can induce it seems in line with the "risk-taking channel of monetary policy" (cf. Borio and Zhu, 2012). Section 5 explores the effects of monetary policy on bank risk-taking in the context of our model in more detail.

interest rate r_0 based on their break-even condition that internalizes bank risk-taking:

$$p(1 + r_0) + (1 - p)(R - \theta X) = 1. \tag{22}$$

This condition is similar to that for date 1 creditors (10), except that the repayment in case of bank bankruptcy is $(R - \theta X)$ rather than θX, reflecting a different relative seniority of date 0 creditors.

Further, the creditors know that the bank's profit (similar to (12)):

$$\Pi^{r_0}_{Risky} = p\left(R - 1 - r_0 + \left(\alpha - \frac{(1-p)(1-\theta)}{p}\right) X\right) \tag{23}$$

is increasing in X: $\partial \Pi^{r_0}_{Risky}/\partial X > 0$. Accordingly, the bank will make the risky investment on the maximal possible scale (similar to (19)):

$$X = X_{\max}(r_0) = \frac{p(R - (1 + r_0)) - b}{b - p\alpha + (1-p)(1-\theta)}. \tag{24}$$

Substituting X from (24) into (22) and solving for r_0 obtains the interest rate r_0^{Risky} that reflects the bank's anticipated risk-taking:

$$r_0^{Risky} = \frac{1-p}{p} \cdot \frac{(R-1)(\theta - (b - p\alpha + 1 - p)) - b\theta}{b - p\alpha + 1 - p}. \tag{25}$$

It is easy to verify that $r_0^{Risky} > 0$ for $b = b^*$ and $\partial r_0^{Risky}/\partial b < 0$. The intuition for the latter effect is that when b declines, the bank's leverage constraint becomes looser, so the bank can make the risky investment on a larger scale. This dilutes the date 0 creditors' claim in a possible bankruptcy, as they have to share the core project's payoff R with a higher mass of date 1 creditors.

3. A sufficiently high r_0 prevents bank risk-taking An alternative reaction of date 0 creditors to the possibility of bank risk-taking for $b < b^*$ is to set r_0 high enough, so as to reduce the bank's profit and thus tighten its borrowing capacity at date 1 sufficiently to make the risky investment unattractive for the bank. Indeed, from (24), an increase in r_0 decreases the bank's borrowing capacity: $\partial X_{\max}(r_0)/\partial r_0 < 0$. Consequently, for any $b < b^*$ there exists $r_0^{Prevent}(b) > 0$

such that in response to that interest rate the bank does not take risk. To derive $r_0^{Prevent}$, consider the minimal scale at which the bank starts preferring a risky market-based investment to a safe one, $X_{\min}(r_0)$ (similar to (16)):

$$X_{\min}(r_0) = \frac{(1-p)(R-(1+r_0))}{p\alpha - \varepsilon - (1-p)(1-\theta)}, \tag{26}$$

and set $X_{\min}(r_0) = X_{\max}(r_0)$ (use (24)) to obtain:

$$r_0^{Prevent} = (R-1) - \frac{b(p\alpha - \varepsilon - (1-p)(1-\theta))}{p(\alpha-\varepsilon) - (1-p)(1-\theta) - (1-p)b}. \tag{27}$$

Note that $r_0^{Prevent} \to 0$ for $b \to b^*$. Recall that $r_0^{Risky} > 0$ for $b \to b^*$. Therefore, it holds that $r_0^{Prevent} < r_0^{Risky}$ for $b \to b^*$: when b is below but close to b^*, date 0 creditors can prevent bank risk-taking with a relatively small increase in r_0, and the interest rate that prevents bank risk-taking is lower than the one that prices it in. At the same time, $\partial r_0^{Prevent}/\partial b < 0$: as b declines, the bank's leverage constraint becomes looser, so the interest rate that prevents bank risk-taking increases.

The feature of our model where higher funding cost may prevent bank risk-taking is rarely present in other risk-shifting models. It is an artefact of the same link between bank profitability and its ability to expand leverage that drove our main result (Proposition 1). It makes solving the model somewhat more complex.

4.2 Equilibrium strategy

Recall that date 0 creditors choose the minimal interest rate consistent with at least breaking even under correctly anticipated bank risk-taking strategy. For $b \geq b^*$ that is $r_0 = 0$. For $b < b^*$ that is either $r_0^{Prevent}$ or r_0^{Risky}, whichever is lower. Unfortunately, the closed-form solution to $r_0^{Prevent} = r_0^{Risky}$ is too complex to be tractable. Therefore, from this point on we need to examine the model numerically.

A numerical exercise needs to be carefully interpreted. Any numerical exercise demonstrates the existence of parameter values for which the model insights hold, not the generality of the findings.

There are two ways to reflect on this limitation. On the one hand, the purpose of this paper is to show that the effect where higher bank profitability leads to more bank risk-taking may exist, rather than to argue that it holds universally. In this context, a numerical exercise can confirm that the results of Propositions 1 and 2 hold for a plausible set of parameter values. On the other hand, we study multiple variations of parameter values and find that the results of Propositions 1 and 2 hold consistently across them. This suggests a degree of generality of our numerical results.

We first characterize mutually consistent combinations of date 0 interest rate r_0 and bank risk-taking choices, depending on the intensity of the leverage constraint b. Figure 4 panel A illustrates the evolution of $r_0^{Prevent}$ (from(27)) and r_0^{Risky}(from(25)) in b for the following headline set of parameter values: $R = 1.07$; $\varepsilon = 0.02$; $\alpha = 0.03$; $p = 0.97$; $\theta = 0.75$. This parameter set satisfies all restrictions (2)-(5) as well as that on θ: $\theta_{\min} < \theta < \min\{R/X, 1\}$ from (6) and (17). In addition to this set, we examined alternative sets of parameter values that cover a substantial range of their plausible values and obtained similar results.[17] The following summarizes:

Numerical result 1. *Equilibrium date 0 interest rate and bank risk-taking are characterized by two thresholds: b^* (from (21)) and b^{**}, $b^{**} < b^*$, obtained from solving $r_0^{Prevent} = r_0^{Risky}$, as follows:*

- *For $b \geq b^*$, date 0 creditors set $r_0 = 0$, and the bank makes the safe market-based investment.*
- *For $b^{**} \leq b < b^*$, date 0 creditors set $r_0 = r_0^{Prevent} > 0$ (given by (27)), and the bank makes the safe market-based investment. Date 0 creditors earn positive rents, but a lower interest rate would induce the bank to take risk, which would lead to a violation of the date 0 creditors' break-even condition.*
- *For $b < b^{**}$, date 0 creditors set $r_0 = r_0^{Risky}$ (given by (25)), and the bank makes the risky market-based investment.*

[17] The sets were: $R \in [1.05; 1.15]$ to reflect return on bank loans; $\varepsilon \in [0.01; 0.05]$ to reflect 10-year treasury interest rates; $\alpha \in [0.02; 0.10]$ to reflect ABS or bond yields; $p \in [0.95; 0.98]$ to reflect ABS or bond risk; $\theta \in [0.75; 0.95]$ to reflect substantial use of senior (e.g., repo) funding for market-based investments. We used those combinations of parameter values from these sets that satisfied conditions (2)-(6) and (17).

The intuition is as follows. As b declines below b^*, the bank chooses a risky investment in response to $r_0 = 0$. Yet a small increase in the date 0 interest rate from $r_0 = 0$ to $r_0 = r_0^{Prevent}$ tightens the bank's leverage constraint and prevents bank risk-taking (recall that $r_0^{Prevent} \to 0$ for $b \to b^*$). Interestingly, for $b^{**} \leq b < b^*$, date 0 creditors earn positive rents. Yet $r_0^{Prevent}$ is the smallest interest rate consistent with them at least breaking even: reducing it would induce bank risk-taking and make date 0 creditors lose money on expectation. As b declines further, the interest rate that is necessary to prevent bank risk-taking increases. At $b = b^{**}$ the two interest rate functions: $r_0^{Prevent}$ and r_0^{Risky} intersect, and for lower values of b, $b < b^{**}$, it requires a lower interest rate to price risk-taking in the cost of debt rather than to prevent it. Thus, for $b < b^{**}$, date 0 creditors charge r_0^{Risky} and break even, while the bank makes the risky investment.[18]

The key implication of Numerical result 1 is that the threshold value of b at which bank takes risk is not anymore b^* as it was under an exogenous $r_0 = 0$ in Section 3, but $b^{**} < b^*$. The reason for a lower threshold is that allowing a positive r_0 reduces the bank's core profitability and hence its risk-taking incentives. Accordingly, a bank makes a risky market-based investment for a narrower range of parameter values.

4.3 Determinants of bank risk-taking

We can now characterize how the threshold b^{**} (where the bank takes risk for $b < b^{**}$) responds to changes in R and θ. Figure 4 panel B illustrates the evolution of b^{**} in R and θ for the same as above headline set of parameter values: $\varepsilon = 0.02$; $\alpha = 0.03$; $p = 0.97$. We also examined same alternative sets of parameter values as those described in footnote 17 and verified the results for them too. The following summarizes:

Numerical result 2. *The threshold b^{**} increases in R and θ, and is convex in the combination of R and θ.*

The evolution of b^{**} in response to R and θ is similar to the evolution of b^* in Propositions 1 and

[18] Note that $r_0^{Risky} = r_0^{Prevent}$ is a quadratic equation in b. The threshold b^{**} is the larger root of that equation. Within our parameter values, the other root is always below $p\alpha$, which is the lowest value of b consistent with the parameters of our model (see (5)).

2. Banks take risk for a wider range of parameter values when their core profitability R is higher, and when the feasible seniority of debt used to finance market-based investments θ is higher. The numerical exercise therefore confirms that the results of Propositions 1 and 2 hold for plausible sets of parameter values under an endogenous date 0 interest rate r_0. The key intuition, again, is that a bank's higher profitability increases its ability to borrow. A more profitable bank can take risky side investments on a larger scale, which offsets its lower incentives to take risk of fixed size.

4.4 Endogenous seniority of date 1 debt

Up to now we have treated the seniority of date 1 creditors θ as an exogenous parameter. We can now verify that if a bank can choose θ after the date 0 funding is attracted, it will always choose the highest possible θ, and that for such θ our results hold. Consider an arbitrary range $[\theta_1,\theta_2]$ from the interval $(\theta_{\min}, \theta_{\max})$, the feasible range of θ defined in (17) and (20). The bank chooses θ from $[\theta_1,\theta_2]$ to maximize its expected profits. From (23):

$$\frac{\partial \Pi_{Risky}}{\partial \theta} = \frac{(1-p)b(p(R-1-r_0)-b)}{(b-p\alpha+(1-p)(1-\theta))^2} > 0. \tag{28}$$

Thus, the bank chooses the highest possible θ from $[\theta_1, \theta_2]$: $\theta = \theta_2$. This result is consistent with our initial interpretation of an exogenous θ as the maximal feasible seniority of date 1 funding (see the discussion that follows expression (6)). Therefore, for any $\theta_2 \in [0.75, 0.95]$ (corresponding to the range for exogenous θ in our numerical simulation, see footnote 17) our numerical results hold also for the maximum feasible seniority.

5 Extensions

This section offers two extensions to the main model. First, we consider a non-deterministic core project and let the bank exert effort to improve its performance. We show that access to an opportunistic market-based investment may induce more bank effort in the core project. The reason is that a more valuable core project enables the bank to pursue privately-profitable side investments on a larger scale. A bank then strategically combines a prudent core business with risky market-based investments.

Second, we consider the effects of a change in bank funding costs (as might be driven by monetary policy) on bank risk-taking in its core business versus that in its market-based investments. We show that a lower cost of funding induces more bank effort in the core project, but – at the same time – more risk-taking in the bank's market-based activities. The reason is that a lower cost of funding is akin to a more profitable core project. It makes a bank more willing to preserve the value of the core project, but enables the bank to lever up more and take larger-scale risk in its side activities. This finding points to possible differential effects of monetary policy on bank risk-taking depending on whether a bank activity is scalable or not.

To derive closed form solutions, we go back to the assumption of an exogenous date 0 interest rate: $r_0 = 0$. (Endogenizing r_0 would not affect the results.)

5.1 Effort in the core project

Consider the case where the return on the core project is no longer deterministic. Instead, the bank needs to exert effort to improve the performance (increase the probability of success) of the core project. We analyze how access to an opportunistic market-based investment may affect bank effort in the core project.

Assume that the return on the core project is R with probability e and 0 otherwise (as opposed to a certain R in the main model). The probability e corresponds to the bank's effort, which carries a private cost $ce^2/2$. We focus on c high enough such that the model admits an interior solution in effort. The bank exerts effort after date 0 funding is attracted. The outcome of the effort becomes public knowledge immediately afterwards. If it becomes known that the core project returns 0, the bank goes bankrupt (it cannot make a market-based investment either because the leverage constraint (1) is not satisfied for standalone market-based investments (see (5)). If it becomes known that the core project returns R, the rest of the game is similar to the model in Section 3. The timeline is summarized in Figure 5.

We are interested in two questions. First, how does the bank's effort in the core project e depend on the feasible scale of its market-based side investments, as captured by b (a lower b implying a looser leverage constraint and more scope for side investments). Second, how effort e is affected by the bank's access to an opportunistic, risky market-based investment, compared to a hypothetical case when the bank only has access to a safe market-based investment.

When the core project returns 0, the payoff to the banker is also 0. When the core project returns R, the bank subsequently chooses a safe market-based investment for $b \geq b^*$ and a risky one for $b < b^*$ (with b^* given in (21)). When the bank makes the safe investment, its profit is:

$$\Pi^e_{Safe} = e(R - 1 + \varepsilon X) - \frac{ce^2}{2}, \tag{29}$$

where $(R - 1 + \varepsilon X)$ is the bank's profit conditional on successful effort (similar to (7)), e is the probability of the core project's success, and $-ce^2/2$ is the cost of effort. The scale of the market-based investment X is obtained by setting to equality the leverage constraint (1) that takes form:

$$R - 1 + \varepsilon X \geq b(1 + X), \tag{30}$$

giving: $X = (R - 1 - b) \,/\, (b - \varepsilon)$. Substituting X from (30) into Π^e_{Safe} (29) and maximizing with respect to e gives:

$$e^*_{Safe} = \frac{b}{c} \cdot \frac{R - 1 - \varepsilon}{b - \varepsilon}. \tag{31}$$

When the bank chooses the risky investment, its profit is:

$$\Pi^e_{Risky} = ep\left(R - 1 + \left(\alpha - \frac{(1-p)(1-\theta)}{p}\right) X\right) - \frac{ce^2}{2}, \tag{32}$$

where $p(\cdot)$ is the bank's profit conditional on successful effort (similar to (12)). Deriving X and maximizing Π^e_{Risky} in a manner similar to (31) gives effort:

$$e^*_{Risky} = \frac{b}{c} \cdot \frac{p\,(R - 1 - \alpha) + (1 - p)\,(1 - \theta)}{b - p\alpha + (1 - p)(1 - \theta)}. \tag{33}$$

It is easy to obtain by differentiation of (31) and (33) that the bank's effort increases in the profitability of the core project: $\partial e^*_{Safe}/\partial R > 0$ and $\partial e^*_{Risky}/\partial R > 0$. This is natural: a higher upside of the core project induces the bank to exert more effort to make it succeed. More interesting, the bank's effort in the core project also increases with the feasible scale of the bank's market-based investments: $\partial e^*_{Safe}/\partial b < 0$ and $\partial e^*_{Risky}/\partial b < 0$, with a lower b capturing a higher feasible scale of market-based investments. The reason is that a successful core business ensures the bank's ability to undertake market-based investments, and a higher feasible scale makes market-based investments more valuable.

We can now proceed with the following exercise. Consider $b < b^*$, so that the bank normally chooses the risky market-based investment when the core project succeeds. Compare this with the case when the bank is restricted to the safe market-based investment only, even for these low values of b. We can demonstrate the following:

Proposition 3 (Safe Core Business, Risky Side Investments) *For $b < b^*$, a bank's effort in the core business when the risky market-based investment is available is higher than that if the bank was restricted to the safe market-based investment only: $e^*_{Risky}|_{b<b^*} > e^*_{Safe}|_{b<b^*}$.*

Proof. See Appendix. ■

Proposition 3 shows that a bank's access to a risky market-based investment may increase its effort in the core project. The reason is that, although the risky market-based investment has a lower NPV, it is still more profitable for bank shareholders than the safe market-based investment for $b < b^*$ (this is the nature of risk-shifting). Accordingly, for $b < b^*$, when the bank gains access to a privately-profitable risky market-based investment, it would increase its effort in the core business in order to enhance its ability to undertake this side investment. The bank then strategically combines high effort in the core project (higher than that if the bank was restricted to safe side investments) with risky side activities. While the literature has explained the seeming inconsistency of combining a prudent core business with risky side activities through a "clash of cultures" between conservative bankers and risk-loving traders (Froot and Stein, 1998), our model explains it based on shareholder value maximization under the possibility of privately-profitable risk-shifting in the bank's side activities.

5.2 Monetary policy and bank risk-taking

Now consider the case where the bank's cost of funding can exogenously vary, for example due to changes in the monetary policy stance. Assume that the reference interest rate for bank funding is i, so that the exogenous cost of date 0 debt is $r_0 = i$, and the cost of date 1 debt is determined by a break-even condition with the reservation return i. We allow i to vary, $i \lesseqgtr 0$, as opposed to $i = 0$ in the main model.[19]

When the bank makes the safe market-based investment, $r_1 = i$. When the bank makes the risky market-based investment, the break-even condition for date 1 creditors is (similar to (10)):

$$p(1 + r_1)X + (1 - p)\theta X = (1 + i)X, \tag{34}$$

which gives (similar to (11)):

$$r_1 = \frac{i + (1 - p)(1 - \theta)}{p}. \tag{35}$$

With the cost of funding i, the threshold for the bank's choice of safe versus risky market-based investment, b_i^*, becomes (similar to (21)):

$$b_i^* = \frac{(R - 1 - i)\,(p(\alpha - \varepsilon) - (1 - p)(1 - \theta + i))}{(1 - p)(R - 1 - i) + p\alpha - \varepsilon - (1 - p)(1 - \theta)}. \tag{36}$$

And the equilibrium effort in the core project (similar to (31) and (33)) becomes:

$$\begin{aligned} e^*_{Safe,i} &= \frac{b}{c} \cdot \frac{R - 1 - \varepsilon}{b - \varepsilon + i} \text{ for } b \geq b_i^*, \text{ and} && (37) \\ e^*_{Risky,i} &= \frac{b}{c} \cdot \frac{p(R - 1 - i) - p\alpha + i + (1 - p)(1 - \theta)}{b - p\alpha + i + (1 - p)(1 - \theta)} \text{ for } b < b_i^*. && (38) \end{aligned}$$

[19] Monetary policy may also affect the return on bank assets. But the effect of monetary policy on the return on bank assets is arguably smaller than its effect on the cost of bank funding, for two reasons. First, bank assets are longer-term than bank liabilities, so their return is less responsive to variations in short-term monetary policy rates. Second, the variation in the return on bank assets is also affected (and may be cushioned over the cycle) by the effects of interbank competition in lending markets (Dell'Ariccia et al., 2014). We abstract from the effects of monetary policy on the return on bank assets.

Differentiation of (36)-(38) obtains the following result:

Proposition 4 (Monetary Policy and Bank Risk-Taking) *A decrease in the bank's cost of funding increases the bank's effort in the core project, making it safer:* $\partial e^*_{Safe,i}/\partial i < 0$ *and* $\partial e^*_{Risky,i}/\partial i < 0$*, but at the same time increases the bank's risk-taking incentives in its market-based investments:* $\partial b^*_i/\partial i < 0$*.*

Proof. See Appendix. ■

Proposition 4 suggests a novel heterogeneity in the possible impact of monetary policy on bank risk-taking. A lower cost of funding (corresponding to more accommodative monetary policy) increases bank margins. For those bank activities that have fixed scale, such as the core relationships-based business, higher margins induce higher effort. But for scalable bank activities, such as market-based investments, higher margins make the bank's leverage constraint less binding, increasing the bank's incentives to use such side investments for risk-shifting.

The fact that accommodative monetary policy may differently affect bank risk-taking in the core business versus that in side investments suggests that the impact of monetary policy on bank risk-taking may depend on a bank's mix of activities. For example, accommodative monetary policy may have a small effect on bank risk-taking for "local" banks involved in relationship lending, but an acute effect for large banks active in financial markets (cf. Borio and Zhu, 2012). This finding complements other heterogeneities in the impact of monetary policy on bank risk-taking that were established in the literature (e.g., those related to banks' leverage and interbank competition, as in Dell'Ariccia et al., 2014).

6 Discussion

6.1 Empirical implications

The key empirical prediction of our model is that a bank's higher *ex ante* profitability increases its ability to borrow, and through this may induce bank risk-taking in side activities. While a formal econometric examination of this relationship is beyond the scope of this paper, here we offer illustrative evidence that such a channel of risk-taking may have been present for multiple U.S. and European banks in the run up to the 2008 crisis. (That is, our premise that many banks with high profitability took risk before the crisis does not seem to be limited to the three cases of UBS, Washington Mutual, and AIG discussed in the Introduction.) To provide this illustration, we consider the relationship between the profitability of U.S. and European banks in the 1990s and their risk-taking in the run up to the 2008 crisis. We use the banks' net income to total assets ratio over 1995-2000 (the time when banks' market-based activities were still relatively limited; Boot, 2014) as a proxy for banks' core profitability.[20] We use the bank equity losses during the crisis (end 2007 to end 2009) to proxy for the banks' pre-crisis risk-taking (as in Beltratti and Stulz, 2012). Assuming that bank risk has realized during the crisis, the extent of bank equity losses captures the banks' risk-taking intensity. We focus on banks with assets over 50 billion dollars in 2006. All data comes from Bankscope.

Figure 6 shows the resulting scatterplot.[21] The dotted fitted line shows a negative relationship between bank profitability in the late 1990s and bank equity returns in 2007-2009, indicating that more profitable banks took more risk in the run-up to the crisis. In addition, the solid fitted line shows this relationship for those banks whose non-loan assets growth during 2001-2006 was above-median (such banks are indicated with solid dots). The relationship between core profitability and equity returns during the crisis is steeper for these banks, indicating that risk-taking in profitable banks was related to the expansion of their side activities, in line with the predictions of our model. We can obtain similar figures with alternative measures, such as net interest margins instead of net income over total assets to capture banks' core profitability; total assets growth or securities and trading assets growth instead of non-loan assets growth to capture the banks' investment in side activities; as well as for U.S. and European banks separately (although in this case the sample sizes would become smaller). All the described methods obtain the same result: higher risk-taking in *ex*

[20] A long lag in measuring bank profitability, as well as the fact that many banks' business models have changed since 1990s with the deepening of financial markets, also make the reverse causality interpretation where banks were profitable because they took risk, less likely.

[21] While studies of bank performance based on cross-country data may raise issues of comparability, this chart is based on large global banks, which had generally similar risk-taking methods pre-crisis, so in this case a cross-country comparison seems acceptable, at least for illustrative purposes.

ante more profitable banks, especially in those that have expanded their non-core activities more. While the scatter plot is not a formal econometric test, we feel that it provides useful motivation and empirical direction for thinking about the link between bank profitability, side investments, and risk, in line with the predictions of our analysis.

6.2 Policy implications: Bank capital

The key implication of our analysis is that, contrary to the traditional Keeley (1990) intuition, high bank profitability may be ineffective in limiting bank risk-taking, and may in fact induce it. This intuition can be expanded to bank capital. Bank capital is similar to bank profitability in that both capture the exposure of bank shareholders to downside risk realizations, and affect a bank's capacity to take additional leverage. Indeed, it is easy to demonstrate that, in our model, explicit bank equity is a perfect substitute for its implicit equity derived from the NPV of the bank's core project. To see this, assume that at date 0 the owner-manager is endowed with wealth $k < 1$ that she invests into the bank as equity, and finances the rest ($1 - k$ for the core project and X for the market-based investment) with debt. Note that k can also be interpreted as a bank's *ex ante* capital ratio, similar to how R was interpreted as the core project's profitability. With explicit equity k, one can rewrite thresholds $X_{\min}$ and $X_{\max}$ of the benchmark model ((16) and (19)) as:

$$X_{\min}^{k} = \frac{(1-p)\,(R-1+k)}{p\alpha-(1-p)(1-\theta)-\varepsilon}, \text{ and} \tag{39}$$

$$X_{\max}^{k} = \frac{p\,(R-1+k)-b(1-k)}{b-p\alpha+(1-p)(1-\theta)}, \tag{40}$$

and the threshold b^* (21) as:

$$b_k^* = \frac{(p(\alpha-\varepsilon)-(1-p)(1-\theta))(R-1+k)}{(1-p)(R-1+k)+(1-k)(p\alpha-\varepsilon-(1-p)(1-\theta))}. \tag{41}$$

Note that bank capital k only enters the expressions in its sum with the bank's core profitability $R-1$. Therefore, the bank capital k has the same impact on model outcomes as that of bank profitability R. This is not surprising: both represent shareholder value at stake. Accordingly, one can show that $\partial b_k^*/\partial k > 0$ (similar to the effect for R in Proposition 1): an increase in explicit bank capital expands the range of parameter values for which the bank chooses the risky market-based investment, because it increases the bank's ability to borrow. All other effects of the model also persist with explicit bank capital.

The idea that bank capital may be ineffective in preventing bank risk-taking is consistent with empirical evidence that the link between pre-crisis bank capital and bank risk during the 2008 crisis was tenuous or indeed positive (i.e., better-capitalized banks took more risk). In Beltratti and Stulz (2012), higher pre-crisis capital improves bank performance during the 2008 crisis, but only in a sample that includes banks from emerging market economies and even then not in all specifications. In Berger and Bouwman (2013), higher capital improves U.S. banks' performance during multiple banking crises, but not specifically during the 2008 crisis. Coccorese and Girardone (2017) find in a sample of banks from 77 developed and developing economies that over 2000-2013 better capitalized banks were more profitable yet also riskier: they invested more in non-traditional assets. In contrast, studies that focus exclusively on banks in advanced economies during the 2008 crisis suggest a weak or indeed *negative* link between pre-crisis bank capital and performance. Huang and Ratnovski (2009) on a sample of large OECD banks find no relationship between banks' pre-crisis capital and performance during the 2008 crisis. Camara et al. (2013) show that better-capitalized European banks took more risk before the 2008 crisis. IMF's Global Financial Stability Report (2009) finds that major global banks that were intervened in during the crisis had statistically higher capital metrics before the crisis than the non-intervened banks.[22] Our model explains how a positive relationship between pre-crisis bank capital and bank risk during the 2008 crisis established in some of the above papers may have arisen.[23]

While in our model bank capital *per se* cannot reduce bank risk-taking incentives, effective

[22] Also, on pre-crisis data, Barth et al. (2006) find no relationship between bank capital ratios and stability, and Bichsel and Blum (2004), Lindquist (2004), Jokipii and Milne (2008), and Angora et al. (2011) find no or negative relationship between bank capital and performance.

[23] The link between bank profitability and risk-taking also offers insights into the relationship between interbank competition and financial stability. A common argument is that low competition increases banks' profitability and reduces bank risk-taking incentives. But there are also counter-arguments, based on general equilibrium effects (Boyd and De Nicoló, 2005), or the fact that in the absence of competition banks become less efficient and as a result unstable (Carlson and Mitchener, 2006; Calomiris and Haber, 2013; Akins et al., 2016). Our paper suggests another reason why restricted competition may make banks riskier. A lack of interbank competition may increase bank profits in the core business (cf. Boot and Thakor, 2000), enabling the bank to expand its side activities and use them for opportunistic risk-taking.

minimum bank capital requirements may do so. The easiest way to see this is to consider leverage requirements – limits on bank balance sheet size as a multiple of bank equity, equivalent in our model to a higher b. Leverage requirements that impose a $b > b^*$ restrict the bank's ability to expand assets sufficiently to make risk-shifting in side activities attractive.

7 Conclusions

This paper studies risk-taking incentives in banks. Traditional Jensen and Meckling (1976) intuition suggests that more profitable banks should have lower risk-taking incentives. But in the run up to the recent crisis many profitable financial institutions became exposed to risky financial instruments, resulting in significant losses. Explaining this contradiction between the theory and the evidence from the crisis seems important to better understand challenges to bank risk-management and governance, as well as for systemic risk regulation, as otherwise we might be missing an important determinant of bank risk-taking.

Our model highlights that many banks are organized around a stable core business and take risk through scalable market-based side investments. In the presence of leverage constraints, more profitable banks can borrow more and make side investments on a larger scale. Larger scale makes risk-taking more attractive. This indirect effect can offset the traditional effect where more profitable banks have lower incentives to take risk of fixed size. Consequently, more profitable banks may have higher, rather than lower, risk-taking incentives. We also show that banks have higher risk-taking incentives when the side investments can be financed with senior funding (e.g., repos), and in countries with better protection of creditor rights (because that makes bank leverage constraints looser). Banks may strategically combine high effort in the core business with opportunistic risk-taking in side activities. Accommodative monetary policy makes banks' core activities safer, but their side activities riskier. Overall, the description of bank risk-taking as occurring in side activities, as well as the cross-sectional patterns of bank risk-taking predicted by the model, appear to match well the patterns of bank risk-taking in the run-up to the recent crisis.

The key lesson of the analysis is that higher bank profitability (or, similarly, higher bank capital or franchise value) is not panacea against risk-taking. Profitable banks have superior capacity to borrow and therefore can rapidly accumulate risks. (And they may have strong incentives to do so, in line with the practitioners' assertions that banks face pressure to 'put to risk' their 'unused' capital.) Bank risk-taking should be understood as a dynamic concept. Regulators need to consider not only contemporaneous bank risks, but also the banks' ability to increase risk going forward. Such dynamic effects are particularly relevant when banks have easy access to scalable market-based investments. Since financial markets have deepened in the 2000s, the banks' ability to quickly accumulate large-scale exposures has increased (Morrison and Wilhelm, 2007; Boot, 2014; Boot and Ratnovski, 2016). Accordingly, the concerns about banks' risky side activities that are highlighted by our study may have become particularly pertinent.

References

[1] Acharya, Viral V., Thomas Cooley, Matthew Richardson, and Ingo Walter (2009), Manufacturing Tail Risk: A Perspective on the Financial Crisis of 2007-2009, *Foundations and Trends in Finance*, 4(4), 247-325.

[2] Acharya, Viral V. and T. Sabri Öncü (2013), A Proposal for the Resolution of Systemically Important Assets and Liabilities: The Case of the Repo Market, *International Journal of Central Banking*, 9, 291-349.

[3] Acharya, Viral V. and Matthew Richardson (2009), *Restoring Financial Stability: How to Repair a Failed System?,* John Wiley & Sons.

[4] Adrian, Tobias and Hyun Song Shin (2014), Procyclical Leverage and Value-at-Risk, *Review of Financial Studies*, 27(2), 373-403.

[5] AIG [American International Group], 2008, Annual Report.

[6] Akerlof, George A. and Paul M. Romer (1993), Looting: The Economic Underworld of Bankruptcy for Profit, *Brookings Papers on Economic Activity*, 2, 1-73.

[7] Akins, Brian, Lin Li, Jeffrey Ng, and Tjomme O. Rusticus (2016), Bank Competition and Financial Stability: Evidence from the Financial Crisis, *Journal of Financial and Quantitative Analysis*, 51(1), 1-28.

[8] Allen, Franklin, Elena Carletti, and Robert Marquez (2011), Credit Market Competition and Capital Regulation, *Review of Financial Studies*, 24(4), 983-1018.

[9] Angora, Alain, Isabelle Distinguin, and Clovis Rugemintwari (2011), A Note on Bank Capital Buffer: Does Bank Heterogeneity Matter?, *Empirical Economic Letters*, 10(9).

[10] Barth, James, Gerard Caprio, and Ross Levine (2006), *Rethinking Bank Regulations: Till Angels Govern*, Cambridge University Press.

[11] Beltratti, Andrea and Rene M. Stultz (2012), The Credit Crisis Around the Globe: Why Did Some Banks Perform Better?, *Journal of Financial Economics*, 105, 1-17.

[12] Berger, Allen N. and Christa H.S. Bouwman (2013), How Does Capital Affect Bank Performance During Financial Crises?, *Journal of Financial Economics*, 109, 146-176.

[13] Bichsel, Robert and Jurg Blum (2004), The Relationship Between Risk and Capital in Swiss Commercial Banks: A Panel Study, *Applied Financial Economics*, 14, 591-597.

[14] Blum, Jurg (1999), Do Capital Adequacy Requirements Reduce Risks in Banking?, *Journal of Banking and Finance*, 23, 755–771.

[15] Boot, Arnoud W.A. (2014), Financial Sector in Flux, *Journal of Money, Credit, and Banking*, 46(1), 129-135.

[16] Boot, Arnoud W.A. and Lev Ratnovski (2016), Banking and Trading, *Review of Finance*, 20(6), 2219-2246.

[17] Boot, Arnoud W.A. and Anjan V. Thakor (2000), Can Relationship Banking Survive Competition?, *Journal of Finance*, 55(2), 679–713.

[18] Borio, Claudio and Haibin Zhu (2012), Capital Regulation, Risk-Taking and Monetary Policy: A Missing Link in the Transmission Mechanism?, *Journal of Financial Stability*, 8(4), 236-251.

[19] Boyd, John H., Chun Chang, and Bruce.D. Smith (1998), Moral Hazard under Commercial and Universal Banking, *Journal of Money, Credit and Banking*, 30(3), 426-468.

[20] Boyd, John H. and Gianni De Nicolo (2005), The Theory of Bank Risk Taking and Competition Revisited, *Journal of Finance*, 60(3), 1329-1343.

[21] Boyd, John H. and Hendrik Hakenes (2014), Looting and Risk Shifting in Banking Crises, *Journal of Economic Theory*, 149, 43-64.

[22] Brunnermeier, Marcus and Martin Oehmke (2013), Maturity Rat Race, *Journal of Finance*, 68(2), 483–521.

[23] Burkart, Mike and Tore Ellingsen (2004), In-Kind Finance: A Theory of Trade Credit, *American Economic Review*, 94(3), 569-590.

[24] Calem, Paul and Rafael Rob (1999), The Impact of Capital-Based Regulation on Bank Risk Taking, *Journal of Financial Intermediation*, 8, 317-352.

[25] Calomiris, Charles and Stephen H. Haber (2013), *Fragile by Design: The Political Origins of Banking Crises and Scarce Credit*, Princetown University Press.

[26] Calomiris, Charles V. and Charles M. Kahn (1991), The Role of Demandable Debt in Structuring Optimal Bank Arrangements, *American Economic Review*, 3, 497-513.

[27] Camara, Boubacar, Lepetit, Laetitia, and Amine Tarazi (2013), Ex Ante Capital Position, Changes in the Different Components of Regulatory Capital and Bank Risk, *Applied Economics*, 45(34), 4831-4856.

[28] Carlson, Mark and Kris James Mitchener (2006), Branch Banking, Bank Competition, and Financial Stability, *Journal of Money, Credit, and Banking*, 38(5), 1293-1328.

[29] Claessens, Stijn, Giovanni Dell'Ariccia, Deniz Igan, and Luc Laeven (2010), Cross-Country Experiences and Policy Implications from the Global Financial Crisis, *Economic Policy*, 25(62), 267-293.

[30] Coccorese, Paolo and Claudia Girardone (2017), Bank Capital and Profitability: Evidence from a Global Sample, Essex Finance Center, Working Paper No.17.

[31] Dell'Ariccia, Giovanni, Luc Laeven, and Robert Marquez (2014), Real Interest Rates, Leverage, and Bank Risk-Taking, *Journal of Economic Theory*, 149, 65-99.

[32] Dell'Ariccia, Giovanni, Luc Laeven, and Gustavo Suarez (2017), Bank Leverage and Monetary Policy's Risk-Taking Channel: Evidence from the United States, Journal of Finance, 72(2), 613-654.

[33] Dell'Ariccia, Giovanni and Robert Marquez (2006), Lending Booms and Lending Standards, *Journal of Finance*, 61(5), 2511-546.

[34] Demiroglu, Cem and Christopher James (2012), How Important is Having Skin in the Game? Originator-Sponsor Affiliation and Losses on Mortgage-backed Securities, *Review of Financial Studies*, 25(11), 3217-3258.

[35] Demsetz, Rebecca, Mark R. Saidenberg, and Philip E. Strahan (1996), Banks with Something to Lose: The Disciplinary Role of the Franchise Value, *Federal Reserve Bank of New York Economic Policy Review*, 2(2), 1–14.

[36] Demyanyuk, Yuliya and Otto Van Hemert (2011), Understanding the Subprime Mortgage Crisis, *Review of Financial Studies*, 24(6), 1848-1880.

[37] Fahlenbrach, Rüdiger, Robert Prilmeier, and René M. Stulz (2016), Why Does Fast Loan Growth Predict Poor Performance for Banks?, NBER Working Paper 22089.

[38] Freixas, Xavier, Gyöngyi Lóránth, and Alan D. Morrison (2007), Regulating Financial Conglomerates, *Journal of Financial Intermediation*, 16(4), 479-514.

[39] Froot, Kenneth A. and Jeremy C. Stein (1998), Risk Management, Capital Budgeting, and Capital Structure Policy for Financial Institutions: An Integrated Approach, *Journal of Financial Economics*, 47, 55-82.

[40] Gennaioli, Nicola, Alberto Martin, and Stefano Rossi (2014), Sovereign Default, Domestic Banks, and Financial Institutions, *Journal of Finance*, 69(2), 819-866.

[41] Gennaioli, Nicola, Andrei Shleifer, and Robert Vishny (2012), Neglected Risks, Financial Innovation, and Financial Fragility, *Journal of Financial Economics*, 104, 452-468.

[42] Giannone, Domenico, Michele Lenza, and Lucrezia Reichlin (2011), Market Freedom and the Global Recession, *IMF Economic Review*, 59(1), 111-135.

[43] Gorton, Gary (2010), *Slapped in the Face by the Invisible Hand: Banking and the Panic of 2007*, Oxford University Press.

[44] Gorton, Gary and Andrew Metrick (2012), Securitized Banking and the Run on Repo, *Journal of Financial Economics*, 104(3), 425-451.

[45] Gourinchas, Pierre-Olivier, Helene Rey, and Kai Truempler (2011), The Financial Crisis and the Geography of Wealth Transfers, *Journal of International Economics*, 88(2), 266-283.

[46] Hart, Oliver (1995), *Firms, Contracts, and Financial Structure*, Oxford University Press.

[47] Hellmann, Thomas F., Kevin C. Murdock, and Joseph E. Stiglitz (2000), Liberalization, Moral Hazard in Banking, and Prudential Regulation: Are Capital Requirements Enough?, *American Economic Review*, 90(1), 147-165.

[48] Holmstrom, Bengt and Jean Tirole (1997), Financial Intermediation, Loanable Funds, and the Real Sector, *Quarterly Journal of Economics*, 112(3), 663-691.

[49] Holmstrom, Bengt and Jean Tirole (1998), Public and Private Supply of Liquidity, *Journal of Political Economy*, 106(1), 1-40.

[50] Huang, Rocco and Lev Ratnovski (2009), Why Are Canadian Banks More Resilient?, IMF Working Paper 09/152.

[51] IMF Global Financial Stability Report (2009), *Responding to the Financial Crisis and Measuring Systemic Risks*, April, Chapter 3, *Detecting Systemic Risk*.

[52] Jensen, Michael C. and William H. Meckling (1976), Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure, *Journal of Financial Economics*, 3(4), 305-360.

[53] Jensen, Michael C. (1986), Agency Costs of Free Cash Flow, Corporate Finance, and Takeovers, *American Economic Review*, 76(2), 323-329.

[54] Jiménez, Gabriel, Steven Ongena, José-Luis Peydró, and Jesús Saurina (2014), Hazardous Times for Monetary Policy: What Do Twenty-Three Million Bank Loans Say About the Effects of Monetary Policy on Credit Risk-Taking?, *Econometrica,* 82(2), 463-505.

[55] Jokipii, Terhi and Alistair Milne (2008), The Cyclical Behaviour of European Bank Capital Buffers, *Journal of Banking and Finance*, 32, 1440-1451.

[56] Keeley, Michael C. (1990), Deposit Insurance, Risk, and Market Power in Banking, *American Economic Review*, 80(5), 1183-1200.

[57] La Porta, Rafael, Florencio Lopez-de-Silanes, and Guillermo Zamarripa (2003), Related Lending, *Quarterly Journal of Economics*, 118(1), 231-268.

[58] Laeven, Luc (2001), Insider Lending and Bank Ownership: The Case of Russia, *Journal of Comparative Economics*, 29, 207-229.

[59] Laeven, Luc (2002), Pricing of Deposit Insurance, World Bank Policy Research Working Paper 2871.

[60] Lindquist, Kjersti-Gro (2004), Bank's Buffer Capital: How Important Is Risk, *Journal of International Money and Finance*, 23, 493-513.

[61] Martin, Antoine and Bruno M. Parigi (2013), Bank Capital Regulation and Structured Finance, *Journal of Money, Credit and Banking*, 45(1) 87-119.

[62] Matutes, Carmen and Xavier Vives (2000), Imperfect Competition, Risk Taking, and Regulation in Banking, *European Economic Review*, 44, 1-34.

[63] Mendoza, Enrique G., Vincenzo Quadrini, and Jose-Victor Rios-Rull (2009), Financial Integration, Financial Development, and Global Imbalances, *Journal of Political Economy*, 117(3), 371-416.

[64] Morrison, Alan D. and William J. Wilhelm Jr. (2007), *Investment Banking*, Oxford University Press.

[65] Myers, Stewart C. and Raghuram G. Rajan (1998), The Paradox of Liquidity, *Quarterly Journal of Economics*, 113(3), 733-771.

[66] NY Fed [Federal Reserve Bank of New York] (2015), *Quarterly Trends for Consolided U.S. Banking Organizations* (Fourth Quarter).

[67] Perotti, Enrico, Lev Ratnovski, and Razvan Vlahu (2011), Capital Regulation and Tail Risk, *International Journal of Central Banking*, 7(4), 123-163.

[68] Petersen, Mitchell A. and Raghuram G. Rajan (1995), The Effect of Credit Market Competition on Lending Relationships, *Quarterly Journal of Economics*, 110(2), 407-443.

[69] Pritzker, Matthew (2012), Knightian Uncertainty and Interbank Lending, *Journal of Financial Intermediation*, 22(1), 85–105.

[70] Repullo, Rafael (2004), Capital Requirements, Market Power, and Risk-Taking in Banking, *Journal of Financial Intermediation*, 13, 156-182.

[71] Stiglitz, Joseph E. and Andrew Weiss (1981), Credit Rationing in Markets with Imperfect Information, *American Economic Review*, 71(3), 393-410.

[72] Shin, Hyun Song (2009), Reflections on Northern Rock: The Bank Run that Heralded the Global Financial Crisis, *Journal of Economic Perspectives*, 23(1), 101-119.

[73] Stein, Jeremy C. (2002), Information Production and Capital Allocation: Decentralized versus Hierarchical Firms, *Journal of Finance*, 57(5), 1891-1921.

[74] UBS, 2007, Annual Report.

A Proofs

A.1 Proof of Lemma 1

First, we show that the bank's strategy of choosing a risky over a safe market-based investment reduces itself to a condition on b (i.e., $b < b^*$). Second, we show that there exist parameter values such that the intersection between conditions $b < b^*$ and $\theta_{\min} < \theta < \theta_{\max}$ is non-empty.

Recall from (16) and (17) that the bank makes a risky investment only when the investment can be undertaken at a sufficient scale $X > X_{\min}$, conditional on that a minimal seniority $\theta > \theta_{\min}$ is offered to date 1 creditors. Also, recall from (19) and (20) that the bank has the ability to make a risky investment at a maximal scale $X_{\max}$, conditional on promising to date 1 creditors a repayment in case of bankruptcy that does not exceed the bank's available resources, $\theta < \theta_{\max}$. Substituting from (16) and (19) and rearranging terms gives that $X_{\min} < X_{\max}$ for:

$$b < b^* = \frac{(p(\alpha - \varepsilon) - (1-p)(1-\theta))(R-1)}{(1-p)(R-1) + p\alpha - \varepsilon - (1-p)(1-\theta)}.$$

The bank's profit from a risky investment is increasing in X: by differentiation (use (12)) $\partial \Pi_{Risky}(X)/\partial X = p\alpha - (1-p)(1-\theta)$ which is positive for $\theta > \theta_{\min}$. Thus, the bank chooses the maximal scale $X = X_{\max}$ whenever $X_{\min} < X_{\max}$. Note that $X_{\max} > 0$ if $b < p(R-1)$. For $\theta > \theta_{\min}$, $X_{\max} > 0$ if $b < b^*$, since then $X_{\max} > X_{\min} > 0$, implying that $b^* < p(R-1)$.

For $b > b^*$, the bank makes safe market-based investment. The scale of safe investment is given by $\Pi_{Safe} = b(1+X)$ (from (1) and (7)), which gives: $X_{\max}^{Safe}$=$(R-1-b)/(b-\varepsilon)$.

Next we show that there exist parameter values such that the intersection between conditions $b < b^*$ (when $X_{\min} < X_{\max}$) and $\theta_{\min} < \theta < \theta_{\max}$ is non-empty. Namely, we derive the conditions under which risk-taking equilibrium exists. For this we rewrite the condition $X_{\min} < X_{\max}$ as a restriction on the space of θ rather than b as we have it in (21).

Rearranging the terms in (21) gives that $X_{\min} < X_{\max}$ holds for

$$\theta > \theta^e = 1 - \frac{p\alpha}{1-p} + \frac{(1-p)(R-1)b + \varepsilon(p(R-1)-b)}{(1-p)(R-1-b)}, \tag{42}$$

corresponding to $b < b^*$.

Recall that for $\theta < \theta_{\max}$, we have that $X_{\max} < \frac{R}{\theta}$, and that for $\theta > \theta^e$, we have just proved that $X_{\min} < X_{\max}$. To find whether the risk-taking takes place under $\theta_{\min} < \theta < \theta_{\max}$, we need to show that $(\exists)$ $\theta_{\max} > \theta^e$, such that $X_{\max} < \frac{R}{\theta}$ $(\forall)$ $\theta \in [\theta^e, \theta_{\max})$.

To proceed, we first establish the correspondence and intersection points of $X_{\min}$, $X_{\max}$ and $\frac{R}{\theta}$ as functions of θ. By differentiation (use (16) and (19)):

$$\frac{\partial X_{\min}}{\partial \theta} = -\frac{(1-p)^2(R-1)}{(p\alpha - \varepsilon - (1-p)(1-\theta))^2} < 0, \tag{43}$$

$$\frac{\partial X_{\max}}{\partial \theta} = \frac{(1-p)(p(R-1)-b)}{(b - p\alpha + (1-p)(1-\theta))^2} > 0. \tag{44}$$

Note also that $\partial(\frac{R}{\theta})/\partial\theta = -\frac{R}{\theta^2} < 0$. Using (16) we obtain that $X_{\min} < \frac{R}{\theta}$ for

$$\theta > \hat{\theta} = R\left(1 - \frac{p\alpha - \varepsilon}{1-p}\right), \tag{45}$$

where $\hat{\theta} > \theta_{\min}$ from (17).

This implies that the decreasing function $X_{\min}(\theta)$ intersects from above with the decreasing function $(\frac{R}{\theta})$ at $\theta = \hat{\theta}$, and intersects from above with the increasing function $X_{\max}(\theta)$ at $\theta = \theta^e$. Also, the increasing function $X_{\max}(\theta)$ intersects from below with $\frac{R}{\theta}$ at $\theta = \theta_{\max}$.

Given that, $\theta_{\max} > \theta^e$ (risk-taking region exists) if and only if $(\forall)$ $\theta \geq \theta^e$, both functions $X_{\max}(\theta)$ and $\frac{R}{\theta}$ lie above $X_{\min}(\theta)$. This is equivalent to showing that $(\exists)$ $\theta^e \in (\hat{\theta}, 1)$, such that $X_{\min} < X_{\max}$ $(\forall)$ $\theta > \theta^e$. We proceed with finding the conditions for $\hat{\theta} < \theta^e < 1$.

Using (42) and (45) and rearranging terms we can rewrite these restrictions with respect to b.

We can show that $\hat{\theta} < \theta^e$ holds for

$$b > b_{low} = \frac{(R-1)(1-p-p\alpha+\varepsilon)+\varepsilon(1-p)}{2-2p-p\alpha-\varepsilon},$$

and that $\theta^e < 1$ holds for

$$b < b_{high} = \frac{p(R-1)(\alpha-\varepsilon)}{(1-p)(R-1)+p\alpha-\varepsilon}.$$

implying that $\hat{\theta} < \theta^e < 1$ is equivalent to the condition $b_{low} < b < b_{high}$.

From (4) and (5) it must be that both b_{low} and b_{high} are in the range $(p\alpha, R-1)$. Note that $b_{high} < R-1 \Leftrightarrow \frac{p(\alpha-\varepsilon)}{(1-p)(R-1)+p\alpha-\varepsilon} < 1 \Leftrightarrow \varepsilon < R-1$ (which holds from (4) and (5)). To complete the proof we distinguish between two possible configurations of parameters. For the first configuration, $p\alpha < b_{low} < b_{high}$, which holds for:

$$\begin{cases} 1+p\alpha+\frac{(1-p)(p\alpha-\varepsilon)}{1-p-p\alpha+\varepsilon} < R < \frac{1-p}{1-p-p\alpha+\varepsilon} \\ \varepsilon < \frac{\alpha(2p+p\alpha-1)}{1+\alpha} \\ p(1+\alpha)-1 > -p \end{cases}.$$

For the second configuration, $b_{low} < p\alpha < b_{high}$, which holds for:

$$\begin{cases} 1+\alpha < R < 1+p\alpha+\frac{(1-p)(p\alpha-\varepsilon)}{1-p-p\alpha+\varepsilon} \\ \varepsilon < \frac{\alpha(2p+p\alpha-1)}{1+\alpha} \\ p(1+\alpha)-1 > -p \end{cases}.$$

Thus, there $(\exists)$ $\theta^e \in (\hat{\theta}, 1)$, such that $X_{\min} < X_{\max}$ $(\forall)$ $\theta > \theta^e$, whenever

$$\begin{cases} 1+\alpha < R < \frac{1-p}{1-p-p\alpha+\varepsilon} \\ \varepsilon < \frac{\alpha(2p+p\alpha-1)}{1+\alpha} \\ p(1+\alpha)-1 > -p \end{cases}. \tag{46}$$

QED

A.2 Proof of Proposition 1

By differentiation (use (21)):

$$\frac{\partial b^*}{\partial R} = \frac{(p(\alpha - \varepsilon) - (1-p)(1-\theta))(p\alpha - \varepsilon - (1-p)(1-\theta))}{((1-p)(R-1) + p\alpha - \varepsilon - (1-p)(1-\theta))^2}. \tag{47}$$

Recall that from (17):

$$\theta > \theta_{\min} = 1 - \frac{p\alpha - \varepsilon}{1-p}. \tag{48}$$

Substituting into the numerator of (47) obtains:

$$\frac{\partial b^*}{\partial R} = \frac{(1-p)^2(\theta - \theta_{\min} + \varepsilon)(\theta - \theta_{\min})}{((1-p)(R-1) + p\alpha - \varepsilon - (1-p)(1-\theta))^2}.$$

The numerator of (47) is positive for $\theta > \theta_{\min}$. The denominator is a square, and thus it is always positive. Therefore, $\partial b^*/\partial R > 0$. *QED*

A.3 Proof of Proposition 2

By differentiation (use (21)):

$$\frac{\partial b^*}{\partial \theta} = \frac{(1-p)^2(R-1)(R-1-\varepsilon)}{((1-p)(R-1) + p\alpha - \varepsilon - (1-p)(1-\theta))^2}. \tag{49}$$

Recall that $R - 1 > \varepsilon$ from (4) and (5), therefore, the numerator is positive. The denominator is a square, and thus it is always positive. Hence $\partial b^*/\partial \theta > 0$.

Also, by differentiation (use (19)):

$$\frac{\partial X_{\max}}{\partial \theta} = (1-p)\,\frac{p\,(R-1) - b}{\left(b - p\alpha + (1-p)(1-\theta)\right)^2}. \tag{50}$$

From (5) and (19), the numerator is positive. The denominator is a square, and thus it is always positive. Therefore, $\partial X_{\max}/\partial \theta > 0$.

Further, by differentiation (use (21)):

$$\frac{\partial^2 b^*}{\partial R \partial \theta} = \frac{(1-p)^2 \left((R-1)\varepsilon(1-p) + (2(R-1)-\varepsilon)\left(p\alpha - \varepsilon - (1-\theta)(1-p)\right)\right)}{\left((1-p)(R-1) + p\alpha - \varepsilon - (1-p)(1-\theta)\right)^3}.$$

The numerator and denominator are both positive because $p\alpha - \varepsilon - (1-p)(1-\theta) > 0$ for $\theta > \theta_{\min}$. Finally:

$$\frac{\partial^2 X_{\max}}{\partial R \partial \theta} = \frac{p(1-p)}{\left(b - p\alpha + (1-p)(1-\theta)\right)^2} > 0.$$

QED

A.4 Proof of Proposition 3

Substitute (37) and (38) into $e^*_{Risky} > e^*_{Safe}$ to obtain:

$$\frac{b}{c} \cdot \frac{p(R-1-\alpha) + (1-p)(1-\theta)}{b - p\alpha + (1-p)(1-\theta)} > \frac{b}{c} \cdot \frac{R-1-\varepsilon}{b-\varepsilon},$$

Rearranging the terms gives:

$$p(R-1-\alpha)(b-\varepsilon) - (1-p)(1-\theta)(R-1-b) - (R-1-\varepsilon)(b-p\alpha) > 0.$$

Rearranging the terms again gives:

$$b < \frac{(p(\alpha-\varepsilon) - (1-p)(1-\theta))(R-1)}{(1-p)(R-1) + p\alpha - \varepsilon - (1-p)(1-\theta)}.$$

The expression on the right-hand side is equal to b^* from (21), implying that $e^*_{Risky} > e^*_{Safe}$ for $b < b^*$. Recall from Section 3 that the banker makes risky market-based investment if $b < b^*$, with b^* given in (21). *QED*

A.5 Proof of Proposition 4

When the policy rate i affects the bank's cost of funding, $X_{\min}$ (similar to (16)) changes to:

$$X > X_{\min}^{i} = \frac{(1-p)(R-1-i)}{p\alpha - \varepsilon - (1-p)(1-\theta)},$$

and $X_{\max}$ (similar to (19)) changes to:

$$X \leq X_{\max}^{i} = \frac{p(R-1-i)-b}{b - p\alpha + (1-p)(1-\theta) + i}.$$

The bank makes a risky investment if $X_{\min}^{i} < X_{\max}^{i}$, or when $b < b_i^*$. From (36):

$$b_i^* = \frac{(R-1-i)\left(p(\alpha-\varepsilon) - (1-p)(1-\theta+i)\right)}{(1-p)(R-1-i) + p\alpha - \varepsilon - (1-p)(1-\theta)}.$$

Note that $b_i^* > 0$ if $\theta > 1 + i - \frac{p(\alpha-\varepsilon)}{1-p}$. From (17): $\theta_{\min} > 1 + i - \frac{p(\alpha-\varepsilon)}{1-p}$ for $i < \varepsilon$ (which typically is true in reality, since ε is the return on treasury securities). Thus, for any $\theta > \theta_{\min}$, we obtain $b_i^* > 0$.

Next, by differentiation (use (36)):

$$\begin{aligned}\frac{\partial b_i^*}{\partial i} &= -\frac{[p(\alpha-\varepsilon) - (1-p)(1-\theta+i)] \cdot [p\alpha - \varepsilon - (1-p)(1-\theta)]}{[(1-p)(R-1-i) + p\alpha - \varepsilon - (1-p)(1-\theta)]^2} - \\ &\quad - \frac{(1-p)(R-1-i) \cdot [(1-p)(R-1-i) + p\alpha - \varepsilon - (1-p)(1-\theta)]}{[(1-p)(R-1-i) + p\alpha - \varepsilon - (1-p)(1-\theta)]^2}. \end{aligned} \tag{51}$$

For any $\theta > \theta_{\min}$, both terms of the expression are negative, implying that $\frac{\partial b_i^*}{\partial i} < 0$. Similarly, by differentiation (use (37) and (38)):

$$\begin{aligned}\frac{\partial e_{Safe,i}^*}{\partial i} &= -\frac{b}{c} \cdot \frac{R-1-\varepsilon}{(b-\varepsilon+i)^2}, \text{ and} \\ \frac{\partial e_{Risky,i}^*}{\partial i} &= -\frac{b}{c} \cdot \frac{p(b - p\alpha + i + (1-p)(1-\theta)) + p(R-1+i) - b}{(b - p\alpha + i + (1-p)(1-\theta))^2}.\end{aligned}$$

Recall that $R - 1 \geq b > p\alpha > \varepsilon$ from (4) and (5). Therefore, the numerator is positive in both expressions. The denominator is a square in both expressions, and thus it is always positive. Hence $\partial e^*_{Safe,i}/\partial i < 0$ and $\partial e^*_{Risky,i}/\partial i < 0$.

QED

Figure 1. The timeline.

Date 0

- A bank attracts 1 unit of funds at the interest rate r_0 to invest in the core project.

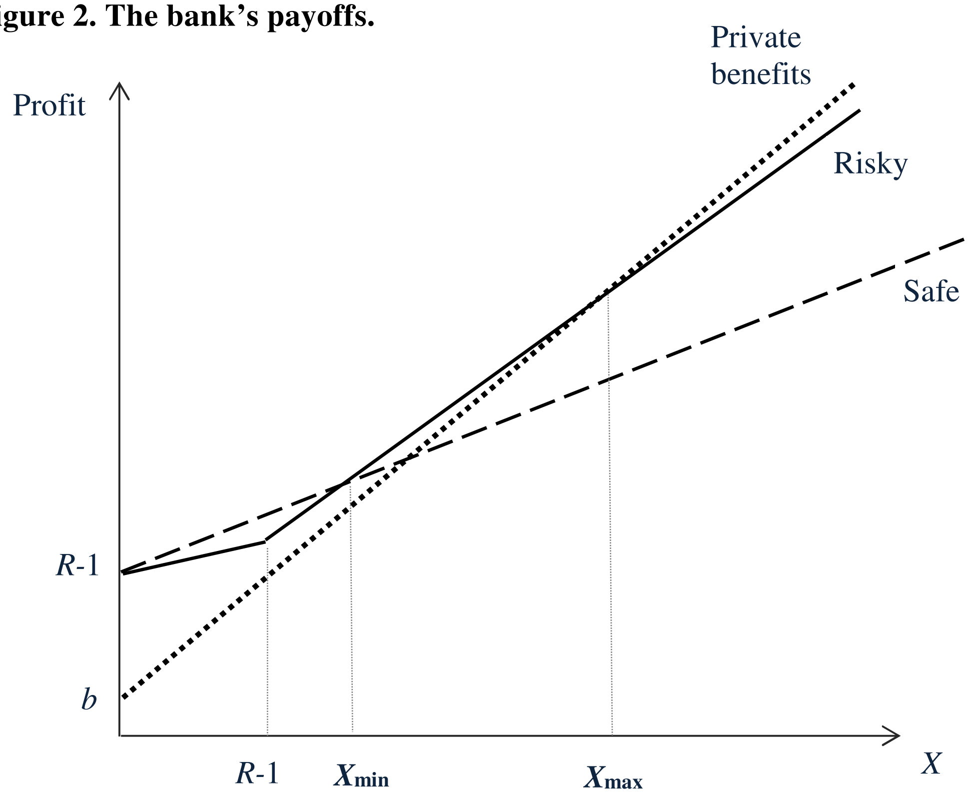
Date 1

- A bank attracts X units of funds at the interest rate r_1 to undertake a market-based investment
- A bank can convert its assets into private benefits $b(1+X)$.

Date 2

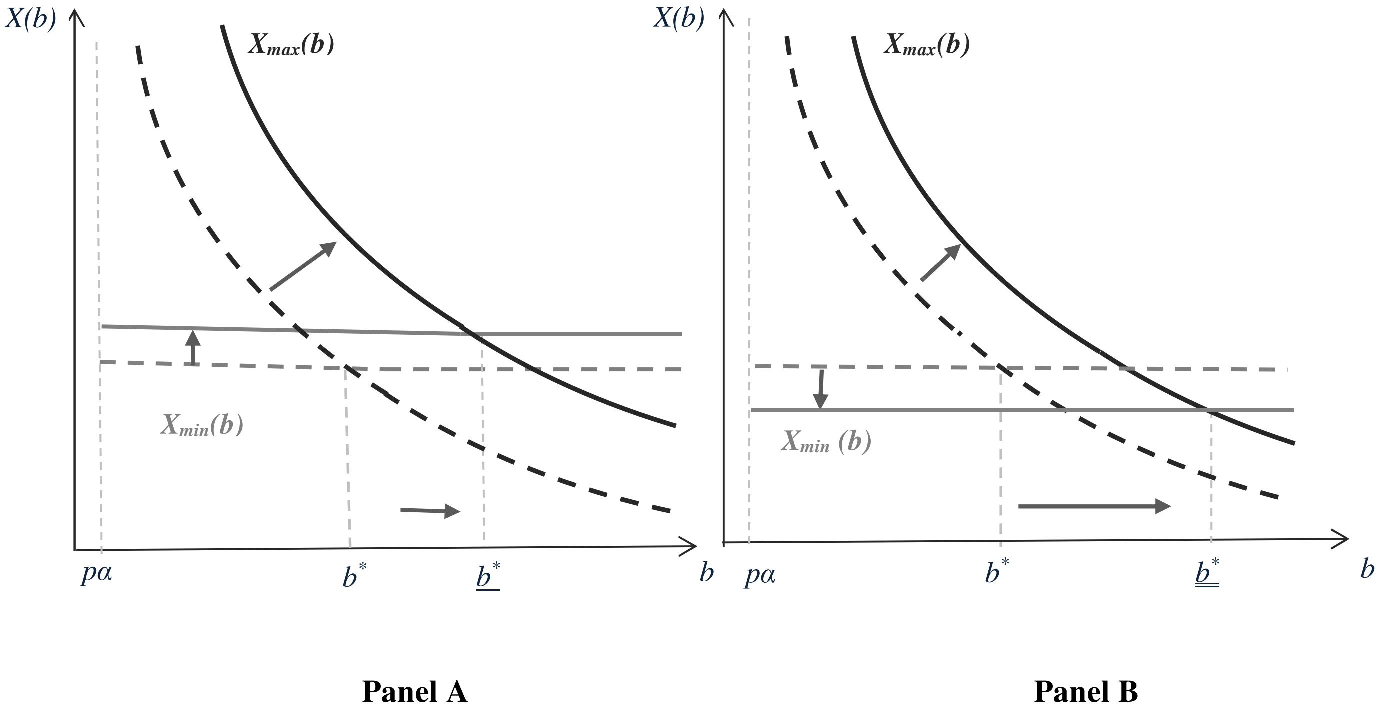
- Projects returns are realized and distributed.

Figure 2. The bank's payoffs.



The figure plots the bank's expected returns from three alternative projects undertaken alongside the core project. The solid line shows the bank's return from the risky market-based investment. For X=0, the bank's return is the core return R-1. For $X \leq R$-1, the bank internalizes the downside risk realizations; the slope of the line is thus gradual (positive if the NPV of the risky project is positive, or negative otherwise). For $X > R$-1, the bank does not internalize the downside risk realizations, and the slope of the line steepens. The dashed line represents the bank's return from the safe market-based investment. The return to the risky investment dominates the return to the safe investment for high enough scale X, $X > X_{min}$. The dotted line is the banker's private benefits $b(1+X)$, which are equal to b if no side investment is made. The bank does not abscond as long as its profit in normal operations exceeds its return from absconding. Therefore, the maximum scale of the risky investment is limited to $X \leq X_{max}$. As a result, the bank can make a risky investment for $X_{min} < X \leq X_{max}$.

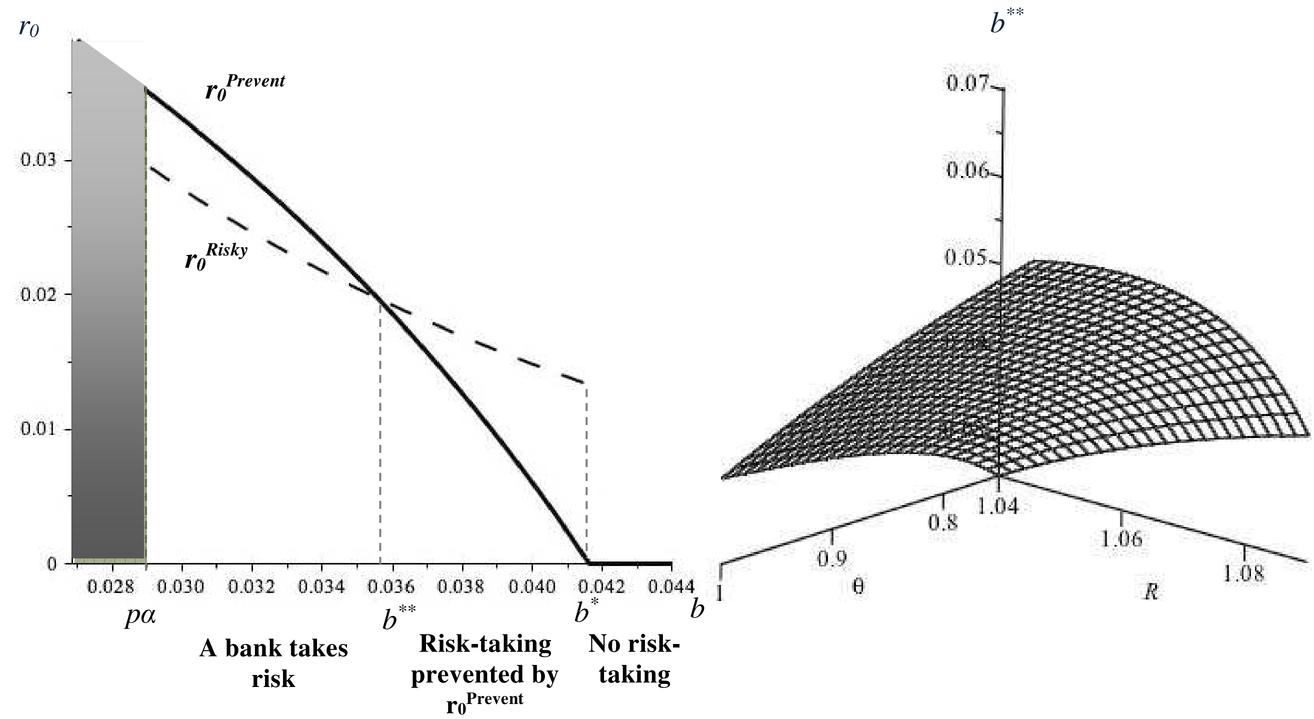
Figure 3. The impact of the bank's core business profitability and new debt seniority on bank risk-taking.



Panel A shows the impact of an increase in the bank's core business profitability, R, on the bank's risk-taking strategy. A higher R increases the minimal scale at which the bank finds it profitable to make the risky market-based investment, X_{min}, as well as the maximum feasible scale of the risky investment, X_{max}. On net, the effect on X_{max} dominates, so that a higher R leads to a higher intersect b^*, indicating a wider range of parameter values for which a bank undertakes the risky investment.

Panel B shows the impact of an increase in the feasible date 1 debt seniority, θ, on the bank's risk-taking strategy. A higher θ reduces the minimal scale at which the banks finds it profitable to make the risky market-based investment X_{min}, and increases the maximum feasible scale of the risky investment X_{max}. As a result, higher θ leads to a higher intersect b^*, indicating a wider range of parameter values for which a bank undertakes the risky investment.

Figure 4 Solution with endogenous r_0.



Panel A **Panel B**

Panel A shows the evolution of the interest rates required by date 0 creditors depending on b, for the set of parameter values: R=1.07; ε=0.02; α=0.03; p=0.97; θ=0.75. A looser leverage constraint (as indicated by a lower b) increases both the interest rate that prices bank risk-taking r_0^{Risky} and the interest rate that prevents bank risk-taking $r_0^{Prevent}$. For $b^{**}<b\leq b^{*}$, $r_0^{Prevent} < r_0^{Risky}$; so date 0 creditors set $r_0 = r_0^{Prevent}$ and the bank makes the safe market-based investment. For $b<b^{**}$, $r_0^{Risky} < r_0^{Prevent}$; so date 0 creditors set $r_0 = r_0^{Risky}$ and the bank makes the risky investment. Note that b is restricted to $b>p\alpha$ under the model parametrization (equation (5)).

Panel B shows the evolution of threshold b^{**} depending on the bank's core profitability, R, and the feasible date 1 debt seniority, θ, for the set of parameter values: ε=0.02; α=0.03; p=0.97. Higher R, and higher θ lead to a higher b^{**}, indicating a wider range of parameter values for which a bank undertakes the risky market-based investment. Further, b^{**} is convex in the combination of R and θ.

Figure 5. Effort in the core project: The timeline.

Date 0

- A bank attracts 1 unit of funds at the interest rate r_0 to invest in the core project
- A bank can exert effort to increase the probability of success of the core project
- If effort is unsuccessful, the project is terminated.

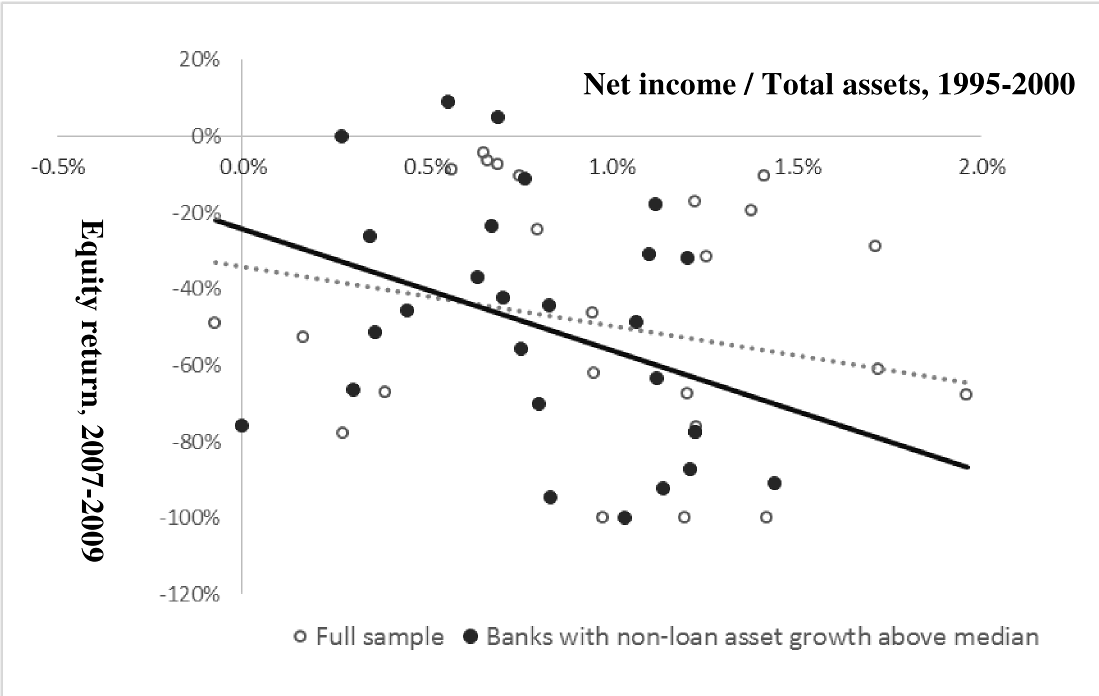
Date 1

- A bank attracts X units of funds at the interest rate r_1 to undertake a market-based investment
- A bank can convert its assets into private benefits $b(1+X)$.

Date 2

- Projects returns are realized and distributed.

Figure 6. The relationship between banks' core profitability and losses during the 2008 crisis.



The scatterplot shows the relationship between the banks' average net income to total assets over 1995-2000 (a proxy for a bank's core profitability) and bank equity losses during the crisis (end 2007 – end 2009, a proxy for bank risk-taking), on a sample of North American and European banks with assets over USD 50 billion at end-2006. The dashed line is the trend conditional on all observations, showing that banks that were more profitable in late 1990s experienced larger losses during the crisis, suggesting higher risk-taking. Solid dots highlight banks with above-median non-loan assets growth in 2001-2006. The solid line is the trend conditional on those observations. It is steeper than the unconditional trend, indicating that risk-taking by profitable banks was related to the expansion of their side activities.