Policy Uncertainty and Bank Bailouts*

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Abstract

We study bank portfolio choices with policy uncertainty over government intervention upon bank failure. In our model, banks face bailout uncertainty because the government does not guarantee that it will rescue each and every failed bank. The probability of both bank failure and government intervention upon failure are determined simultaneously. In theory, the number of bank failures (after the government has intervened and has bailed out as many banks as its budget allows) can be higher or lower than in laissez faire. However, in our baseline calibration, government intervention leaves the economy with as much as 9% more failed banks than laissez faire.

Key words: Policy Uncertainty, Portfolio Choice, Bailouts, Moral Hazard.

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1. Introduction

Regulated industries such as banking seem to face increasing policy uncertainty in the U.S. Baker, Bloom, Canes-Wrone, Davis, and Rodden (2014) estimate that policy uncertainty is 4 times higher now than it was a half-century ago. This trend is related to a near-doubling in the size of government expenditure as a share of GDP and a 6-fold increase in the size of the *Code of Federal Regulations.* Growth in policy uncertainty is also accompanied by increased polarization in American politics. The views of the Democratic and Republican parties have increasingly diverged in recent years, creating additional policy uncertainty around political elections (Baker, Bloom, and Davis (2013)). In short, in the words of Sargent (2005), "*What we do not know today is how subsequent political deliberations from shifting majority coalitions will render U.S. fiscal policy coherent.*"

In this paper we focus on policy uncertainty about whether the government will bail out banks if they fail.[1] Although bailouts are meant to prevent financial crises, the common concern is that they encourage banks to make riskier bets than they otherwise would (moral hazard). Intuitively, the degree of policy uncertainty should affect the severity of the moral hazard problem, with banks taking their most risky bets when the likelihood of a bailout is highest. Our goal is to quantitatively assess how policy uncertainty affects bank portfolio choices and hence bank failures.

Bailout uncertainty is an empirically relevant phenomenon. Banks and other financial institutions, particularly large ones, don't know in advance whether they will be rescued if their investments fail. For example, in 2008 the U.S. government bailed out Bear Stearns but then let Lehman Brothers and Washington Mutual fail a few months later. The policy uncertainty index created by Baker, Bloom, and Davis (2013) hit a peak after Lehman Brothers failed and President George W. Bush signed the Troubled Asset Relief Program (TARP) into law, suggesting a general feeling of uncertainty about the government's intentions. Even though 42% of all publicly traded banks in the U.S. received TARP bailout funds (Blau, Brough, and Thomas (2013)), hundreds of

[1] We use the word *bank* to mean any financial institution that leverages its initial assets by borrowing funds at relatively low rates and purchasing risky assets with those borrowed funds.

banks were left to fail during the Financial Crisis and in the years since (e.g., see the FDIC's list of failed banks, updated every Monday).

Moreover, recent legislation does not resolve bailout uncertainty. The Dodd-Frank Wall Street Reform and Consumer Protection Act, signed into law on July 21, 2010, was explicitly meant to put an end to bailouts. In particular, it created the Financial Stability Oversight Council, charged with the duty to "*promote market discipline, by eliminating expectations...that the government will shield [banks and other financial institutions] from losses in the event of failure.*" However, leading regulators still worry about the potential for future bailouts, despite the promises made by current policy makers. For example, a few months after Dodd-Frank, Federal Reserve Chairman Ben Bernanke testified before the Financial Crisis Inquiry Commission that "*Simple declarations that the government will not assist firms in the future, or restrictions that make providing assistance more difficult, will not be credible on their own. Few governments will accept devastating economic costs if a rescue can be conducted at a lesser cost; even if one Administration refrained from rescuing a large, complex firm, market participants would believe that others might not refrain in the future.*" And while Congress was in the process of drafting the Dodd-Frank Act, the President of the Federal Reserve Bank of Minneapolis, Narayana Kocherlakota (2010), warned that "*no legislation can completely eliminate bailouts [and] any new financial regulatory structure must keep this reality in mind.*"[2]

We think it is reasonable, if not obviously correct, to assume that banks face uncertainty about future bailouts when making portfolio choices. To capture this policy uncertainty, we model government intervention as a "bailout lottery": to qualify for a bailout, a bank must be insolvent and it must hold a winning ticket. The lottery is funded by taxing all banks ex ante.[3] The government chooses the probability of winning the lottery, which may be (much) smaller than 100%. This leaves uncertainty about whether a given bank will be rescued if it fails. Like TARP, our bailout lottery provides a limited or fixed pool of resources to fund bailouts and does not provide explicit guarantees that every bank will be rescued. The likelihood of winning the bailout lottery and the probability of bank failure are determined simultaneously in our setting.

[2]See also Chari and Kehoe (2010) for similar remarks. Also see the "Bailout Barometer" calculated by the Federal Reserve Bank of Richmond. As of June 8, 2015, this barometer predicts that over half of the financial sector would be bailed out in the future, notwithstanding recent political efforts (like Dodd-Frank) to end bailouts.

[3]We also consider an extension in which taxpayers, not banks, pay for the bailout.

The latter equals the share of failed banks that get bailed out because there are many banks in our model.

We use our model to perform a series of quantitative experiments. Our computations center around a summary statistic that we call *unfunded moral hazard*, which is the ratio of bank failures in a bailout equilibrium (after the lottery has cleared) to bank failures in a laissez faire economy. If unfunded moral hazard is greater than 1, then there are more failed banks in the bailout equilibrium than in laissez faire, even *after* the government has bailed out as many banks as its lottery fund allows. If unfunded moral hazard is less than 1, then the lottery will cover all of the incremental bank failures that can be attributed to moral hazard and it will also cover at least some additional banks that would have failed anyway in a laissez faire economy. By one definition, we may say that a government bailout program is unsuccessful if it bails out fewer failed banks than it causes through moral hazard.

We find that the number of bank failures (after the lottery has cleared) can be higher or lower than in laissez faire. However, when the degree of policy uncertainty is high—when the probability of winning the lottery is far from 0 *and* also far from 1—a bailout lottery can cause serious damage to the banking sector. For example, in our baseline calibration, a bailout lottery with maximum policy uncertainty (probability of winning the lottery is 1/2) leaves the economy with 9% more failed banks than laissez faire. The probability of winning the lottery is high enough to encourage significant risk taking and yet the probability of winning is still low enough that the bailout lottery does not have the resources to keep up with all of the extra bank failures caused by moral hazard.

Importantly, these results go away if there is no policy uncertainty. If the probability of winning the lottery is 1 (perfect insurance), then unfunded moral hazard is zero because the lottery covers all bank failures by definition.[4] The danger zone is when there is policy uncertainty. Then the government runs the risk of creating more failures than its lottery can accommodate.

These estimates are sensitive to the assumptions that we make about the variance of the return on risky assets held by banks. In our baseline parameterization we assume returns on risky bank assets share the same variance as equity returns. However, if banks hold assets that are more risky than equities, then the unfunded moral hazard problem can be an order of magnitude worse. For instance, if the variance of the return on risky assets held by banks is twice the variance of

[4] Such a generous lottery requires huge taxes (as much as 25% of bank assets) to finance all bank failures.

equity returns, then a bailout program with lottery risk can leave the economy with over 100% more failed banks (after the lottery has cleared) than laissez faire. This peak in the moral hazard problem happens to occur when the probability of winning the lottery is 8/10.

Of course, right from the start, the bailout architects themselves were worried about moral hazard. In a CNN interview on March 16, 2008, Treasury Secretary Henry Paulson said: "*I'm as aware as anyone is of moral hazard.*" And on May 29, 2008, Chairman Bernanke echoed Paulson's remarks in a speech at the Federal Reserve Bank of Atlanta: "*A central bank that is too quick to act as liquidity provider of last resort risks inducing moral hazard.*" Our results provide some guidance for thinking about the potential *magnitude* of the moral hazard problem.[5]

Our paper fits into a rapidly growing literature on policy uncertainty that is too big to cite here in a comprehensive way. Briefly, research on this topic fits into two categories. Papers in the first category seek to measure policy uncertainty and to understand changes in policy uncertainty over time. Prominent examples include Baker, Bloom, and Davis (2013), Baker, Bloom, Canes-Wrone, Davis, and Rodden (2014), and Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2013).

Papers in the second category study the effects of specific types of policy uncertainty on economic outcomes. For example Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2013) find that idiosyncratic volatility shocks to tax rates depress economic activity and can be a stand-alone cause of a recession. Davig and Foerster (2014), Stokey (2014), and Caliendo, Gorry, and Slavov (2015) study one-time fiscal reforms that feature uncertainty about both the timing and structure of reform. Davig and Foerster show that uncertainty about the timing and structure of future tax policy can create a recession even if no change in fiscal policy actually materializes. Stokey shows that uncertainty about the timing and structure of tax policy creates periods of inaction, in which investors adopt a "wait-and-see" attitude. Caliendo, Gorry, and Slavov show that the welfare loss from uncertainty about Social Security reform depends on how well households are solving an optimal hedging problem.

Our paper falls into the second category of analyzing the impact of a specific type of policy

[5] See Black and Hazelwood (2012) for an empirical investigation of the effect of TARP on bank risk taking. They estimate the degree to which banks used TARP funds ex post to turn around and make risky loans, while we are interested in how the ex ante beliefs about a future bailout could induce risk taking.

uncertainty on economic outcomes. Like these papers, our paper is motivated by recent episodes of obvious policy uncertainty and by a concern that such uncertainty may persist. Our specific focus on uncertainty about bailouts distinguishes our paper from the others in this literature.

2. Description of the Portfolio Choice Model

We begin by describing the players, actions, timing, and notation in our model.

Players. There is a continuum of (ex ante) identical banks and a government.[6] Firms and households are taken as given and are therefore exogenous to the model.

Actions. Banks solve a portfolio choice problem by allocating their funds between a risky asset and a safe asset. Banks can leverage their risky assets by holding negative quantities of the safe asset. The government taxes banks ex ante and runs a bailout policy for banks with failed investments ex post. If a bank's risky investments lead to bankruptcy, that bank enters a lottery to potentially qualify for a bailout. The government only bails out as many banks as its budget allows, leaving uncertainty about whether a given bank will get bailed out if it fails. It is important to emphasize that the lottery feature of our model is the source of the policy uncertainty. Banks know that if they fail, they will enter a lottery. They just don't know if they hold a winning ticket.[7]

Timing. We consider a four period model. At time 0, banks are exogenously endowed with initial funds (e.g., through the sale of equity shares). Also at time 0, the government announces a bailout policy that is financed by taxing bank assets at time 0. The bailout policy consists of two objects, (i) a tax rate on bank assets and (ii) a probability of being bailed out if bank failure occurs. At time 1, banks select an optimal portfolio of risky and safe investments. At time 2, uncertainty about the returns on risky investments is resolved. At time 3, banks with failed investments appeal

[6] Ex post, banks experience different realizations on their risky investments and are no longer identical.

[7] We could envision a second layer of uncertainty in which banks don't even know if the government will operate a bailout lottery. In that case, banks don't know if they are living in a laissez faire regime or a bailout regime, nor do they know if they will be a lottery winner if it turns out that they are living in a bailout regime. We do not consider such "double uncertainty" in this paper, though we discuss this as a possibility for future work in the final section.

to the government by entering a bailout lottery, and the winners (and only the winners) of the lottery receive a bailout that is just large enough to prevent bank failure.

Notation. Throughout the paper, random variables will be denoted with a tilde, such as $\tilde{y}$, with mean $y = E(\tilde{y})$ and variance $\mathrm{Var}(\tilde{y})$.

Within this setting we will consider two separate worlds. First, we consider the portfolio decisions of banks living in a laissez faire economy as a benchmark. Second, we consider portfolio decisions in an economy with a bailout policy. For now, we will assume that the bailout policy is the only potential type of government intervention. Later in the paper we will also consider leverage limits in order to understand the chemistry of interacting policies.

3. Laissez Faire Benchmark

The bank's initial asset is A. It chooses to invest x in the risky asset, and $A - x$ in the risk-free asset (which will be calibrated to be a negative quantity to capture leverage). The risk-free asset has return r_f, and the return on the risky asset, $\tilde{r}$, is a random variable that follows a normal distribution $f_{\mathrm{N}}(r, \sigma^2)$. Total profit, $\tilde{\pi}$, is therefore also a random variable,

$$\tilde{\pi} = x\tilde{r} + (A - x)r_f.$$

For most of our calculations, banks will choose $x > A$ implying that banks will leverage risky investments by borrowing at the risk-free rate. Of course, banks cannot borrow at the risk-free rate in reality, but what is important to our analysis is merely that they can borrow at a rate that is lower than the expected return on the risky asset.

The moments of the random variable $\tilde{\pi}$ are

$$\begin{aligned} \pi &= E(\tilde{\pi}) = xr + (A - x)r_f, \\ \mathrm{Var}(\tilde{\pi}) &= x^2\sigma^2. \end{aligned}$$

Each bank has mean-variance utility with risk aversion γ, and its optimization problem is[8]

$$\max_x \left\{ xr + (A - x)r_f - \frac{\gamma}{2}x^2\sigma^2 \right\}.$$

The solution to this problem is

$$x^*_{LF} = \frac{1}{\gamma}\frac{r - r_f}{\sigma^2}.$$

4. Bailouts with Lottery Risk (Policy Uncertainty)

In this section we start with the microeconomics of the bank portfolio choice problem, and then we define an equilibrium lottery between the banking sector and the government.

4.1. Microeconomic Behavior

We consider two scenarios about how the lottery is funded. In the first scenario, banks self-finance the lottery. In the second scenario, the lottery is financed from outside the banking sector (e.g., by taxpayers) and banks are given free lottery tickets. In both cases, banks know which world they are in before making portfolio decisions. For most of our analysis we will assume that we are in the first world.[9] Ultimately, we will show that the issue of who pays the tax has important level effects on our moral hazard calculations.

The lottery will clear after bank investments are realized. If a bank's investments turn out good, then the bank is disqualified from the lottery. If a bank's investments leave it insolvent, then it holds onto the lottery ticket and awaits the announcement of the winners.

The winners of the lottery receive a bailout that is just large enough to stay solvent. Lottery winners receive idiosyncratic bailouts because each bank experiences a different portfolio shock (different realizations of returns on risky assets), and therefore the bailout that is required to restore solvency varies across winning ticket holders.[10]

[8] Risk aversion is an important assumption. Without it, there is no internal solution to the portfolio choice problem because banks choose infinite leverage in our model when $r > r_f$.

[9] This is consistent with proposals by Kocherlakota (2010) and others who want banks to internalize the bailout externality that is otherwise imposed on taxpayers.

[10] A subtle issue that we do not address is that a high likelihood of a bailout allows financial institutions, even highly leveraged ones, to borrow at artificially low rates (Kocherlakota (2010)). In our analysis we will assume that the cost of borrowing is fixed for simplicity, regardless of the probability of a bailout.

Formally, the probability that an insolvent bank gets bailed out is α. The price of a lottery ticket is a fraction ϕ of initial assets. We will refer to ϕ as the "tax rate". We denote pre-tax assets as A and after-tax assets as $A' = A(1-\phi)$.

Without a bailout, a bank will be insolvent if profit falls below the negative of initial assets,

$$\tilde{r} < \frac{-A' - (A'-x)r_f}{x} \equiv r_C(x)$$

where $r_C(x)$ is the "cut-off" return.[11]

Define the lottery

$$\mathcal{L} = \begin{cases} 1, & \text{with probability } \alpha, \\ 0, & \text{with probability } (1-\alpha), \end{cases}$$

and the size of the bailout is a random variable $\tilde{B}$,

$$\tilde{B} = \begin{cases} \mathcal{L}\left[-(x\tilde{r} + (A'-x)r_f) - A'\right], & \text{if } \tilde{r} < r_C(x), \\ 0, & \text{if } \tilde{r} \geq r_C(x). \end{cases}$$

The moments are

$$\begin{aligned} B &= \mathrm{E}(\tilde{B}) = \int_{-\infty}^{\infty} \mathbf{1}\left\{\tilde{r} < r_C(x)\right\}\left[-(x\tilde{r} + (A'-x)r_f) - A'\right]\alpha f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r} \\ &= \int_{-\infty}^{r_C(x)} \left[-(x\tilde{r} + (A'-x)r_f) - A'\right]\alpha f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r}, \end{aligned}$$

$$\begin{aligned} \mathrm{Var}(\tilde{B}) &= \int_{-\infty}^{r_C(x)} \left(-x\tilde{r} - (A'-x)r_f - A' - B\right)^2 \alpha f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r} \\ &\quad + \int_{-\infty}^{r_C(x)} (-B)^2 (1-\alpha) f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r} + \int_{r_C(x)}^{\infty} (-B)^2 f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r} \\ &= \int_{-\infty}^{r_C(x)} [\left(-x\tilde{r} - (A'-x)r_f - A' - B\right)^2 - B^2]\alpha f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r} + \int_{-\infty}^{\infty} B^2 f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r}. \end{aligned}$$

[11] Note that $dr_C(x)/dx > 0$ which means that the more the bank leverages its risky position, the more likely it is to fail. Indeed $\lim_{x\to\infty} r_C(x) = r_f$, which means that any realization of the risky return that falls below the borrowing rate will trigger failure when the bank is massively leveraged.

Bank profit $\tilde{\pi}$ satisfies

$$\tilde{\pi} = x\tilde{r} + (A' - x)r_f + \tilde{B}$$
$$\pi = \mathrm{E}(\tilde{\pi}) = xr + (A' - x)r_f + B$$
$$\mathrm{Var}(\tilde{\pi}) = x^2\sigma^2 + \mathrm{Var}(\tilde{B}) + 2x\mathrm{Cov}(\tilde{r}, \tilde{B}),$$

where

$$\begin{aligned}
\mathrm{Cov}(\tilde{r}, \tilde{B}) &= \int_{-\infty}^{r_C(x)} (\tilde{r} - r)\left(-x\tilde{r} - (A' - x)r_f - A' - B\right)\alpha f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r} \\
&\quad + \int_{-\infty}^{r_C(x)} (\tilde{r} - r)(-B)(1-\alpha) f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r} + \int_{r_C(x)}^{\infty} (\tilde{r} - r)(-B) f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r} \\
&= \int_{-\infty}^{r_C(x)} (\tilde{r} - r)\left(-x\tilde{r} - (A' - x)r_f - A'\right)\alpha f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r} - \int_{-\infty}^{\infty} (\tilde{r} - r) B f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r} \\
&= \int_{-\infty}^{r_C(x)} (\tilde{r} - r)\left(-x\tilde{r} - (A' - x)r_f - A'\right)\alpha f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r},
\end{aligned}$$

where the last equality holds because $\int_{-\infty}^{\infty} (\tilde{r} - r) B f_{\mathrm{N}}(\tilde{r}; r, \sigma^2)d\tilde{r} = 0$.

The bank's maximization problem becomes

$$\max_x \left\{ xr + (A' - x)r_f + B - \frac{\gamma}{2}\left[x^2\sigma^2 + \mathrm{Var}(\tilde{B}) + 2x\mathrm{Cov}(\tilde{r}, \tilde{B})\right]\right\},$$

or, after substituting terms and using color to emphasize dependence on x,

$$\begin{aligned}
x_B^*(\alpha, \phi) &= \arg\max \Bigg\{ xr + (A' - x)r_f + B(x) - \frac{\gamma}{2}x^2\sigma^2 - \frac{\gamma}{2}\int_{-\infty}^{\infty} B(x)^2 f_{\mathrm{N}}(\cdot)d\tilde{r} \\
&\quad - \frac{\gamma}{2}\int_{-\infty}^{r_C(x)} [(-x\tilde{r} - (A' - x)r_f - A' - B(x))^2 - B(x)^2]\alpha f_{\mathrm{N}}(\cdot)d\tilde{r} \\
&\quad - \gamma x \int_{-\infty}^{r_C(x)} (\tilde{r} - r)\left(-x\tilde{r} - (A' - x)r_f - A'\right)\alpha f_{\mathrm{N}}(\cdot)d\tilde{r} \Bigg\}.
\end{aligned}$$

4.2. Equilibrium Lottery

The government's budget will balance if taxes paid per bank equals the expected bailout per bank

$$A\phi = \int_{-\infty}^{-[A'+(A'-x_B^*)r_f]/x_B^*} (-x_B^*\tilde{r} - (A' - x_B^*)r_f - A')\alpha f_{\mathrm{N}}(\tilde{r}; r, \sigma^2) d\tilde{r}.$$

For simplicity, we assume the government holds taxes in a zero-interest storage account.

Like Kocherlakota's (2010) proposal, the government calculates the expected future bailout per bank and charges banks a tax that exactly equals that amount. The bailout externality is fully internalized by banks in the sense that they collectively fund their own bailouts, but this does not necessarily imply that the moral hazard issue has been resolved. We will define moral hazard in the next section, after we introduce language and definitions pertaining to model equilibria.

Definition 1 *An equilibrium lottery is defined as follows. At time 0, the government announces a bailout lottery (α, ϕ) such that: (i) given (α, ϕ), the allocation $x_B^*(\alpha, \phi)$ solves the bank's portfolio choice problem; and, (ii) given the bank's portfolio choice $x_B^*(\alpha, \phi)$, the government's budget is balanced.*

Notice that the bailout lottery (α, ϕ) is under-identified, which means that many bailout lotteries qualify as equilibrium lotteries. In other words, after substituting bank portfolio choices $x_B^*(\alpha, \phi)$ into the government's budget constraint, we are left with just one equation (the government's budget constraint) and two unknowns (α and ϕ).

Definition 2 *The menu of bailout lotteries $(\alpha, \phi)_{\alpha \in [0,1]}$ is the locus of equilibrium lotteries.*

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5. Moral Hazard

For the world without the government, the probability of bank failure is

$$P(fail|\{LF\}) = \int_{-\infty}^{-[A+(A-x^*_{LF})r_f]/x^*_{LF}} f_{\mathrm{N}}(\tilde{r}; r, \sigma^2) d\tilde{r},$$

and for the world with a government bailout lottery (α, ϕ), the probability of bank failure in equilibrium is

$$P(fail|\{B\}) = \int_{-\infty}^{-[A'+(A'-x^*_B(\alpha,\phi))r_f]/x^*_B(\alpha,\phi)} f_{\mathrm{N}}(\tilde{r}; r, \sigma^2) d\tilde{r}.$$

With this terminology we can state our definitions of moral hazard.

Definition 3 *Moral hazard, M, is defined as $M = P(fail|\{B\})/P(fail|\{LF\})$.*

This statistic tells us how much extra risk banks hold in response to the bailout policy, but it does not tell us how many banks are ultimately left to fail after the government has bailed out what it can. For this reason we have a second definition that captures this second effect.

Definition 4 *Unfunded moral hazard, UM, is defined as $UM = M(1 - \alpha)$, which nets out the portion of banks that fail and receive bailout funds.*

If $UM > 1$, then after the government has bailed out as many banks as it can afford to bail out, we are still left with a net increase in bank failures above and beyond the laissez faire benchmark. If $UM < 1$, then even though the presence of a bailout lottery does cause banks to take riskier positions, in the end society is left with fewer failed banks than the laissez faire benchmark.[12]

[12] We should mention that in our model, technically there is no "problem" with moral hazard since banks like the bailout regime. The bailout policy is actuarially fair in our model so it is sure to increase the expected utility of banks. Our paper is not set up to quantify the costs of moral hazard because we don't model the effect of bank failures on the broader economy. Our paper is better suited to quantify risk taking by banks (which is our stated purpose) rather than to measure the welfare consequences of such risk taking (which is a separate topic).

6. Quantitative Results

Initial assets A are normalize to unity throughout. We set parameters to the following values. The risk-free interest rate $r_f = 3\%$, and the mean return on risky investments $r = E(\tilde{r}) = 10\%$, which matches the 7% risk premium in the U.S. over the last half century. The variance of the risky asset takes on one of three possible values, and banks and the government know which of the three worlds they live in: the medium-risk world $\sigma^2 = 0.04$ which is approximately equal to the historical variance on equity returns (risky assets) in the U.S. economy, as well as a low-risk world with half the variance $\sigma^2 = 0.02$ and a high-risk world with twice the variance $\sigma^2 = 0.08$. We set the risk aversion parameter to $\gamma = 0.5$, and we will treat ϕ as a free parameter that can be used to calibrate lottery equilibria to the desired bailout probability α. We then consider the full menu of equilibrium (α, ϕ) combinations.

Each of the three graphs in Figure 1 give the full menu of equilibrium bailout lotteries (α, ϕ) for a given variance of the risky asset σ^2. We let the probability of winning the bailout lottery α range from 0 to 1, in step sizes of 0.1, and for each of these α values we analyze three σ^2 values and compute the tax on bank assets ϕ that is needed to close the general equilibrium. Each bailout lottery (α, ϕ) is completely self-financed, given the optimal portfolio decisions of banks. It is intuitive that each menu is convex; it is increasingly expensive to finance the bailout lottery as the share of failed banks to be bailed out α increases. In all three cases, a policy that bails out 50% of failed banks can be funded with a tax on bank assets that is less than 5%, and in some cases much less than 5%. But a policy that rescues 100% of failed banks requires taxes that are many times greater, reaching 1/3 of bank assets in the high variance case.

Perhaps even more interesting is the non-monotonic effect of the variance of the risky asset. It may be intuitive to guess that, as the variance of the risky asset increases, the required tax to close the equilibrium would also increase. But this is not always the case. When the probability of winning the bailout lottery α falls in the low to medium range, then increased volatility in the risky asset actually leads to *lower* required taxes to fund the bailout lottery. This is because banks naturally choose a portfolio with less risk when the variance of the risky asset is high. And even though there is a greater likelihood of failure for a given portfolio, banks adjust their portfolios enough to more than compensate and therefore the government doesn't need large taxes to fund the small number of banks that fail. On the other hand, for large values of α (e.g., $\alpha = 1$) banks face less downside risk on the risky asset and instead the large upper tail of the return on the risky asset becomes very attractive and banks load up on risk. In such a case, the government must tax banks aggressively in order to stand ready to finance a large number of bank failures.

Figure 2 plots the probability of bank failure $P(fail|\{B\})$ as a function of each potential bailout lottery (α, ϕ), for different assumptions about the variance of the risky asset σ^2. The dashed lines reference the probabilities of bank failure in laissez faire economies $P(fail|\{LF\})$ for the three different assumptions about σ^2. As in Figure 1, the tax on bank assets ϕ is always calibrated to keep the model in equilibrium. Regardless of the value of σ^2, the probability of bank failure is increasing in the probability of winning the bailout lottery α, and of course the presence of any bailout lottery increases the likelihood of bank failure (i.e., $P(fail|\{B\}) > P(fail|\{LF\})$ for any feasible lottery (α, ϕ)). However, as explained in the previous paragraph, the effect of σ^2 on the probability of bank failure depends crucially on α. At low or medium values of α, a higher σ^2 means a lower probability of bank failure because banks choose to hold very little of the risky asset. It is not until α is very high that the probability of bank failure is positively related to the variance of the risky asset (only for $\alpha > 90\%$ is it the case that we see a positive link between the probability of failure and the variance of the risky asset).

Figure 3 shows the unfunded moral hazard problem, UM, which is the ratio of bank failures under the bailout equilibrium (after the lottery has cleared) to bank failures under laissez faire. By definition, this statistic equals 1 when $\alpha = 0$ and it equals 0 when $\alpha = 1$. But it can take on any positive value when α is between 0 and 1.

Recall that if UM is greater than 1, then there are more failed banks in the bailout equilibrium than under laissez faire, even after the government has bailed out as many banks as it can afford to. If this is the case, the potential of winning the bailout lottery causes so much extra risk taking by banks and hence bank failures that the bailout fund is exhausted before it can pay for all of the extra bank failures caused by moral hazard. The result is a new equilibrium with more failed banks than under laissez faire, which cuts squarely against the very purpose of bailouts.

On the other hand, if UM is less than 1, then even though the presence of a bailout lottery encourages banks to hold more risk in their portfolios (as can be seen in Figure 2), the extra risk taken by banks is relatively modest and the bailout fund is more than sufficient to pay for all of the extra bank failures caused by moral hazard. In such a case, the remainder of the bailout fund is then used to bail out some banks that would have failed even under laissez faire, leaving the economy with fewer failed banks overall.

Figure 3 shows when the unfunded moral hazard problem UM is above or below the reference line at 1. In the low-risk world, UM is always below 1 for all $\alpha > 0$. In this world, even though the presence of the bailout lottery causes banks to take on more risk and thereby subject themselves to a greater likelihood of failure (as seen in Figure 2), we end up with fewer bank failures after the government has exhausted the bailout fund. However, in the medium-risk world, unfunded moral hazard is above 1 for all α between 0 and approximately 70%. This means that there is a huge segment of the menu of potential bailout lotteries for which government intervention ultimately leaves more failed banks in the economy than without intervention. Moreover, in the high-risk world the unfunded moral hazard problem can be huge, reaching as high as 2, which means that government intervention could leave the economy with twice as many bank failures as laissez faire.

The take home message from Figure 3 is that many of the bailout policies from the menu of feasible policies will leave the economy with more failed banks than laissez faire. Bailout policies that rescue many/most but not all failed banks are the most dangerous in terms of the unfunded moral hazard problem. The only way the government can ensure that unfunded moral hazard is below 1 is to remove the lottery and give every failed bank a winning ticket (set $\alpha = 1$). Anything less than full insurance can leave the economy with significantly more bank failures. While full insurance solves the unfunded moral hazard problem, it is incredibly expensive (again, see Figure 1), requiring taxes on the order of a quarter of bank assets.

Tables 1-3 summarize all of the quantitative results behind Figures 1-3. In addition to the data used to create the figures, these tables also report the bank's equilibrium risky position $x_B^*(\alpha, \phi)$, the ex ante expected bailout per bank B, and the equilibrium cutoff rate of return $-[A' + (A' - x_B^*(\alpha, \phi))r_f]/x_B^*(\alpha, \phi)$.

So far we have abstracted from limits on leverage. Hence, as the probability of winning the bailout lottery α increases, banks choose to further leverage their assets and this amplifies the risk of bank failure. Under laissez faire ($\alpha = 0$), accounting leverage—assets divided by the difference between assets and liabilities—is 3.5, while accounting leverage is closer to 10 when $\alpha = 1$. Given the portfolio choices of banks, profits will drop below initial assets and hence banks will enter the lottery if the return on the risky asset drops below -26.43% in laissez faire and below -4.35% when $\alpha = 1$. A natural question is whether a limit on leverage could correct the unfunded moral hazard problem. We consider this issue in the next section.

Finally, it is worth emphasizing the role that one of our key modeling assumptions—ex ante homogenous bank size—plays in the interpretation of our results. While the long-term consequences of Dodd-Frank are unclear, it seems likely that big, highly interconnected banks still face a higher probability of being bailed out than small banks. In fact, some commentators would argue that big banks don't face any policy uncertainty at all because they know for sure that they will be bailed out. This is where our homogeneity assumption works well for us because it allows us to be agnostic about the connection between bank size and the probability of being bailed out. We merely assume in our model that banks *of a given size* all face the same probability of being bailed out. For big banks this probability may be very high (or even 1), in which case we would consider equilibria with high α as more plausible. For small banks, this probability may be very low and we would consider equilibria with low α as more plausible. In either case, our results are quite general because we report the full menu of equilibria for a cross section of equal-size banks.

7. Two Extensions

We consider two extensions. First, we assume the government imposes limits on bank leverage. Reducing bank leverage has been at the center stage of political discourse during and after the Financial Crisis. Second, we consider a world in which banks get a free lunch because the bailout lottery is financed outside the banking sector (by taxpayers). Following the analysis above, we quantitatively assess how the moral hazard problem of bank bailouts relates to the degree of policy uncertainty that banks face.

7.1. Interacting Policies: Leverage Limits + Bailouts

We now consider a world in which the government imposes multiple policies at once: a bailout policy just as before, and also a leverage limit that limits a bank's risky position (through limiting the short position taken in the risk-free asset). This allows us to understand the chemistry of interacting policies.

We define leverage as assets divided by the difference between assets and liabilities (accounting leverage). Suppose the government sets a leverage limit, $\mathbb{L}$, as a function of pre-tax initial bank assets. Thus, banks face the constraint

$$\frac{x}{A} < \mathbb{L}.$$

We compute *constrained lottery equilibria* as follows. First, we check to see if bank leverage exceeds the leverage limit in the unconstrained lottery equilibria. If not, then there is of course no need to re-simulate the results. But if bank leverage exceeds the limit for a given bailout lottery (α, ϕ), then we set bank leverage at the legal maximum and, while holding α fixed, we compute a new (lower) value for ϕ that balances the government's budget.

Throughout this section of the paper we assume that we are in the medium-risk world ($\sigma^2 = 0.04$). In a laissez faire economy, banks choose $x^*_{LF} = 3.5$. However, in the bailout regime, x^*_B can reach as high as 10 when the bailout policy is at its most generous ($\alpha = 1$). To generate meaningful results in which the leverage limit is binding for high values of α and non-binding for low values of α, we must choose a leverage limit somewhere between 3.5 and 10. We pick $\mathbb{L} = 5$ to illustrate the role of the leverage limit, though other values could be used.

Figure 4 is analogous to Figure 1. It plots the menu of bailout lotteries with and without leverage. In both cases, ϕ adjusts to ensure that the government budget is balanced given the portfolio choices of banks. When α is less than approximately 60%, banks choose less leverage than the legal maximum. When α is greater than 60%, banks would like more leverage than the limit and so they settle for the limit. The required tax rate to balance the government's bailout budget is still increasing in α as in the world without leverage, but the increase is much more gradual. An increase in α requires only a small increase in ϕ to fund the extra bank failures implied by the higher α because banks are not able to increase their leverage. The vertical distance between the open and closed balls therefore captures the extra taxation that is needed to accommodate extra risk taking by banks when there are no leverage limits. Notice that the vast majority of the high taxes that are required to finance a generous bailout policy with a very high α actually go toward offsetting the additional bank failures that come indirectly from moral hazard rather than directly though higher α per se.

Figure 5 is analogous to Figure 2. It plots the probability of bank failure $P(fail|\{B\})$ as a function of each potential bailout policy (α, ϕ) with and without leverage limits. The dashed line is the probability of bank failure in laissez faire $P(fail|\{LF\})$. As in Figure 4, the tax on bank assets ϕ is calibrated to keep the model in equilibrium for each α, whether we are in a world with leverage limits or without. Notice that after the leverage limit becomes binding, the probability of failure is drastically reduced.

Figure 6 shows the unfunded moral hazard problem, UM, with and without leverage limits. Of course, when α is low the leverage limit is non-binding and has no effect on unfunded moral hazard. But if α is large enough to bind, then unfunded moral hazard is always lower when there are limits to leverage.

However, imposing a leverage limit doesn't necessarily solve the unfunded moral hazard problem. For instance, at $\alpha = 0.6$, the lottery equilibria with and without leverage limits both feature an unfunded moral hazard problem greater than 1. In other words, even though the government has put a limit on leverage and hence a limit on how much risk banks can hold, the introduction of a bailout policy still leaves the economy with more failed banks than laissez faire even after the government has exhausted its bailout fund. This is in part because the leverage limit is only slightly below the bank's optimal choice of leverage $x_B^* = 5.15$ for that particular bailout policy, while the limit is far above the bank's optimal choice of leverage under laissez faire $x_{LF}^* = 3.5$.

On the other hand, if the same leverage limit is combined with a more generous bailout policy of $\alpha = 70\%$, then the presence of the leverage limit actually converts unfunded moral hazard from above 1 to dramatically below 1. In other words, a self-financed bailout policy with $\alpha = 70\%$ and no limit on leverage leaves the economy with *more* failed banks than laissez faire, while a self-financed bailout policy with the same α and also a limit on leverage will leave the economy with *fewer* failed banks than laissez faire.[13]

7.2. Exogenous (Non-Bank) Taxation

In our baseline model above, we assumed that banks pay taxes on their initial assets. That is, all banks must buy a lottery ticket before they make their investment decisions and the bailout

[13] It is important to note that we only allow banks to increase risk through leverage. In reality, a leverage limit will limit leverage, but it may simultaneously increase the investment risk chosen. Our model does not have this extra feature.

lottery is therefore self-financed by the banking sector. The purpose of this extension is to study the implications of a different modeling assumption: the lottery is funded from other non-bank sources outside the model (e.g., through taxpayer dollars).

Technically speaking, the government simply announces a probability of winning the bailout lottery if failure occurs α and the government sets the bank tax to $\phi = 0$. This adjustment makes our model a partial equilibrium model, and we need only compute the bank's optimal portfolio decisions in the face of the free-lunch bailout policy.

Figure 7 plots the unfunded moral hazard induced by the bailout lottery. One curve corresponds to the case in which the bailout lottery is self-financed by banks (just as in Figure 3), and the other curve corresponds to the new case where banks are off the hook and make no contribution to the lottery. Both curves correspond to the medium-risk world ($\sigma^2 = 0.04$). The unfunded moral hazard statistic still follows the same general pattern, but with a very interesting (almost counter-intuitive) level effect. Unfunded moral hazard is quantitatively *less* worrisome when banks don't pay for the lottery themselves. The maximum increase in unfunded bank failures is now 3%, rather than 9%.

What is the intuition? When banks don't fund the lottery themselves, their initial assets remain higher than otherwise and this reduces the unconditional probability of winning the bailout lottery. That is, with more assets, banks are less likely to become insolvent and are therefore less likely to be bailed out, which causes them to take a less risky position. Considering an extreme example makes the intuition more clear. If banks must pay huge taxes, leaving them with very little assets to buffer a negative shock, then there is a high unconditional likelihood of being bailed out which in turn encourages more risk taking. The policy lesson is important: although it may be politically desirable to require banks to finance their own bailout, doing so can make the moral hazard problem worse. Taxing bank assets makes insolvency more likely and makes the bailout safety net a more likely outcome, causing optimizing banks to "throw in the towel" and load up on risk.

Quantitatively, in the world with a bailout lottery that is bank-financed, say $(\alpha, \phi) = (50\%, 1.54\%)$, then $x_B^* = 4.64$, whereas in a world where banks don't fund the lottery, say $(\alpha, \phi) = (50\%, 0\%)$, then $x_B^* = 4.59$. The reduction in risk taking in the second world makes banks less likely to fail; $P(fail|\{B\})$ drops from 7.46% to 7.04%.

8. Concluding Remarks and Direction for Future Work

In this paper we seek to better understand the affect of large-scale government bailout policies on risk taking by banks and bank failures. In particular, we are interested in bailout policies that offer only partial insurance: the government does not guarantee that it will rescue each and every failed bank. We capture partial insurance by modeling government policy as a bailout lottery. Insolvent banks in our model enter a bailout lottery. Only banks with a winning ticket get bailed out. This lottery-like risk (policy uncertainty) captures the fact that banks don't know for sure whether the government will provide assistance if their investments go bad.

We have focused specifically on the interaction between the banking sector and policy uncertainty while abstracting from the broader macroeconomic context that would include firm production and household consumption. This has allowed us to concentrate on the fundamental question that we are interested in—Do bailout policies with "lottery risk" (policy uncertainty) tend to reduce or increase the number of bank failures?—without the extra complexity of a full blown general equilibrium model. In the future, it would be useful to add these additional features to our model to further study how policy uncertainty in the banking sector affects firm investment spending, aggregate output, household consumption, and household welfare.

Throughout our analysis, we have assumed that banks know which regime they are living in (be it laissez faire or bailouts). Therefore, in our setting policy uncertainty refers specifically to the fact that, conditional on living in the bailout regime, banks don't know if they will be a lottery winner. We could envision another outer layer of policy uncertainty about which regime will prevail. In that case, banks don't know if they are living in a laissez faire regime or a bailout regime, nor do they know if they will be a lottery winner if it turns out that they are living in the bailout regime. Future work could consider how adding this second layer of uncertainty affects our results about risk taking and bank failure.

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Table 1. Summary of Quantitative Results for Model with Bailout Lottery:

Moderate Variance ($\sigma^2 = 0.04$), *No Leverage Limits, and Self-Financed Lottery*

Pr win, α	tax, ϕ	portfolio, $x_B^*(\alpha, \phi)$	bailout, $\mathrm{E}(\tilde{B})$	cutoff	$P(fail \mid \{B\})$	UM
0	0	3.50	0	-26.43%	3.4%	1.000
10%	0.11%	3.63	0.001	-25.35%	3.9%	1.015
20%	0.27%	3.79	0.003	-24.11%	4.4%	1.026
30%	0.52%	3.99	0.005	-22.65%	5.1%	1.050
40%	0.90%	4.26	0.009	-20.94%	6.1%	1.068
50%	1.54%	4.64	0.015	-18.88%	7.5%	1.091
60%	2.68%	5.15	0.027	-16.47%	9.3%	1.088
70%	4.73%	5.86	0.047	-13.75%	11.8%	1.031
80%	8.49%	6.85	0.085	-10.75%	15.0%	0.876
90%	15.35%	8.20	0.153	-7.63%	18.9%	0.552
100%	28.01%	10.09	0.280	-4.35%	23.7%	0.000

Note: Laissez faire benchmark in red. Initial assets (equity) A normalized to \$1. The risky position of the bank's portfolio $x_B^*(\alpha, \phi)$ is also equal to pre-tax accounting leverage ratio.

Table 2. Summary of Quantitative Results for Model with Bailout Lottery:

High Variance ($\sigma^2 = 0.08$), *No Leverage Limits, and Self-Financed Lottery*

Pr win, α	tax, ϕ	portfolio, $x_B^*(\alpha,\phi)$	bailout, $E(\tilde{B})$	cutoff	$P(fail\|\{B\})$	UM
0	0	1.75	0	-55.86%	1.0%	1.000
10%	0.01%	1.78	0.0002	-54.83%	1.1%	0.989
20%	0.05%	1.82	0.0004	-53.63%	1.2%	0.983
30%	0.08%	1.86	0.0008	-52.19%	1.4%	0.986
40%	0.12%	1.93	0.0013	-50.44%	1.6%	0.984
50%	0.21%	2.01	0.0021	-48.06%	2.0%	1.011
60%	0.38%	2.16	0.0037	-44.57%	2.7%	1.084
70%	0.89%	2.48	0.0089	-38.16%	4.4%	1.342
80%	4.03%	3.50	0.0403	-25.24%	10.6%	2.147
90%	13.41%	5.02	0.1342	-14.75%	19.1%	1.926
100%	33.20%	6.94	0.3319	-6.91%	27.4%	0.000

Note: Laissez faire benchmark in red. Initial assets (equity) A normalized to \$1. The risky position of the bank's portfolio $x_B^*(\alpha,\phi)$ is also equal to pre-tax accounting leverage ratio.

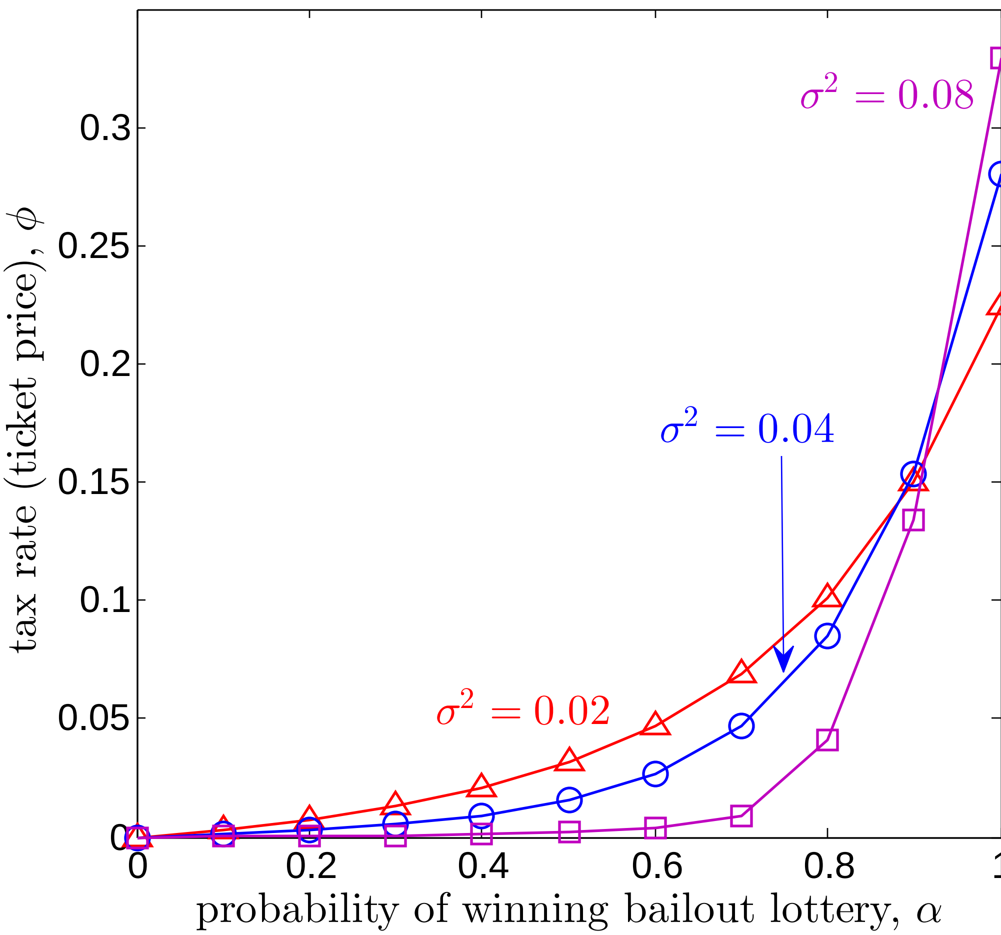
Table 3. Summary of Quantitative Results for Model with Bailout Lottery:

Low Variance ($\sigma^2 = 0.02$), *No Leverage Limits, and Self-Financed Lottery*

Pr win, α	tax, ϕ	portfolio, $x_B^*(\alpha, \phi)$	bailout, $\text{E}(\tilde{B})$	cutoff	$P(fail \vert \{B\})$	UM
0	0	7.00	0	-11.71%	6.2%	1.000
10%	0.30%	7.29	0.003	-11.08%	6.8%	0.991
20%	0.73%	7.64	0.007	-10.38%	7.5%	0.968
30%	1.29%	8.05	0.013	-9.64%	8.2%	0.929
40%	2.05%	8.53	0.021	-8.82%	9.1%	0.883
50%	3.15%	9.12	0.031	-7.93%	10.2%	0.824
60%	4.70%	9.85	0.047	-6.97%	11.5%	0.744
70%	6.90%	10.72	0.069	-5.94%	13.0%	0.627
80%	10.14%	11.82	0.101	-4.83%	14.7%	0.473
90%	15.00%	13.20	0.150	-3.63%	16.7%	0.270
100%	22.41%	14.99	0.224	-2.33%	19.1%	0.000

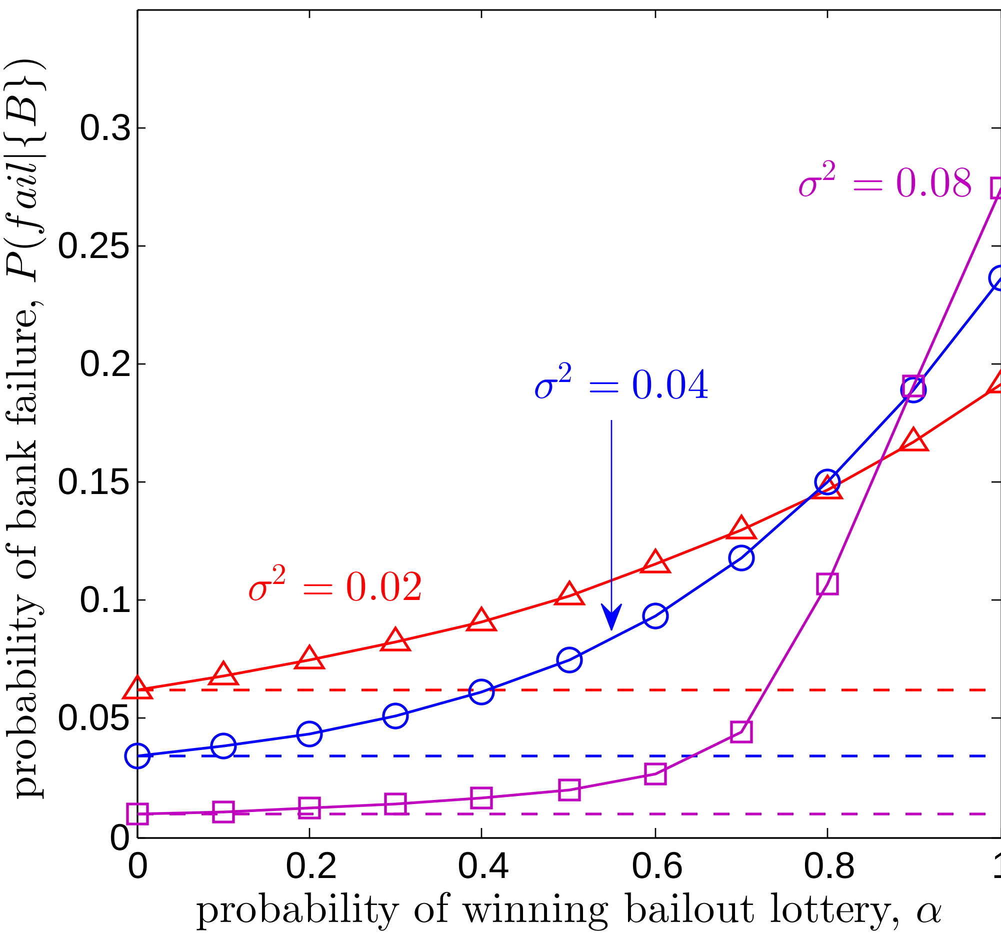
Note: Laissez faire benchmark in red. Initial assets (equity) A normalized to \$1. The risky position of the bank's portfolio $x_B^*(\alpha, \phi)$ is also equal to pre-tax accounting leverage ratio.

Figure 1. The Menu of Equilibrium Bailout Lotteries (α, ϕ)



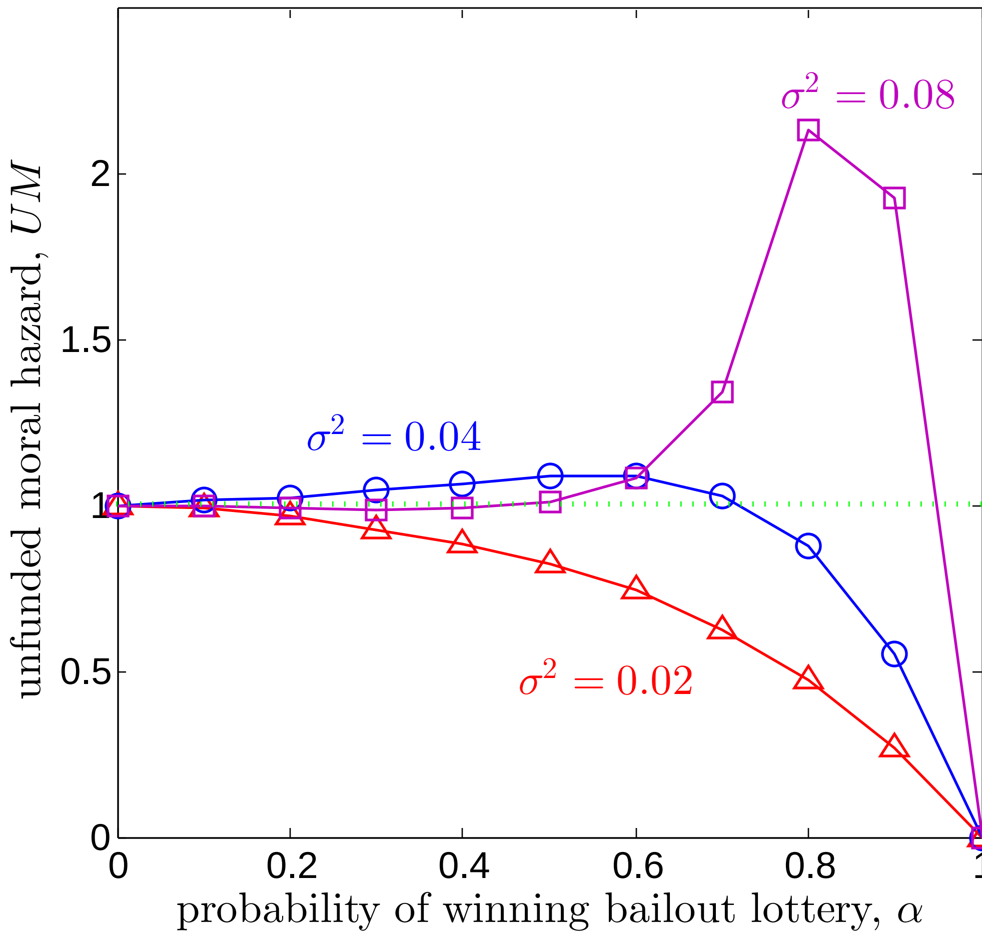
Note: This figure shows the tax rate on bank assets ϕ that is needed to close the equilibrium, given the probability of winning the lottery α and given the variance of risky assets σ^2.

Figure 2. Probability of Bank Failure across the Menu of Bailout Lotteries



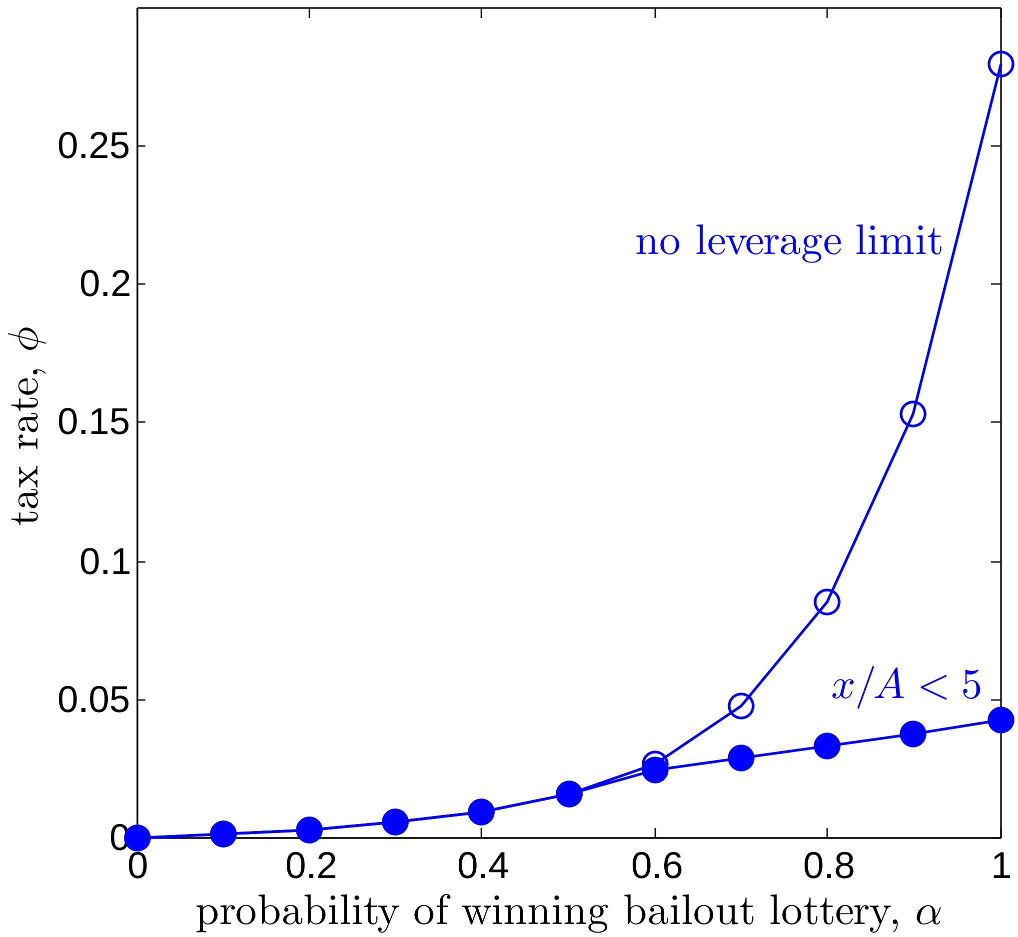
Note: This figure shows the probability of bank failure $P(fail|\{B\})$ for each bailout lottery (α, ϕ), where ϕ is chosen to close the equilibrium and dashed lines are laissez faire $P(fail|\{LF\})$.

Figure 3. Unfunded Moral Hazard across the Menu of Bailout Lotteries



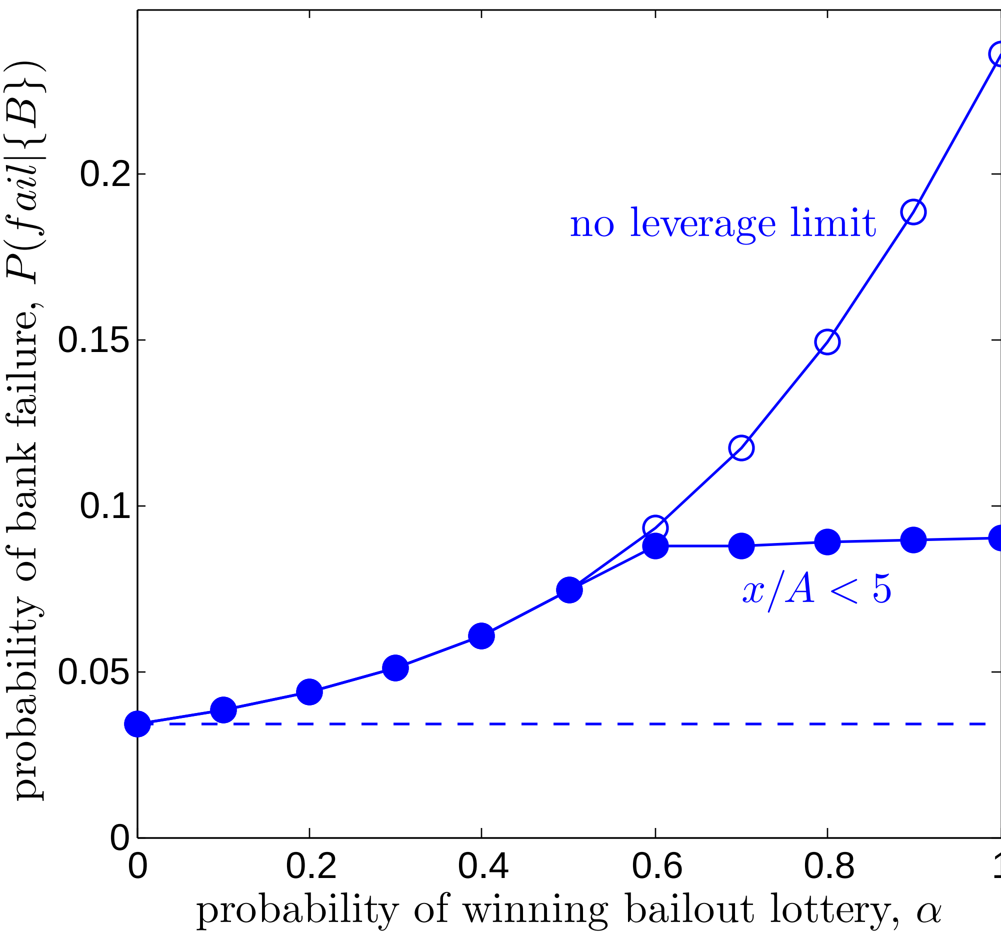
Note: This figure shows the unfunded moral hazard problem, $UM = (1-\alpha) * P(fail|\{B\})/P(fail|\{LF\})$ for each bailout lottery (α, ϕ), where ϕ is chosen to close the equilibrium.

Figure 4. The Menu of Bailout Lotteries (α, ϕ) with Leverage Limits



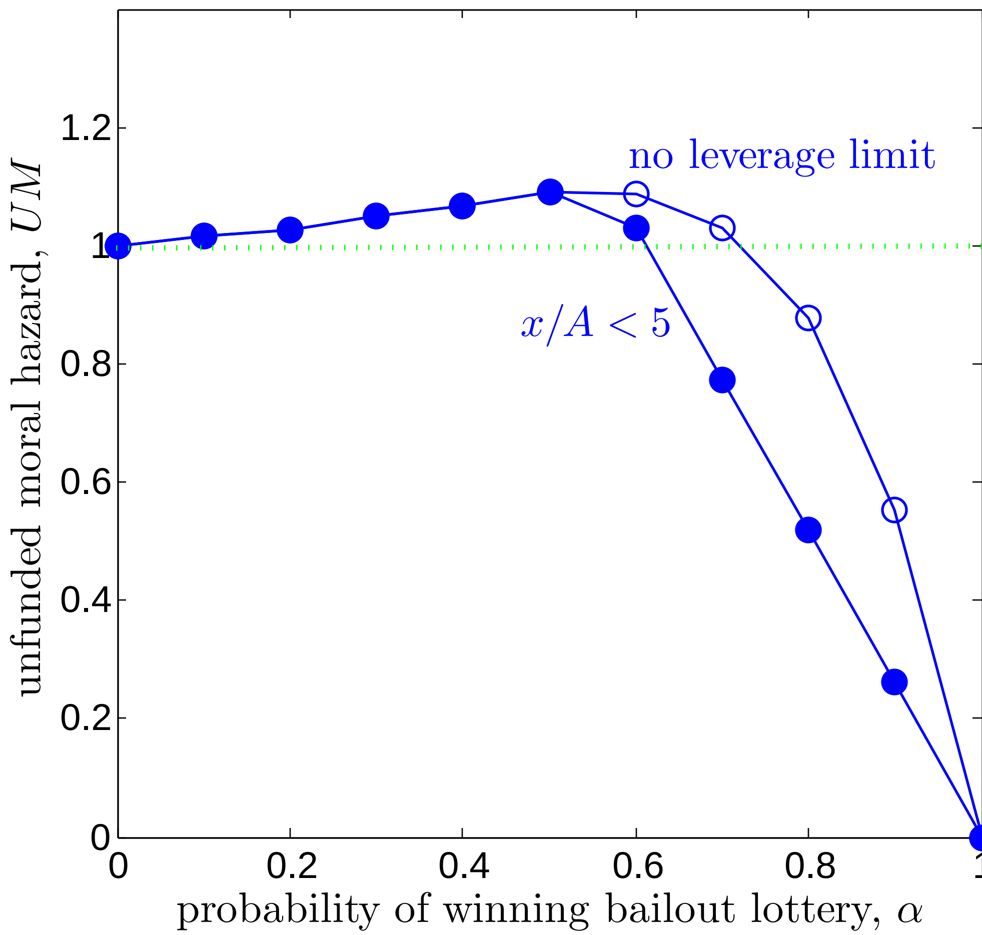
Note: This figure shows the tax rate on bank assets ϕ that is needed to close the equilibrium, given the probability of winning the lottery α and the variance of risky assets $\sigma^2 = 0.04$.

Figure 5. The Probability of Bank Failure with Leverage Limits



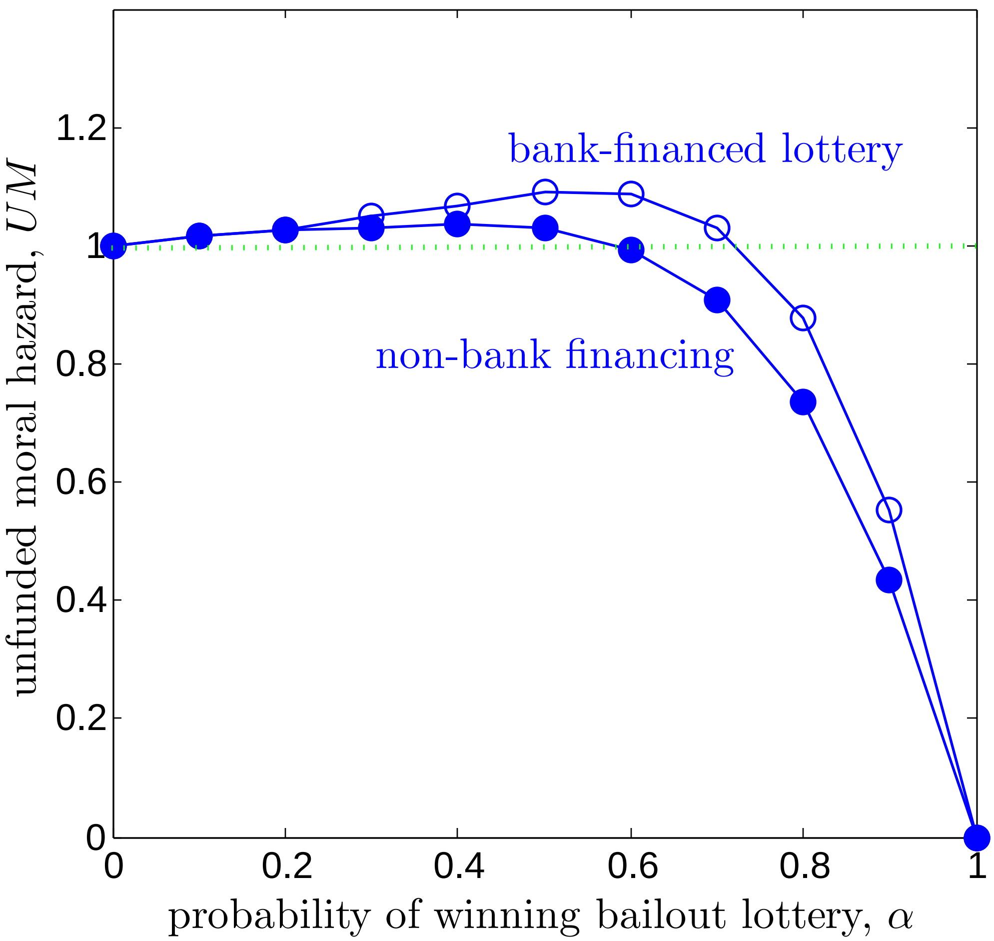
Note: This figure shows the probability of bank failure $P(fail|\{B\})$ for each bailout lottery (α, ϕ), where ϕ is chosen to close the equilibrium, dashed line is laissez faire $P(fail|\{LF\})$, and $\sigma^2 = 0.04$.

Figure 6. Unfunded Moral Hazard with Leverage Limits



Note: This figure shows the unfunded moral hazard problem, $UM = (1-\alpha) * P(fail|\{B\})/P(fail|\{LF\})$ for each bailout lottery (α, ϕ), where ϕ closes the equilibrium and $\sigma^2 = 0.04$.

Figure 7: Unfunded Moral Hazard with Exogenous Taxation



Note: This figure shows the unfunded moral hazard problem, $UM = (1-\alpha) * P(fail|\{B\})/P(fail|\{LF\})$ for different assumptions about taxation and with $\sigma^2 = 0.04$.