



Bailout uncertainty in a microfounded general equilibrium model of the financial system [☆]

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ABSTRACT

This paper develops a micro-founded general equilibrium model of the financial system composed of ultimate borrowers, ultimate lenders and financial intermediaries. The model is used to investigate the impact of uncertainty about the likelihood of governmental bailouts on leverage, interest rates, the volume of defaults and the real economy. The distinction between risk and uncertainty is implemented by applying the multiple priors framework to beliefs about the probability of bailout.

Results of the analysis include: (i) An unanticipated increase in bailout uncertainty raises interest rates, the volume of defaults in both the real and financial sectors and may lead to a total drying up of credit markets. (ii) Lower ex ante bailout uncertainty is conducive to higher leverage, which in turn raises moral hazard and makes the economy more vulnerable to ex post increases in bailout uncertainty. (iii) Bailout uncertainty affects the likelihood of bubbles, the amplitude of booms and busts as well as the banking and the credit spreads. (iv) Higher bailout uncertainty is associated with higher returns' variability in diversified portfolios and higher systemic risks, (v) Pre-crisis expansionary monetary policy reinforces those effects by inducing higher aggregate leverage levels. (vi) The larger the change in bailout uncertainty and the change in aversion to this uncertainty, the stronger the pre-crisis buildup and the deeper the ensuing crisis.

A central policy implication of the analysis is that the vaguest is bailout policy prior to a crisis, the lower is the magnitude of investments destroyed or missed due to errors in evaluating bailout and other intervention policies. On the other hand, the clearer is bailout policy upon the eruption of a crisis, the smaller the contraction of credit and the destruction of investment activity.

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1. Introduction

Financial sector bailouts in the US and more recently in Europe have revived the well known dilemma between restoration of confidence in the face of a panic and the costs of moral hazard. On one hand, when a panic engulfs financial markets, bailouts appear indispensable in order to restore confidence and prevent further collapses in the financial system. On the other hand, by subsidizing opportunistic behavior at the expense of taxpayers, bailouts encourage excessive risk taking on the part of financial institutions, borrowers and lenders, and plant the seeds of the next bubble.

Different experts in both policymaking circles, as well as in academia, often find themselves at odds regarding the ways to handle this problem. Therefore, in spite of currently ongoing reforms in regulation, this dilemma is likely to be a central issue during the upcoming decade. Whether, and how exactly will bailout policies be deployed in the future is largely an open issue. Due to the lack

of consensus about the precise ways to deal with the (ex ante and ex post) tradeoffs induced by bailouts, bailout uncertainty is extremely likely to be non negligible in the foreseeable future. The 2008 bailout zigzags in the US (Bear-Stern versus Lehman) and the ex ante uncertainties about the reaction of EMU governments to sovereign debt problems in Greece, Cyprus Portugal and Spain attest to that.

The main objectives of this paper are: (i) To identify the mechanisms through which beliefs about bailout policy affect short term credit within the financial system, interest rates, credit to the real sector and real investment. (ii) To trace out the impact of an ex post (after long term investment decisions have been made) change in bailout perceptions on interest rates and the volume of defaults throughout the entire financial system. (iii) To analyze the impact of expansionary monetary policy on leverage and risk appetite. The paper's framework makes it possible to trace out both the ex ante and the ex post consequences of beliefs about the generosity of bailout policies. Ex ante, a more generous bailout policy increases moral hazard in all segments of the financial system and induces an overall expansion of credit.¹ But ex post the maintenance of a generous bailout policy becomes necessary just to avoid a crisis even if government no longer desires to maintain high bailout levels.

The paper's main findings follow. An unexpected ex post increase in bailout uncertainty raises interest rates and the volume of defaults in both the real and the financial sectors. In extreme cases it may lead to a total drying up of credit markets. Low ex ante bailout uncertainty and expansionary monetary policy induce high levels of leverage and of real investments encouraging the formation of bubbles. This raises, in turn, moral hazard and the economy's vulnerability to changes in bailout uncertainty and other shocks. At the micro level an ex post increase in bailout uncertainty operates by lowering expected returns and by increasing the variability of those returns in diversified portfolios, which leads to higher systemic risks. The larger the difference in bailout uncertainty or in the aversion to this uncertainty (prior to a crisis triggering event in comparison to after its realization) the stronger the pre-crisis credit bubble buildup and the deeper the ensuing crisis.

It is well known since Knight (1921) that risk and uncertainty are distinct concepts. Modern formulations of this distinction in the context of pecuniary returns conceptualize risk as some measure of spread for a *known distribution* of the stochastic return. Uncertainty, on the other hand, is a situation in which individuals are *unsure about the probability distribution* of returns and entertain the possibility that several alternative probability distributions have positive measure. An increase in uncertainty is then viewed as an enlargement of the set of plausible probability distributions. Ellsberg (1961) and others have demonstrated by means of experiments that individuals are averse to ambiguity in the sense that, other things the same, they prefer a lottery with a known probability distribution to a lottery in which several distributions are believed to be possible.

Gilboa and Schmeidler (1989) conceptualize an investor's uncertainty by postulating that she possesses a subjective set of probability measures (multiple priors) over outcomes.² Their framework implies that for each possible action the investor assumes that the worst (by the expected utility criterion) possible distribution will realize and chooses her action so as to attain maximum expected utility over this set of worst outcomes. This paper utilizes the Gilboa and Schmeidler (1989) notion of uncertainty and the associated maxmin behavioral criterion to analyze the impact of an increase in uncertainty about governmental bailout

policy on financial markets, the aggregate level of credit and, through them, on the real economy.

Prior to Lehman's collapse the financial market beliefs about the probability of bailout have been relatively optimistic due to Bear-Stern's bailout in March 2008 as well as to the implicit US government guarantees of Fannie Mae and Freddie Mac's liabilities (Meltzer, 2009). In terms of Gilboa and Schmeidler's (1989) framework this means that the family of binomial bailout distributions with positive mass was concentrated in the relatively high range of bailout probabilities. After Lehman's collapse in mid September 2008 this range expanded downward toward bailout probabilities that previously were given zero mass.³

The behavior of credit default swap (CDS) spreads during the two weeks following Lehman's collapse provides a dramatic illustration of the sensitivity of bailout perceptions to public signals. In the aftermath of this collapse credit markets experienced substantial waves of deleveraging, totally drying up in some cases, and both the level and variability of CDS spreads went through the roof. To demonstrate it, Fig. 1 shows the behavior of Citibank's CDS spread index during the period just preceding Lehman's default and the final approval of the TARP bailout package at the beginning of October 2008.⁴ The figure demonstrates the high sensitivity of the CDS spread to ongoing public signals about the likelihood of bailouts. In particular, the spread strongly reacts to events like the rejection of the proposed TARP bailout package by Congress in September 2008 and its final approval in early October. This supports the view that financial markets participants are quite sensitive to news about the likelihood of bailouts.

Following Lehman's collapse and the ensuing public debate among policymakers about the wisdom of governmental bailouts two things happened. Public uncertainty (also known as ambiguity in the decision theory literature) about the likelihood of bailouts increased and so did the public's aversion to this uncertainty (or ambiguity aversion in the terminology of decision theory). Importantly, beliefs are not the only determinant of an individual's subjective set of priors, but also her preferences concerning ambiguity. That is, this set need not be the set of priors that is literally deemed possible by the individual. In particular, suppose two individuals share the same subjective information, i.e., they both believe the same set of bailout probabilities are possible. Then modern decision theory implies that the set of multiple priors of the *less* ambiguity averse individual is a *subset* of the set of multiple priors of the *more* ambiguity averse individual.⁵

Expansion of the set of multiple bailout priors in the aftermath of Lehman's collapse may, thus, reflect more ambiguous beliefs or a higher degree of ambiguity aversion or both. Obviously both factors reinforce each other. Our sense is that, in the aftermath of the financial trauma caused by Lehman's default the increase in ambiguity aversion might have been more important and more persistent. The reason for this is, that after a traumatic event individuals remain fearful (aversion to uncertainty) long after danger is over.⁶ Be that as it may, the upshot is that following this episode the set of multiple priors about the probability of bailouts expanded. As a consequence the lower bound on the set of binomial

³ Note that, although such expansion of beliefs involves assignment of positive mass to bailout probabilities that had zero mass prior to Lehman's collapse, the latter is not quite a "black swan" event (Taleb, 2007). Taleb's black Swan is an event whose perceived probability had zero mass (or this event has not even been considered in the state space due to unawareness) prior to its initial realization. By contrast the perceived probability of no bailout prior to Lehman's collapse was not zero. However, after this event some bailout distributions that previously were assigned zero mass entered the set of (plausible) bailout distributions with positive mass.

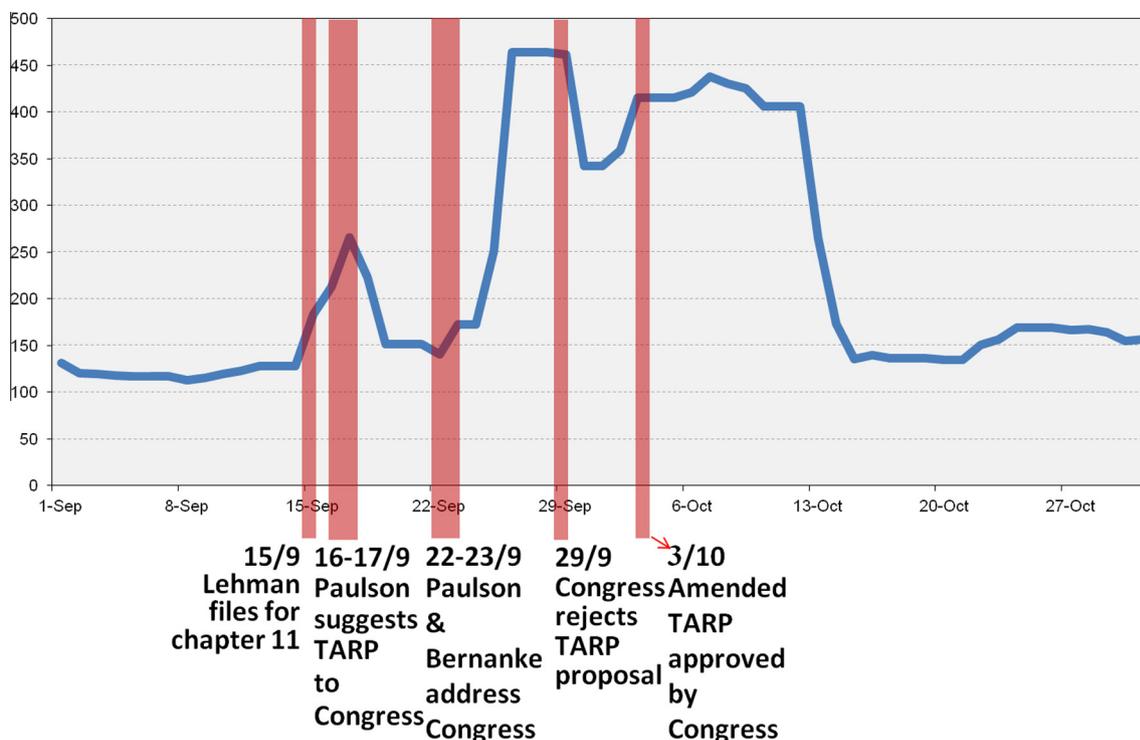
⁴ Source: Cochrane and Zingales (2009).

⁵ See, for example Ghirardato and Marinacci (2002, Theorem 17 (ii)) and Klibanoff et al. (2005, p. 1872).

⁶ A further elaboration of this reasoning is given two paragraphs below.

¹ Borio and Drehmann (2009) convincingly argue that such a credit buildup raises the likelihood of a financial crisis.

² The recent literature on robustness is also based upon the notion of multiple priors (Hansen and Sargent, 2008)



Source: Bloomberg - Ticker: CINC CDS USD SR 1Y Corp and Cochrane Zingales, Wall Street Journal, September 15

Fig. 1. Chronology of CDS rate around Lehman's collapse.

distributions with perceived positive mass went down. The paper shows that lenders' expected utility is lower the lower is the probability of bailout. In conjunction with the Gilboa and Schmeidler (1989) maxmin criterion, the expansion in the set of multiple priors implies that, once a traumatic event like Lehman's collapse materializes, lenders become more reluctant to lend either because the ambiguity of bailouts has increased, or because ambiguity aversion has increased, or both.

Since, by the maxmin behavioral criterion individuals ultimately act in each period on the basis of only one bailout distribution their micro optimization problems collapse to maximization of expected utility contingent upon a *unique* probability of bailout in each period. Consequently, results identical to ours also obtain in the presence of only bailout risk provided the unique bailout probability is taken to be the worst probability distribution (both prior to and following Lehman's collapse). This begs the question of why we choose to utilize the more cumbersome multiple priors framework rather than the simpler and more standard "risk only" framework.

The answer has two parts. First, following Keynes, we believe that the impacts on financial markets of major, largely unanticipated, events like the Lehman episode and its immediate aftermath are not adequately captured by the risk only framework.⁷ Since there is no single objective probability that government will repay, the debts of failing financial institutions it is natural for individuals to believe that several bailout probability distributions are possible and to adjust the set of such priors in line with actual developments

and news about government's intentions. The modern multiple priors framework provides an operational way to capture this uncertainty and to reduce its complexity to manageable proportions. Second, an increase in ambiguity aversion induces an enlargement of the set of priors. Such an enlargement and the associated lower minimal probability of bailout also capture increases in ambiguity aversion following salient traumatic events.

Two recent real life episodes are consistent with this view. First, according to the Non-Life Insurance Rating Organization of Japan (NLIRO) stricken Fukushima prefecture, bearing the brunt of the huge earthquake and tsunami that devastated the region at the beginning of 2011, saw rates of new earthquake insurance coverage increase almost threefold in the aftermath of the earthquake (Majirox news, August 24 2011). Provided this event did not appreciably change the beliefs of individuals about the objective probability distribution of such events, this evidence is consistent with the view that, following the trauma caused by the tsunami, the set of multiple priors concerning such events expanded mainly because of an increase in ambiguity aversion rather than in ambiguity.

Second, the risk only approach appears to be inconsistent with the evolution of events over the entire five years since Lehman's collapse. Although it is reasonable to expect that during the first several months following this event the (assumed single) bailout probability was adjusted downward it is harder to maintain such a position later on. The reason is that since Lehman's collapse US policymakers introduced various measures, such as TARP and numerous quantitative easing programs, that most likely, have led the public to believe that the probability of bailout moved back up. In spite of this, the share of total US banks reserves in total banking credit that increased by a factor of about 20 upon Lehman's collapse (from half a percent to 12 percent) remains even above this elevated level as of April 2014.⁸ This behavior is

⁷ Keynes (1937, pp. 114-115) writes "Now a practical theory of the future ... has certain marked characteristics. In particular, being based on so flimsy a foundation, it is subject to sudden and violent changes. The practice of calmness and immobility, of certainty and security, suddenly breaks down. New fears and hopes will, without warning, take charge of human conduct. The forces of disillusion may suddenly impose a new conventional basis of valuation. All these pretty, polite techniques, made for a well-paneled board room and a nicely regulated market, are liable to collapse. At all times vague panic fears and equally vague and unreasoned hopes are not really lulled, and lie but a little way below the surface."

⁸ The dramatic increase in US banks' demand for reserves during the first three and a half years following Lehman's collapse is documented in Cukierman (2013).

inconsistent with a story of a single bailout prior that first went down and subsequently back up. By contrast it is consistent with a *persistent* change in ambiguity aversion within a multiple priors framework.

The rest of the paper is organized as follows. Section 2 presents a general overview of the model. Sections 3–5 introduce the three main agents: borrowers, financial intermediaries and lenders. They characterize the optimal microeconomic behavior of each type of agent. In addition, Section 5 specifies the perceived government bailout policy. General equilibrium of the financial system and the determination of market rates are discussed in Section 6. The impact of an ex post increase in bailout uncertainty is analyzed in Section 7. Section 8 analyzes the impact of an ex ante change in perceptions about the likelihood of bailout on financial markets and discusses the implications of low bailout uncertainty for moral hazard. Section 9 reflects on some policymaking aspects of governmental commitment to a bailout policy. Section 10 discusses related recent literature and, when relevant, compares it to the contribution of this paper. This is followed by concluding remarks in Section 11. Most proofs are presented in the Appendix.

2. Overview of the model

The financial system is composed of large numbers of each of the following: Ultimate borrowers (investors), fully diversified ultimate lenders (like pension and mutual funds) and financial intermediaries that borrow from the lenders and lend to investors. Leverage levels assumed by borrowers and extended to them by financial intermediaries depend on the cost of credit and on (rational) expectations about the future cost of credit. Since returns to investors are stochastic some of them default and do not repay their debts to financial intermediaries. As a consequence some of the intermediaries are unable to repay their debts to lenders. Government bailout policy consist in (stochastically) repaying the debt of failing intermediaries to lenders. Beliefs about the likelihood of such bailouts affect the amount of credit offered ex ante to financial intermediaries by lenders, and through them on the amount of credit offered by the latter to borrowers and on the general equilibrium level of interest rates. Thus, in spite of the fact that potential bailouts only target loans from lenders to financial intermediaries, government's stochastic bailout policy affects leverage and interest rate throughout the entire financial system.

Important features of the model include: (i) An individual trade-off between return seeking through higher levels of leverage and higher probability of total loss at the *individual level*. (ii) Ex ante and ex post relations between the worst probability of bailout and leverage at the *aggregate level*. (iii) *Duration mismatches*: Borrowers need financing for two periods but get only one period loans from financial intermediaries in each period. (iv) The model's focus is on the segment of the *shadow banking system* (like SIV and hedge funds) in which funds are secured only for short periods. Accordingly, financial intermediaries are assumed to borrow for only one period.

We turn next to specifics. There is a large number of each of the following risk averse (identical within each group) 3 types of agents: Borrowers (B), Financial intermediaries (F) and Lenders (L) each possessing one unit of equity capital.⁹ The initial masses of each type of agent are M_B, M_L and M_F for borrowers, financial intermediaries and lenders, respectively.¹⁰

There are 3 time periods labeled 0, 1 and 2. Only borrowers-investors have access to real investment. Their decisions are made in period 0 and (as in Diamond and Dybvig, 1983) are long term in the sense, that once chosen, the project's size cannot be adjusted. The selected project size is $(1 + L_B)$, where 1 is the borrower's initial equity capital and L_B is the leverage she selects to take. Only short term loans are available to borrowers with interest rates r_{B1} and r_{B2} for loans assumed in the first and in the second period, respectively. Interest rates on loans and project's yields are all specified in terms of net returns.

Each borrower can get loans only from financial intermediaries. The amount of leverage, L_B , demanded by a borrower in period 0 is determined as a function of r_{B1} and of expected r_{B2} , by means of individual optimization. Each financial intermediary can obtain short-term funds, L_F , from lenders. The intermediaries generally splits her total funds $(1 + L_F)$ between a fraction z_F allocated to a partially diversified portfolio of loans to borrowers and a fraction $(1 - z_F)$ allocated to a risk free asset that pays a fixed interest rate r_f .¹¹ The return on the risk free asset, r_f , is determined by the monetary authority.

Financial intermediaries pay to lenders short term interest rates r_{L1} and r_{L2} in periods 1 and 2 (for loans taken in periods 0 and 1) respectively. A typical lender splits her initial wealth of 1 between a fraction z_L of funds allocated to loans to financial intermediaries and a remaining fraction, $(1 - z_L)$, that is invested in the risk free asset. In contrast to a typical financial intermediary, whose portfolio of loans to borrowers is only partially diversified, a typical lender holds his selected portion of loans to financial intermediaries in a fully diversified portfolio of loans.

The supply of loans to borrowers by an individual financial intermediary and his demand for loans from lenders, L_F , are determined through the intermediary's individual optimization as a function of the interest rates r_{B1}, r_{B2}, r_{L1} and r_{L2} . Those interest rates are determined through general equilibrium competitive clearing in periods 0 and 1 respectively in two markets within each period: the market for loans from intermediaries to borrowers and the market for loans from lenders to financial intermediaries.¹²

As elaborated in the next section, returns on real projects are stochastic and therefore risky. They realize in period 2. A real-project yield, \tilde{Y}_p , depends on two independent random variables: an aggregate economy-wide yield (shock), \tilde{Y}_A , and a specific yield (idiosyncratic shock), \tilde{Y}_i . The realization of the aggregate shock is not revealed prior to period 2, the value of this future realization becomes publicly known for some borrowers already in period 1. Depending on the information available in period 1 borrowers can be classified to one of the following three groups: lucky borrowers for whom it becomes known they will get a high \tilde{Y}_i , unlucky borrowers for whom it becomes known they will get a low \tilde{Y}_i , and regular borrowers for whom no advance return information is available in period 1. The availability of such information is important because it affects the borrower's ability to get refinancing in period 1. Since project yield is random and borrowers have some leverage obligations they generally may default in either of periods 1 or 2. A borrower defaults in period 1 if she does not succeed in securing credit to carry over her project on to period 2. She defaults in period 2 if the total final project return does not suffice to service the debt incurred in the previous period.

A financial intermediary can also default in period 1 or 2 if the principal and the interest rate paid to him by borrowers cannot

⁹ We use the following notational conventions: the subscript $j = \{B, F, L\}$ to a variable x_j indicates the agent type, and subscript $t = \{0, 1, 2\}$ indicates time. When the time index is omitted the variable refers to any of the time periods between 0 and 2. Random variables are identified by a tilde on top of the variable (e.g. \tilde{X}).

¹⁰ The financial markets model in the paper can be thought of as a microfounded version of general equilibrium approaches to monetary theory and policy (Brunner and Meltzer, 1997; Tobin, 1969).

¹¹ An intermediary's portfolio is partially diversified in the sense that only part of the idiosyncratic risk is eliminated. By contrast in a fully diversified portfolio all idiosyncratic risk is eliminated and only the systematic risk remains.

¹² A loan carrying interest rate r_i ($t = 1, 2$) is contracted in period $t - 1$ and settled in period t .

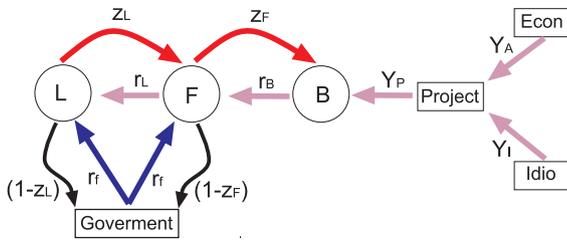


Fig. 2. The financial flows.

cover his obligations to lenders. When a financial intermediary defaults lenders lose their entire investment in this intermediary including the principal and the interest rate. Government can possibly and selectively pay the debt of defaulting financial intermediaries to lenders. But governmental bailout policy is uncertain in the Knightian sense. More precisely, individuals entertain multiple priors about the probability of bailout, or in the language of modern decision theory – government’s bailout policy is ambiguous.

Fig. 2 presents a bird’s eye view of the model’s financial system. In the figure Z_F and Z_L represent the fractions of funds Fs and Ls allocate to risky loans, and r_B and r_L are the rates paid by Bs and received by Ls respectively. \tilde{Y}_A and \tilde{Y}_I are aggregate and individual components of the total net return to a typical borrower.

3. The borrower–investor

This section presents borrower’s (B’s) problem. First it specifies B’s real investments opportunities and her financial requirements in each period. It then derives conditions for her solvency and utilizes them to characterize the optimal project’s size and the optimal leverage conditional upon the project’s characteristics (its outcomes and their probabilities) and the cost of capital she faces in periods 0 and period 1.

3.1. Real investment projects

All real investment made in period 0 are long term in the sense, that once chosen, the project’s size cannot be adjusted, until returns are realized in period 2. The typical investment project yields a stochastic (net) return, \tilde{Y}_P , which may be either positive or negative.¹³ All real projects have the same distribution of returns, and the yields of any two different projects are correlated due to presence of the aggregate common component in \tilde{Y}_P .

A project’s net yield is the sum of an aggregate shock \tilde{Y}_A and of an individual idiosyncratic shock \tilde{Y}_I . In particular

$$\tilde{Y}_P = \tilde{Y}_A + \tilde{Y}_I. \tag{1}$$

We assume, for tractability, that both the aggregate and the idiosyncratic shocks, are binomially and identically distributed. That is

$$\tilde{Y} = \tilde{Y}_A = \tilde{Y}_I = \begin{cases} y, & \Pr(y) = q & y > 0 \\ -y, & \Pr(-y) = 1 - q \end{cases}. \tag{2}$$

The random variables \tilde{Y}_A and \tilde{Y}_I are statistically independent and the idiosyncratic shock, \tilde{Y}_I , is independent across projects.¹⁴ Together Eqs. (1) and (2) imply that the distribution of \tilde{Y}_P is

$$\tilde{Y}_P = \begin{cases} 2y, & \Pr(2y) = q^2 \\ 0, & \Pr(0) = 2q(1 - q) \\ -2y, & \Pr(-2y) = (1 - q)^2 \end{cases}.$$

¹³ Returns, whether positive or negative, are cash flows.
¹⁴ The cases $\tilde{Y}_A = y$ and $\tilde{Y}_A = -y$ are referred to as expansion and contraction respectively.

Notice that the risk of a project is a function of y . Given two projects with an identical q , a higher y implies a riskier project. By equations (1) and (2) the expected return of each of the component shocks $\tilde{Y}_i, i = \{A, I\}$ is

$$E[\tilde{Y}_i] \equiv Y_i^E = y(2q - 1), \quad i = A, I.$$

Since the project net return is the sum of \tilde{Y}_A and \tilde{Y}_I , which are equal in distribution, its expected return is

$$E[\tilde{Y}_P] \equiv Y_P^E = 2y(2q - 1).$$

Projects must have a positive expected return to be considered; i.e. $Y_P^E > 0$, which implies that $q > \frac{1}{2}$.

Assumption 1. As of period 0 the expected return on a project is higher than the expected cost of leverage needed to carry the project to completion in period 2. That is, the distribution of the return, \tilde{Y}_P , on a typical project satisfies

$$1 \leq (1 + r_{B1})(1 + r_{B2}^E) < (1 + Y_P^E),$$

where r_{B1} is the interest rate paid by the borrower in period 1 and r_{B2}^E is the interest rate she expects to pay in period 2 for refinancing in period 1, given the information set of period 0. Since the minimal project size is 1 and the lowest return on a project is $-2y$, we impose the constraint

$$0 \leq y \leq \frac{1}{2}.$$

This constraint enforces limited liability by ruling out negative realizations of wealth when there is no leverage.

3.2. Borrower’s financial requirements

Projects are financed by a combination of equity and of leverage supplied by financial intermediaries to borrowers. In period 0, each borrower–entrepreneur owns one unit of equity capital. The initial financing structure (equity-1 versus leverage – L_B) is chosen by each B in period 0 along with the project’s size, denoted by x . Since B’s initial equity capital is 1, $x = 1 + L_B$. In each period loans by Fs to Bs are one period loans. Consequently, a B’s project has to be financed by two consecutive one period loans.

In the presence of positive leverage and since projects’ yields are obtained only in period 2, a B must seek refinancing in period 1. Therefore, she depends on the availability and the cost of credit in period 1. If excluded from the credit market in that period she defaults and loses the entire investment project including her equity. A borrower’s financial requirements in period 1 are equal to the amount needed to repay the principal, L_B , and period’s 1 interest charges, $r_{B1}L_B$. Hence, B’s total financial requirements (FR) in period 1 are

$$FR_{B1} = \underbrace{(1 + r_{B1})L_B}_{\text{Debt service}}.$$

When she gets credit in period 1, B’s ultimate debt service in period 2 is

$$FR_{B2} = (1 + r_{B2})FR_{B1} = (1 + r_{B1})(1 + r_{B2})L_B.$$

The borrower’s cost of capital for the entire project’s life (from period 0 till period 2) is therefore

$$r_B \equiv (1 + r_{B1})(1 + r_{B2}) - 1.$$

It is assumed that when a borrower cannot obtain refinancing in period 1 or cannot repay the debt in period 2, she defaults. In this case, the project is lost and neither the borrower nor the financial

intermediary receives any payoff. Thus, due to limited liability, the amount needed to cover losses (if any) is 0. The following subsection turns to explore the borrower's solvency condition.

3.3. Borrower's solvency conditions

3.3.1. Period 0

A borrower is able to get a loan in period 0 only if the total expected payoff from her project is higher than the total debt service liability expected for period 2, that is

$$L_B(1 + r_B^E) \leq (1 + L_B)(1 + \bar{Y}_P), \quad (3)$$

where $r_B^E \equiv (1 + r_{B1})(1 + r_{B2}^E) - 1$ is the expected (as of period 0) cumulated interest rate factor over the lifetime of the project. **Assumption 1** implies that this condition is satisfied for all non-negative leverage levels.

3.3.2. Period 1

Although all borrowers are identical ex ante (in period 0), they split into three groups in period 1. Those groups differ in terms of the information that becomes available to markets in that period about the realizations of their idiosyncratic shocks in period 2. In particular, it becomes known in period 1 that a fraction, $\theta_{LB} < q$, of borrowers will have $\tilde{Y}_I = y$, a fraction $\theta_{UB} < 1 - q$ will get $\tilde{Y}_I = -y$, and no new information is revealed in period 1 about the remaining fraction θ_{RB} of borrowers. We refer to those three types of borrowers as Lucky borrowers (LB), Unlucky borrowers (UB) and Regular Borrowers (RB) respectively.

A borrower who decides to leverage her project in period 0 is solvent in period 1 if and only if she is able to obtain the refinancing required to maintain her project alive till period 2. Financial intermediaries will offer the required credit in period 1 if and only if the expected cash flow of the project in period 2 suffices to cover period's 1 debt service. Obviously this expected cash flow differs across borrowers' types, implying that borrower of type $j = \{LB, UB, RB\}$ obtains refinancing in period 1 if and only if

$$L_B(1 + r_{B1})(1 + r_{B2}) \leq (1 + L_B) \left(1 + E[\tilde{Y}_P | I_1, j] \right), \quad (4)$$

where I_1 is the information set of period 1. Given period's 1 information,

$$E[\tilde{Y}_P | I_1, j] = \begin{cases} 2yq, & j = LB \\ 2y(q + q_{RB1} - 1), & j = RB \\ -2y(1 - q), & j = UB \end{cases} \quad (5)$$

where

$$q_{RB1} \equiv \frac{q - \theta_{LB}}{\theta_{RB}} \quad (6)$$

is the probability that a regular borrower will get a good draw on the idiosyncratic shock, \tilde{Y}_I , given the information available in period 1.¹⁵

Assumption 2. The expected net return of a RB on a real project conditional on the information in period 1 satisfies

$$E[\tilde{Y}_P | I_1, RB] > (1 + r_{B1})(1 + r_{B2}) - 1 \equiv r_B.$$

This assumption is basically an extension of **Assumption 1** from period 0 to period 1. Together, those two assumptions requires that, given r_B , the expected net return perceived by the market for a regular borrower is larger than the expected cost of leverage given

the information of both periods 0 and 1. The following Lemma identifies solvency conditions in period 1 for the three types of borrowers.

Lemma 1. Given $r_{B2} = r_{B2}^E$

- (i) Regular and Lucky borrowers are solvent in period 1 at any level of leverage.
- (ii) Unlucky borrowers are solvent in period 1 if and only if $L_B \leq \frac{1-2y(1-q)}{2y(1-q)+r_B^E} \equiv L_B^C$.

Note that, since $\frac{1}{2} < q \leq 1$, the critical level of leverage, L_B^C , is positive. The lower this critical level, the wider the range of period's 0 debt for which there is a non-zero probability that the unlucky borrower defaults in period 1. When the expected cost of capital, r_B^E , increases the critical level, L_B^C , decreases, implying that, the higher the cost of capital, the wider is the range of leverages at which an unlucky borrower might default in period 1. Increasing risk (measured in terms of returns' variance) has a similar effect since it decreases L_B^C .¹⁶ On the other hand, when the probability of good returns increases (i.e., q increases), the critical leverage, L_B^C , increases widening the range of leverages for which the probability of default of an unlucky borrower in period 1 is zero.

3.3.3. Period 2

A borrower is solvent in period 2 if the payoff from her project suffices to cover her debt obligation, that is

$$L_B(1 + r_{B1})(1 + r_{B2}) \leq (1 + L_B)(1 + \tilde{Y}_P). \quad (7)$$

Straightforward algebra shows that this is equivalent to the requirement that ultimate wealth, $W_B(\cdot)$, is non negative

$$W_B(L_B, \tilde{Y}_P) = 1 + \tilde{Y}_P + (\tilde{Y}_P - r_B)L_B \geq 0. \quad (8)$$

When the final project's payoff does not suffice to cover the principal and interest rate payments the borrower defaults and loses the entire project including her initial equity. Due to limited liability the net return on the project in this case is $\tilde{Y}_P = -1$ and the financial intermediary who own the debt receives nothing.

Lemma 1 provided solvency conditions in period 1 for the three types of borrowers. Given that he survives to period 2 a borrower is exposed to default risk in that period as well. The following lemma identifies a regular borrower's solvency conditions in period 2 for various realizations of total returns.

Lemma 2. If a regular borrower's ultimate return is:

- (i) $\tilde{Y}_P = -2y$ she is solvent in period 2 if and only if $L_B \leq \frac{1-2y}{r_B+2y} \equiv L_B^L$,
- (ii) $\tilde{Y}_P = 0$ she is solvent in period 2 if and only if $L_B \leq \frac{1}{r_B} \equiv L_B^H$,
- (iii) $\tilde{Y}_P = 2y$ she is solvent in period 2 for any level of leverage.

The next lemma identifies solvency conditions for lucky and unlucky borrowers.

Lemma 3. Given $r_{B2} = r_{B2}^E$,

- (i) If an unlucky borrower has chosen L_B^C in period 0, she is solvent in period 1.

¹⁵ The reason this probability differs between periods 0 and 1 is that the realizations of \tilde{Y}_I become known with certainty for a fraction, $(\theta_{LB} + \theta_{UB}) < 1$, of borrowers in period 1.

¹⁶ It is easily checked that increasing y , while keeping the probabilities of good and bad outcomes (q and $(1 - q)$) unchanged, increases the project's variance without changing its expected return.

- (ii) An unlucky borrower that has chosen L_B^C is also solvent in period 2 if and only if there is an aggregate expansion.
- (iii) A lucky borrower is always solvent in period 2.

Next, we analyze the probabilities of default in periods 1 and 2 as functions of the leverage chosen in period 0. Since payoffs are discrete those relations take the form of step functions.

Proposition 1. *Provided $r_{B2} = r_{B2}^E$, the ex-ante probabilities of default in period 1 and in period 2 (as viewed from the vantage point of period 0) are step functions of the leverage chosen in period 0. The precise probabilities of defaults are:*

L_B	$\Pr(D_1)$	$\Pr(D_2)$	$\Pr(D) = \Pr(D_1) + [1 - \Pr(D_1)]\Pr(D_2)$
$L_B \leq L_B^L$	0	0	0
$L_B^L < L_B \leq L_B^C$	0	$(1 - q)^2$	$(1 - q)^2$
$L_B^C < L_B \leq L_B^H$	θ_{UB}	$(1 - q)^2$	$\theta_{UB} + \theta_{RB}(1 - q)^2$
$L_B^H < L_B$	θ_{UB}	$1 - q^2$	$\theta_{UB} + (1 - \theta_{UB})(1 - q^2) + (2\theta_{RB}q + \theta_L)(1 - q)$

where $\Pr(D_1)$ and $\Pr(D_2)$ stand for default probabilities in period 1 and 2 respectively.

3.4. Borrower's optimization

Not surprisingly the individual borrower faces a tradeoff between expected payoff and default probability. In the large, by raising leverage, she raises the expected value of terminal equity but also the chances of default. By Proposition 1, the exante probability of default is a step function of leverage. This implies that the optimal level of leverage (and by implication also the optimal project's size) must coincide with one of the four leverage levels at the jump points of the probability of default function. The reason is that, once leverage is extended beyond a given jump point the probability of default remains constant as long as leverage is not pushed beyond the next jump point. Within such an interval, raising leverage raises the expected payoff without raising the probability of default.

Once leverage is raised beyond a given jump point, it is individually optimal to push it (at least) all the way till just a tiny bit before the probability function's next jump point. It follows that, from the vantage point of period 0, the optimal level of leverage is either zero or one of the following three leverage levels:

$$\begin{aligned}
 L_B^L &= \frac{1 - 2y}{r_B^E + 2y}; \\
 L_B^C &= \frac{1 - 2y(1 - q)}{2y(1 - q) + r_B^E}; \\
 L_B^H &= \frac{1}{r_B^E}.
 \end{aligned} \tag{9}$$

The borrower's utility function is piecewise linear with a penalty in the event of default. In particular, utility is linear in wealth as long as the borrower is solvent. When insolvent, the borrower is subject to a penalty that increases with the magnitude of leverage she defaults on. Formally,

$$u(W_B, L_B) = \begin{cases} W_B \geq 0, & \text{Solvency} \\ -P_B L_B, & \text{Insolvency} \end{cases} \tag{10}$$

where W_B is her period's 2 terminal wealth after servicing all debts, and P_B is a fixed default penalty per unpaid leverage dollar in states of insolvency. Hence, the borrower's expected utility is

$$\begin{aligned}
 V(L_B) &\equiv E[u(W_B(\cdot), L_B)] \\
 &= (1 - \Pr(D|L_B))E[W_B(\cdot)|W_B(\cdot) \geq 0] - \Pr(D|L_B)P_B L_B.
 \end{aligned} \tag{11}$$

Using Proposition 1 and the definition of $W_B(\cdot)$ in Eqs. (8) and (9) establishes that B 's expected utilities at each of the five candidates for optimal leverage (four discussed above plus any level of leverage $L_B^M > L_B^H$) are given by

$$\begin{aligned}
 V(L_B = 0) &= q^2(1 + 2y) + 2q(1 - q) + (1 - q)^2(1 - 2y); \\
 V(L_B^L) &= q^2(1 + 2y + (2y - r_B^E)L_B^L) + 2q(1 - q)(1 - r_B^E L_B^L); \\
 V(L_B^C) &= q^2(1 + 2y + (2y - r_B^E)L_B^C) + 2q(1 - q)(1 - r_B^E L_B^C) - (1 - q)^2 P_B L_B^C; \\
 V(L_B^H) &= (\theta_{LB}q + \theta_{RB}q^2)(1 + 2y + (2y - r_B^E)L_B^H) - \Pr[D|L_B^H]P_B L_B^H; \\
 V(L_B^M) &= (\theta_{LB}q + \theta_{RB}q^2)(1 + 2y + (2y - r_B^E)L_B^M) - \Pr[D|L_B^M]P_B L_B^M,
 \end{aligned} \tag{12}$$

where

$$\begin{aligned}
 \Pr[D|L_B^H] &\equiv \theta_{UB} + \theta_{RB}(1 - q^2), \\
 \Pr[D|L_B^M] &\equiv \Pr[D|L_B^H] + (2\theta_{RB}q + \theta_{LB})(1 - q).
 \end{aligned}$$

Let L_B^* be the optimal level of leverage. The following proposition presents (overly restrictive) sufficient condition for $L_B^* = L_B^H$.

Proposition 2. *Provided*

$$P_B > \frac{(\theta_{LB}q + \theta_{RB}q^2)(2y - r_B^E)}{(2\theta_{RB}q + \theta_{LB})(1 - q)},$$

there exists a dense set of values for the vector of parameters $(q, \theta_{LB}, \theta_{UB})$, such that $1 - q$, $q - \theta_{LB}$ and θ_{UB} are all strictly positive but small, at which the borrower's optimal level of leverage is L_B^H .

The broad intuition underlying this proposition can be appreciated by starting with the particular case in which the unit penalty, P_B , for default is zero. In this case, when the chances of good draws at the individual level are high (q and θ_{LB} are large) and the likelihood that the borrower will be unlucky in period 1 is low (θ_{UB} is small), expected utility is monotonically increasing in leverage. As a matter of fact, given the full linearity of the utility function in the absence of a penalty, the borrower's optimal level of leverage is infinite in this case. However, in the presence of a sufficiently large default penalty extending leverage beyond L_B^H is not individually optimal because of the increase in the risk that the penalty will be triggered once leverage crosses the L_B^H threshold.

In a broad sense, the conditions in the Proposition 2 are analogous to the borrower's second order condition when the penalties from default rise continuously with leverage. In the continuous case, the second order condition assures that, as leverage goes up, the favorable marginal impact of higher leverage on return in good states diminishes in comparison to the unfavorable gradual increase in the default penalty. Similarly, the conditions in Proposition 2 assure that, as leverage rises, the marginal detrimental impact of the default penalty becomes more important relatively to the marginal favorable effect on likely profits.

4. The financial intermediary

For reasons that will become apparent later it is convenient to open this section with a forward look at the relation between various equilibrium rates of interest. The following proposition establishes general equilibrium relations between the equilibrium interest rates, r_B , r_F and r_L .

Table 1
Financial intermediary's payoff.

State	Gross payoff (\tilde{R}_F)	Period 1 probability	Period 2 probability
Both Bs are solvent	$1 + r_B$	$(1 - \theta_{UB})^2 \equiv \gamma_{21}$	$q(1 - q_{RB1}^2) + q_{RB1}^2 \equiv \gamma_{22}$
Exactly one B is solvent	$\frac{1}{2}(1 + r_B)$	$2(1 - \theta_{UB})\theta_{UB} \equiv \gamma_{11}$	$2(1 - q)q_{RB1}(1 - q_{RB1}) \equiv \gamma_{12}$
Both Bs are insolvent	0	$\theta_{UB}^2 \equiv \gamma_{01}$	$(1 - q)(1 - q_{RB1})^2 \equiv \gamma_{02}$

Proposition 3. *In a general equilibrium with risk aversion on the part of borrowers, financial intermediaries and lenders, and positive levels of leverage in both the real and the financial sectors, the following inequalities hold*

$$r_f \leq r_L < r_B.$$

4.1. The typical financial intermediary

There is a large number of financial intermediaries (Fs) each of which possesses one unit of core funds consisting of a combination of equity and of long term (two periods) debt. A typical F can also raise *short term* (one period) funds from lenders.¹⁷ Since the focus of this analysis is on changes in the availability of short term credit in the face of new information, the amount of short term leverage assumed by a typical F is determined endogenously while the sum of equity and of long term debt is taken to be exogenous.

Total financial resources of a typical F consist of the core funds and of short term leverage, L_F . The financial intermediary diversifies his total resources between the risk free asset whose rate, r_f , is a policy instrument, and a risky, not fully diversified, portfolio of loans to borrowers.¹⁸ For reasons of tractability, each F lends to only two borrowers. The fraction of resources invested in the risky loan portfolio to Bs is denoted z_F . Let W_F be the intermediary's terminal wealth after debt service in each period. F is solvent or insolvent in each period depending on whether terminal wealth is non negative or strictly negative. When solvent, F's utility is described by a CRRA utility function with a coefficient, $\delta > 0$, of relative risk aversion that is close to, but not quite equal to, 0. This specification implies that F is almost, but not strictly, risk neutral. When insolvent, the typical intermediary experiences a (per unit of leverage) penalty, P_F . Formally,¹⁹

$$u(W_F) = \begin{cases} \frac{W_F^{1-\delta}}{1-\delta}, & \text{when } W_F \geq 0 \\ -P_F L_F, & \text{when } W_F < 0. \end{cases} \quad (13)$$

4.2. Distribution of returns, solvency and optimization

Total return to a financial intermediary depends on the performance of the two borrowers to whom she lends. Since borrowers are identical ex ante, the optimal risky portfolio of an F consists of a fifty-fifty split between loans to her two debtors. If both borrowers are solvent, both of them pay the full face value of the gross debt service. In this case, the payoff (from one unit) to F is $1 + r_B$. If both of them default, F gets a payoff of 0 on her risky portfolio. If one borrower is solvent and the other defaults, F gets the payoff $\frac{1}{2}(1 + r_B)$. Obviously, the probabilities associated with each of those three payoffs depend on the probabilities of defaults of borrowers and differ between periods 0 and 1. From the vantage point of period zero, the probability that a single B defaults in period 1, $\Pr(D_1)$,

is given in Proposition 1. Since $L_B^* = L_B^H$, the probability that a B is insolvent in period 1 is θ_{UB} . Because the probability of being unlucky of any borrower is statistically independent of this probability for any other borrower, the distribution of gross payoffs, \tilde{R}_F faced by a typical intermediary in period 0 is given by Table 1.²⁰

Recall that q is the probability of a positive (aggregate or idiosyncratic) shock and q_{RB1} , defined in Eq. (6), is the probability of a positive idiosyncratic shock to a regular borrower conditional on the information revealed in period 1. The last column shows the probability distribution of period's 2 payoffs from loans to regular borrowers as perceived by F's in period 1.

The wealth of a typical F at the end of each period is

$$\tilde{W}_F(\tilde{R}_F, L_F) = (1 + L_F)(z_F \tilde{R}_F + (1 - z_F)(1 + r_f)) - (1 + r_L)L_F, \quad (14)$$

where \tilde{R}_F is F's payoff with distribution given in Table 1 and r_L is the interest rate paid by a F on its short term obligations. A representative F chooses her leverage, L_F , and the fraction, z_F , of resources invested in the risky loan portfolio so as to maximize $E[u(\tilde{W}_F)]$ in each of periods 0 and 1. The following proposition presents a preliminary characterization of F's optimal policy.

Proposition 4. *Let $r_f < r_L$. Then at an optimum with positive leverage, F invests all her resources in risky loans to Bs.*

4.2.1. Financial intermediary's solvency condition

Proposition 4 and Eq. (14) imply that F is solvent if and only if

$$\tilde{W}_F(\tilde{R}_F, L_F) = (1 + L_F)\tilde{R}_F - (1 + r_L)L_F = \tilde{R}_F - L_F + (\tilde{R}_F - r_L)L_F \geq 0. \quad (15)$$

Since $r_B > r_L$, F is solvent for any level of leverage, L_F , when both of her borrowers are solvent, so that $\tilde{R}_F = 1 + r_B$. In the other two cases F is solvent only if L_F is sufficiently small. The precise solvency conditions are:

$$\begin{aligned} L_F &\leq \frac{1+r_B}{1+2r_L-r_B} \equiv L_F^C && \text{when } \tilde{R}_F = \frac{1}{2}(1 + r_B) \\ L_F &= 0 && \text{when } \tilde{R}_F = 0 \end{aligned} \quad (16)$$

Table 1 and Eq. (16) imply that F's probability of default is an increasing step function of F's leverage and that the precise functions for periods 1 and 2 are

$$\begin{aligned} \Pr[D_t] &= 0 && \text{when } L_F = 0 \\ \Pr[D_t] &= \gamma_{0t} && \text{when } 0 < L_F \leq L_F^C \\ \Pr[D_t] &= \gamma_{0t} + \gamma_{1t} && \text{when } L_F > L_F^C. \end{aligned} \quad (17)$$

Proposition 5. *Provided:*

- (i) δ is sufficiently small,
- (ii) $\gamma_{2t}(r_{Bt} - r_{Lt}) - (1 - \gamma_{2t})P_F > 0$,

¹⁷ For instance through various deposits including certificates of deposit (CDs).

¹⁸ By contrast, as shown in the next section, the risky portfolio of suppliers of funds to Fs (lenders) is fully diversified.

¹⁹ In spite of the fact that utility functions differ across the three types of agents, the symbol $u(\cdot)$ stands for all of them in order to economize on notation. In each case the identity of the agent should be evident from the context.

²⁰ The notation γ_{nt} stands for the probability of F's getting a given payoff in time t conditional on the number, n , of solvent borrowers.

- (iii) $(\gamma_{2t}(r_{Bt} - r_{Lt}) - (1 - \gamma_{2t})P_F)(L_{Ft}^* - L_F^C) > \gamma_{1t}P_FL_F$,
- (iv) $(\gamma_{1t}/\gamma_{2t})$ is sufficiently small,

F's optimal leverage is

$$L_{Ft}^* = \left(\frac{\gamma_{2t}}{1 - \gamma_{2t}} \right)^{\frac{1}{\delta}} (r_{Bt} - r_{Lt})^{\frac{1-\delta}{\delta}} - \frac{1 + r_{Bt}}{r_{Bt} - r_{Lt}}. \tag{18}$$

Here L_{Ft}^* , $t = \{0, 1\}$ is the financial intermediary's optimal short term leverage in periods 0 and 1.

The following proposition formulates the financial intermediary's solvency condition. If solvent a financial intermediary pays the full debt service to lenders. Otherwise she defaults and pays nothing.

Proposition 6. *Provided δ is sufficiently small the financial intermediary is solvent if and only if the two borrowers to whom she has lent are solvent.*

Proposition 6 implies that (since $L_{Ft}^* > L_F^C$) overly restrictive sufficient conditions for requirements (ii) and (iii) in Proposition 5 are that γ_{2t} is sufficiently large and P_F sufficiently small. The following proposition characterize the determinants of F's optimal leverage.

Proposition 7. *The optimal leverage of a typical financial intermediary is higher*

- (i) the lower is the intermediary's risk aversion, δ ,
- (ii) the lower is the intermediary's default penalty, P_F ,
- (iii) the lower the cost of borrowing, r_{Lt} ,
- (iv) the higher the probability, γ_{2t} , that the intermediary remains solvent,
- (v) the higher the interest rate, r_{Bt} , paid by borrowers.

5. The lender and bailout policy

Through pension or mutual funds a lender (L) splits her equity between a fully diversified portfolio of loans to financial intermediaries and the risk free asset.²¹ Since, ex ante, all Fs have identical distributions of returns the optimal shares of loans to different Fs are all equal. The fraction invested in the risky loan portfolio to Fs is denoted z_L . The typical lender possesses mean-variance (or Constant Absolute Risk Aversion – CARA) preferences

$$u(W_L) = -\frac{1}{\alpha} e^{-\alpha W_L}, \quad \alpha \geq 0, \tag{19}$$

where W_L is her terminal wealth in each period and α characterizes the degree of constant absolute risk aversion.²²

5.1. Perceived government's bailout policy

Government may repay the gross debt owed to lenders by defaulting Fs. In case of bailout a lender receives the full (per unit) debt service, $1 + r_L$. The likelihood that the debt service of a defaulting F is paid by government is independent across Fs debt. It is assumed that all agents face uncertainty about the probability that the government will bailout a given financial intermediary. That is, they are not sure about the precise probability of bailout. We model this Knightian uncertainty (ambiguity) by using Gilboa and Schmeidler's (1989) multiple priors approach which postulates that, in the face of ambiguity, an agent possesses a subjective set of prior probability measures over outcomes as opposed to a unique prior she possesses in the absence of ambiguity.

Formally, each lender possesses a convex set P of plausible (i.e. with positive mass) binomial probability distributions, $(p, 1 - p) \in P$ where p is a probability of bailout and its complement $(1 - p)$ is the probability of no bailout. In our framework, agents make decision in accordance with the Gilboa and Schmeidler (1989) maxmin expected utility with multiple priors. Their framework suggests that for each possible action the investor assumes that the worst (by the expected utility criterion) possible distribution will realize and chooses her action so as to attain maximum expected utility contingent upon this worst prior. Since, in our framework the set of priors consists only of binomial distributions, from lenders' perspective the worst prior is the one with lowest probability of bailout. That is, the worst prior satisfies $(\pi, 1 - \pi) \in \mathcal{P}$, where $\pi = \min\{p \mid (p, 1 - p) \in \mathcal{P}\}$.

Since a typical lender acts according to the maxmin behavioral criterion, the nature of her subjective set of priors and the way it is constructed play an important role in our model. Two main components affect the "size" of the set of possible priors \mathcal{P} : the degree of ambiguity, determined by the information the lender has, and the aversion to this ambiguity, derived from her personal preferences. In particular, when circumstances become more uncertain (ambiguous), the lender may possess a larger set of priors. This means that the set of priors contains now priors that were previously considered implausible, i.e., with zero mass. An increase in ambiguity aversion has the same effect. When the lender becomes more averse to ambiguity, again, the set of priors with positive mass expands to include priors that previously were considered implausible.

Expansion of the set of multiple bailout priors (mostly toward lower values of p) in the aftermath of Lehman's collapse may be taken as an example. Within the maxmin approach, such an expansion is consistent with increases in both the ambiguity of bailout policies as well as in the aversion to this ambiguity. Obviously both factors reinforce each other. Our sense is that, in the aftermath of the financial trauma caused by Lehman's default the increase in ambiguity aversion is likely to have been more persistent than the increase in ambiguity. The reason is that after a traumatic event, such as Lehman's collapse, individuals remain fearful (maintain higher aversion to uncertainty) long after the risks triggered by this collapse recede. Be that as it may, the upshot is that following this episode the set of multiple priors about the probability of bailouts expanded.

An important consequence of the downward expansion in the set of multiple bailout priors is that the lower bound on the set of binomial distributions with perceived positive mass, goes down implying (by the Gilboa and Schmeidler, 1989) maxmin criterion that, following a major traumatic event such as Lehman's collapse, lenders maximize their expected utility "against" a lower probability of bailout, π .

5.2. Lender's returns and optimization

5.2.1. Period 0

On one period loans taken in period 0 borrowers face only idiosyncratic risk because only individually unlucky borrowers default in period 1, implying that financial intermediaries who lend to them also face only idiosyncratic risk in that period. By contrast, since they fully diversify their loans across intermediaries, lenders face no risk at all in period 0. Consequently, and since lenders know from Table 1 that only a fraction, $(1 - \theta_{UB})^2$, of Fs will be solvent in period 1, equilibrium r_{L1} includes a compensation for the average fraction of unpaid debt but no compensation for variability of this fraction, since this variability equals zero due to full diversification. Hence,

$$1 + r_{L1} = \frac{1 + r_f}{1 - (1 - \pi_0)(1 - (1 - \theta_{UB})^2)} \tag{20}$$

²¹ The lender is representative in the sense that all lenders are identical.

²² See, for example, Sargent (1987, pages 154–155).

where $(1 - \pi_0)(1 - (1 - \theta_{UB})^2)$ is the probability that a lender loses the investment in a loan to a single intermediary and π_0 is the time's 0 perceived probability of bailout. It is obtained as the product of the probabilities of the two following independent events: "the intermediary defaults" and "government does not reimburse the delinquent debt to the lender". As a consequence, in period 0, lenders are indifferent between investing in the standard risk free asset at rate r_f and between investing in loans to Fs.

5.2.2. Period 1

By contrast, in period 1, lenders face risk in loans to Fs in spite of their fully diversified portfolios. The reason is that the returns to lenders from loans to different Fs are correlated due to the common shock, \tilde{Y}_A , in the payoff of real investments of borrowers. As explained in the previous section a financial intermediary either pays her debt in full to lenders or fully defaults. When F defaults on the debt service, government may or may not step in and pay the delinquent debt service to a lender. Consequently the lender faces a set \mathcal{P} of binomial distributions of returns from lending to an individual F – she either gets the full debt service, $1 + r_L$, (from F or from government) or 0. Although the bailout policy of government does not affect the binomial nature of the payoffs from a single F, it *does alter their subjective set of distributions* \mathcal{P} . Since the lender assesses her expected utility conditional upon the worst prior $(\pi, 1 - \pi) \in \mathcal{P}$ and since the risky portfolio of L's contains a large number of such binomially distributed loans, the uncertain portfolio of Ls is normally distributed with a mean and a variance that depend on both economic (q) and political (π) uncertainties. Details appear in the following proposition.

Proposition 8. For a given π_1 , period's 2 payoff, \tilde{R}_{L2} , to a lender on her fully diversified portfolio of loans is normally distributed with mean

$$E[\tilde{R}_{L2}] = (\pi_1 + \gamma_{12}(1 - \pi_1))(1 + r_{L2}) = (\pi_1 + (q(1 - q_{RB1}^2) + q_{RB1}^2)(1 - \pi_1))(1 + r_{L2}) \quad (21)$$

and variance

$$\text{Var}[\tilde{R}_{L2}] = (1 - \pi_1)^2(1 - q)(1 - q_{RB1})^2(q + 2qq_{RB1} + q_{RB1}^2)(1 + r_{L2})^2 \quad (22)$$

where we recall that

$$q_{RB1} \equiv \frac{q - \theta_{LB}}{\theta_{RB}} \quad (23)$$

A lender chooses the fraction, z_L , of resources invested in the uncertain loan portfolio to Fs so as to maximize²³

$$E[\tilde{W}_L(z_L)] = -\frac{1}{\alpha} E[e^{-\alpha \tilde{W}_L(z_L)}] \quad (24)$$

in each period, where

$$\tilde{W}_L(z_L) = z_L \tilde{r}_L + (1 - z_L)r_f \quad (25)$$

The next proposition identifies the optimal allocation invested in a portfolio of uncertain loans.

Proposition 9. At an individual optimum, a lender allocates the fraction

$$z_L^*(\pi_t, \tilde{R}_L, q, q_{RB1}) \cong \frac{E[\tilde{R}_L] - (1 + r_f)}{\alpha \text{Var}[\tilde{R}_L]} \quad (26)$$

²³ The right hand side of Eq. (24) is obtained by using the lender's utility function in Eq. (19).

of each single \$ to the diversified uncertain portfolio of loans to Fs, where π_t is the worst perceived probability of bailout with positive mass at time $t = \{0, 1\}$.^{24,25}

5.3. Partial equilibrium comparative statics

We now investigate the impact of a perceived change in bailout policy on the size of lenders' risky portfolios in partial equilibrium. In the absence of bailout uncertainty, government's bailout policy is characterized by a unique probability distribution. In this case the lender's perceived probability that government will pay the debt of delinquent F's to her is known with certainty since the bailout prior is unique. In this case, denoting by p the single probability of bailout, a more generous (towards L's) bailout policy is characterized by a higher p and a less generous bailout policy by a lower p . In the general case, where the lender faces ambiguity and therefore possesses a non-singleton set \mathcal{P} of priors, a more generous bailout policy is characterized by a shift of the entire set \mathcal{P} towards higher p 's and a less generous bailout policy by a shift of \mathcal{P} towards lower p 's. Consequently, a more generous bailout policy is characterized by a higher π and a less generous bailout policy by a lower π . Changes in bailout policy affects the worst perceived probability of bailout, π , and correspondingly the distribution of \tilde{R}_L . As a result, both the mean and the variance of lenders' risky portfolios change.

Proposition 10. Holding r_{L2} constant a perceived less generous bailout policy (lower π_t)

- (i) reduces the mean return on the portfolio of loans from lenders to financial intermediaries,
- (ii) raises the covariance between any two loans in the (fully diversified) portfolio, and therefore,
- (iii) raises the portfolio's variance.

All changes reinforce each other in inducing a "flight to safety" by lenders.

In the presence of uncertainty about the likelihood of bailout, and since they are averse to ambiguity in the Gilboa and Schmeidler (1989) sense, lenders behave as if the probability of bailout is the lowest within their subjective set \mathcal{P} of priors.^{26,27} Stated differently, they choose the fraction of their portfolio invested in risky and ambiguous (uncertain) loans to Fs so as to maximize expected utility under the assumption that bailout probability is π (the lowest within the set \mathcal{P}). We remind the reader that enlargement of the set \mathcal{P} reflects increases in both uncertainty about the correct bailout distribution as well as in the aversion to this uncertainty.

Propositions 10 implies that higher bailout uncertainty or aversion has two effects: Not surprisingly it lowers the expected return from the risky loan portfolio of lenders. More surprisingly, but not less importantly, it raises the correlation between loans in the portfolio which in turn implies higher variances in lenders portfolios. This result appears surprising at first glance, since intuition may lead one to conclude that an increase in bailout probability, by decreasing the likelihood of default, will increase the correlation

²⁴ This approximation is accurate for a small risk premium, $E[\tilde{R}_L] - (1 + r_f)$.

²⁵ An identical allocation, $z_L^*(\pi, \tilde{R}_L, q, q_{RB1})$, is obtained for constant relative risk aversion (CRRA) preferences (see, for example, Merton (1971, 1973)).

²⁶ For simplicity, we use the Gilboa and Schmeidler (1989) model to capture uncertainty. However other model of uncertainty can be incorporated into our model; Klibanoff et al. (2005) or Izhakian and Izhakian (2010, 2014), for example.

²⁷ Lowest in the sense that under this probability distribution expected utility attains its minimal value.

between loans' returns in the portfolio. But this intuition is mistaken. The reason is that the correlation originates uniquely from the aggregate shock whose impact operates only through the fraction of loans in the portfolio that are not bailed out. Since the impact of this fraction on the overall correlation diminishes as more intermediaries are bailed out the variance goes down. Consequently, in the limit, when bailouts are almost certain, this variance tends to zero.

The aggregate covariance between all pairs of loans in the fully diversified portfolio is one measure of systemic risk in financial markets. Hence, Part (ii) of Proposition 10 implies that an increase in bailout uncertainty raises systemic risk. Furthermore, recalling (from the introduction) that expansion of the set of multiple priors toward lower bailout probabilities is likely to reflect a persistent increase in ambiguity aversion following traumatic events, Part (ii) of Proposition 10 implies that systemic risks depend also on preferences.

Proposition 10 implies that, when due to an increase in bailout uncertainty and/or aversion to it π decreases, lenders reduce the share of funds supplied to financial intermediaries. This conclusion plays an important role in the following general equilibrium section.

Proposition 11. *Provided $r_L \leq \frac{1}{2}$, L's optimal allocation to risky and ambiguous loans, $z_L^*(\pi_t, \tilde{R}_L, q, q_{RB1})$ is increasing in r_L . It can be easily verified that the sufficient condition in the proposition is satisfied for practically all normal levels of interest rates.*

6. General equilibrium of the financial system

Given expectations about the future, general equilibrium of the financial system is characterized by two market clearing conditions. One for credit from lenders to financial intermediaries and the other for credit from financial intermediaries to borrowers. These two conditions simultaneously determine the borrowing rate r_B and the lending rate r_L in each period. In period 1, expectations about the future only involve realizations of period's 2 returns to borrowers. As a consequence, the formulation of this equilibrium is relatively simple. But in period 0 they also involve expectations about period's 1 market clearing values of r_B and r_L in period 1 (i.e., r_{B2}^E and r_{L2}^E). Those expectations are assumed to be model consistent in the sense that, in period 0, financial market participants use the information available in that period along with their knowledge of the fact that period's 1 rates will be determined by market clearing to derive r_{B2}^E and r_{L2}^E .

6.1. General equilibrium in period 0

Proposition 1 implies that a borrower is insolvent in period 1 only if she is unlucky, implying (from the discussion in Section 4) that a financial intermediary defaults in period 1 if and only if at least one of her borrowers is unlucky. Being unlucky is related to B's and Fs individual fortunes rather than to the aggregate shock. Although lenders are exposed to both aggregate and idiosyncratic shocks only the aggregate shock introduces risk into their portfolios since idiosyncratic shocks are fully diversified. Consequently, and since they lend to Fs for only one period and the aggregate shock realizes only in period 2, lenders do not face any risk or ambiguity in lending to Fs in period 0. In particular they know for sure (as implied by Table 1) that a fraction $(1 - (1 - \theta_{UB})^2)$ of intermediaries will default in period 1. Hence, they demand a compensation only for this known with certainty fraction of defaults. Consequently, in period 0, r_{L1} is determined exogenously by Eq. (20).

Actual period's 0 equilibrium conditions in the markets for loans from Ls to Fs and from Fs to Bs are given respectively by²⁸

$$M_F L_F^*(r_{B1}, r_{L1}) = M_L z_{L1} \quad (27)$$

and

$$L_B^*(r_{B1}, r_{B2}^E) = \frac{M_B}{(1 + r_{B1})(1 + r_{B2}^E) - 1} = M_F(1 + L_F^*(r_{B1}, r_{L1})), \quad (28)$$

where M_L and M_F stand for the masses of lenders and of financial intermediaries, respectively. These conditions determine the lenders' allocation z_{L1} to loans and the borrowing rate of return r_{B1} as functions of the loan rate paid by Fs to Ls (r_{L1}) and the borrowing rate of return, r_{B2}^E , expected to prevail in period 1.

Since $L_B^*(r_{B1}, r_{B2}^E)$ also depends on period's 0 expectation of the cost of funds to borrowers, r_{B2}^E , in the subsequent period a full characterization of period's 0 equilibrium requires additional conditions for the determination of r_{B2}^E . These required conditions are provided by the hypothesis that, in period 0, agents form their perceptions about r_{B2}^E and r_{L2}^E by utilizing period's 1 expected market clearing conditions given their period's 0 information. Expected period's 1 equilibrium conditions in the markets for loans from Ls to Fs and from Fs to Bs are given, respectively, by

$$(1 - \theta_{UB})^2 M_F L_F^*(r_{B2}^E, r_{L2}^E) = (1 + r_{f1} + z_{L1}(r_{L1} - r_{f1})) M_L z_L^*(\pi_0, r_{L2}^E, q, q_{RB1}) \quad (29)$$

and

$$\theta_{RB} \frac{M_B}{(1 + r_{B1})(1 + r_{B2}^E) - 1} = (1 - \theta_{UB}) M_F \left(\frac{1 + r_{B1} + (r_{B1} - r_{L1}) L_F^*(r_{B1}, r_{L1})}{+ L_F^*(r_{B2}^E, r_{L2}^E)} \right). \quad (30)$$

The market clearing condition expected for period 1 in Eq. (29) takes into consideration that only a fraction $(1 - \theta_{UB})^2$ of Fs will survive and that the resources of Ls will be increased by the factor $(1 + r_f + z_{L1}(r_{L1} - r_f))$ due to their investments in loans to Fs and to government. Similarly, the market clearing condition expected for period 1 in Eq. (30) takes into consideration that only a fraction $(1 - \theta_{UB})$ of borrowers and a fraction $(1 - \theta_{UB})^2$ of Fs will survive in period 1. The term in big parenthesis on the extreme right hand side of this equation reflects the total resources individuals in period 0 expect Fs to lend to Bs in period 1. Those resources are composed of the resources carried over from period 0 to period 1 including principal and interest as well as new, period's 1 leverage, $L_F^*(r_{B2}^E, r_{L2}^E)$. Finally the term θ_{RB} on the extreme left hand side of this equation is due to the fact that, in period 1, Fs lend only to regular borrowers whose fraction is known in advance to be θ_{RB} .²⁹

The two period's 0 market clearing conditions and the two clearing conditions expected for period 1 in Eqs. (29) and (30) jointly determine r_{B1} , r_{B2}^E , r_{L2}^E and z_{L1} . This system is recursive since

²⁸ Due to full diversification lenders are indifferent between lending to government at the low default free rate, r_f , or to Fs at the higher rate, r_{L1} , that includes a compensation for the known with certainty fraction of defaults. The first equilibrium condition is based on the assumptions that when indifferent lenders accommodate Fs first and that they collectively possess enough funds to more than accommodate all the demand for funds by Fs at the going equilibrium rates. As a consequence z_{L1} is determined by the demand for loan by Fs. The second assumption implies that $z_{L1} < 1$ and that the remaining fraction is invested at the rate r_f .

²⁹ The reason for this follows. By Lemma 3, lucky borrowers are not expected to default in either period 1 or 2 when $r_{B1} = r_{B1}^E$. Since the fact that they are lucky is public information in period 1 lending to them is as safe as lending to government. Hence, for $r_{B1} = r_{B1}^E$, they can borrow at the risk free rate, r_f implying that in period 1 Ls are indifferent between lending to government or to lucky borrowers. We assume for simplicity and without much loss of generality that under such circumstances Ls directly accommodate the lucky borrowers demand for credit by splitting the fraction $(1 - z_L^*(\pi_1, r_{L2}^E, q, q_{RB1}))$ of their safe investments between those borrowers and the government. This implies that Fs lend only to risky regular borrowers in period 1 – which is consistent with Proposition 4.

the last three equations simultaneously determine the first three variables leaving the first equation for the determination of z_{L1} .

6.2. General equilibrium in period 1

The actual period's 1 market clearing conditions in the markets for loans from Ls to Fs and from Fs to Bs are given respectively by

$$(1 - \theta_{UB})^2 M_F L_F^*(r_{B2}, r_{L2}) = (1 + r_f + z_{L1}(r_{L1} - r_f)) M_L Z_L^*(\pi_1, r_{L2}, q, q_{RB1}) \tag{31}$$

and

$$\theta_{RB} \frac{M_B}{(1 + r_{B1})(1 + r_{B2}^E) - 1} = (1 - \theta_{UB}) M_F \left(\frac{1 + r_{B1} + (r_{B1} - r_{L1}) L_F^*(r_{B1}, r_{L1})}{+ L_F^*(r_{B2}, r_{L2})} \right) \tag{32}$$

Those equilibrium conditions determine the *actual* interest rates, r_{B2} and r_{L2} in period 1 for predetermined, values of r_{B1} , r_{B2}^E , r_{L1} and of π_1 . Comparing $z_L^*(\pi_0, r_{L2}^E, q, q_{RB1})$ from Eq. (29) with $z_L^*(\pi_1, r_{L2}, q, q_{RB1})$ from Eq. (31) we note that the first two arguments of those functions differ. Not surprisingly the first, which refers to the expected equilibrium, features r_{L2}^E , while the second, that refers to the actual equilibrium, features r_{L2} . Importantly, the effective bailout probabilities, π_0 and π_1 , differ across the expected and the actual period's 1 equilibria. This (at this stage) notational difference is introduced in anticipation of the discussion in the next section that introduces an unanticipated increase in bailout uncertainty.

7. The impact of bailout uncertainty

This section considers the impact of an unanticipated increase in bailout uncertainty on financial markets in period 1. Recall first that π_0 is the lowest bailout probability in the multiple priors set as perceived in period 0 for both periods 0 and 1.³⁰ The fact that, as of period 0, financial market participants do not expect this probability to change in period 1 is reflected in the formulation of the expected period's 1 general equilibrium conditions for period 0 (Eqs. (27)–(30)).

Suppose now that, following a major indication of a shift in government's bailout policy—like not rescuing Lehman—bailout uncertainty and/or aversion to it increase. In particular, the lowest perceived bailout probability with positive mass decreases from π_0 to π_1 . Proposition 10 implies that, holding r_{L2} constant, this change reduces the supply of funds to Fs by Ls. Application of comparative statics methods to period's 1 equilibrium conditions shows that this change triggers a general equilibrium increases in both r_{L2} and r_{B2} above their, respectively, expected counterparts r_{L2}^E and r_{B2}^E . These increments raise the fraction of defaulting borrowers in period 2 and may, under some circumstances, lead to a total drying up of credit in period 1. The string of propositions in this section provides a precise formulation of these and related results.

Let $\frac{\partial L_F^*}{\partial r_B}$ and $\frac{\partial L_F^*}{\partial r_L}$ be respectively the responses of F 's optimal leverage to changes in r_{B2} and in r_{L2} , and let $\frac{\partial z_{L2}^*}{\partial r_L}$ and $\frac{\partial z_{L2}^*}{\partial \pi_1}$ be respectively the responses of L 's optimal share of investments in the risky portfolio to changes in r_{L2} and in π_1 .

Proposition 12. *Given Propositions 7, 10, and 11, an increase in uncertainty about governmental bailout policy or an increase in aversion to it (and thus a decrease in the effective perceived probability of bailout from π_0 to π_1) leads to:*

- (i) A flight to quality by lenders (z_{L2} goes down);

- (ii) An increases in r_{L2} and r_{B2} above r_{L2}^E and r_{B2}^E , respectively;
- (iii) When the increase in r_{B2} is such that $r_{B2} > r_{B2}^E + 2y(q + q_{RB1} - 1)(1 + r_{B2}^E)$, period's 1 credit is denied to **both regular and unlucky borrowers**, so both types of borrowers default in period 1;
- (iv) A sufficiently large increase in r_{B2} beyond $r_{B2}^E + 2y(q + q_{RB1} - 1)(1 + r_{B2}^E)$, triggers a total “financial arrest” in period's 1 credit to Bs in the sense that credit is denied to **all borrowers**.³¹

The comparative statics impacts in Proposition 12 accord well with the flight to quality and the general increase in the cost of debt observed following the downfall of Lehman Brothers. They are consistent with the view that much of the financial market panic, and the associated arrest of financial markets, in the aftermath of this collapse was due to increases in uncertainty and uncertainty aversion about the willingness of the US government to use public funds to compensate creditors' for losses due to defaulting financial intermediaries.

Following the outbreak of the crisis one of the expost explanations offered for the fact that so many market participants failed to see it coming was that they underestimated the systemic risks due to the correlation between the returns on different assets. The framework of this paper suggests that underestimation of this correlation prior to the crisis may be due to the fact that, by Propositions 10 and 12, optimistic bailout expectations are associated with a low perceived correlation and therefore a low variance in lenders portfolios. In this view, underestimation of the covariance between returns prior to the decision not to bailout Lehman was rational in view of the optimistic beliefs held at the time about government bailout policy. But after Lehman's collapse uncertainty about bailout policy and the aversion to this uncertainty increased. This led to a more pessimistic evaluation of the likelihood of bailouts raising the covariance between the returns on loans to financial intermediaries, and with it the variance of lenders' portfolios. The implication of this point of view is that the alleged underestimation of systemic risks prior to Lehman's collapse might have been rational in view of the fact that the Fed had neutralized the impact of failing financial institutions on the portfolios of creditors (lenders in the model) prior to Lehman's episode.

7.1. Bailout uncertainty, the banking spread and the credit spread

The banking (or intermediation) spread is defined as the difference between the borrowing rate, r_B , that financial intermediaries charge to borrowers and the lending rate, r_L , that they pay to lenders. By changing the general equilibrium level of interest rates a change in bailout uncertainty also changes the banking spread. The following proposition links the spread to bailout uncertainty.

Proposition 13.

- (i) Conditional upon whether $\frac{\partial L_F^*}{\partial r_B}$ is smaller (larger) than $\left| \frac{\partial L_F^*}{\partial r_L} \right|$, an increase in bailout uncertainty raises (reduces) the banking spread, $r_{B2} - r_{L2}$.
- (ii) Conditional upon the intermediaries' objective function in this paper, an increase in bailout uncertainty raises the banking spread, $r_{B2} - r_{L2}$.

The credit spread is generally defined as the difference between the yield on private debt instruments and government securities. Within the analytical framework of this paper, the credit spread

³⁰ More generally π_t stands for the lowest belief in period t about the probability of governmental bailout in all relevant future periods.

³¹ This term has recently been suggested by Caballero (2010).

corresponds to the difference between the rate, r_{L2} , charged by lenders to financial intermediaries and the risk free rate, r_f . The following corollary summarizes the impact of period's 1 increase in bailout uncertainty on the credit spread.

Corollary to Proposition 12: *An increase in uncertainty about governmental bailout policy leads to an increase in the credit spread.*

Interestingly, recent empirical proxies of credit spreads due to Gilchrist and Zakrajsek (2011) show that credit spreads rose substantially during the 2007–2009 period. In particular, the substantial increase in CDS spreads in the immediate aftermath of Lehman's collapse in September 2008 is consistent with the view that those increases were due, at least in part, to an increase in bailout uncertainty.

8. Ex ante bailout perceptions and moral hazard

8.1. The impact of lower bailout uncertainty

Unlike period 1 in which the demand for credit by borrowers is already predetermined, period's 0 leverage depends on the borrowing rate in that period as well as on the borrowing rate expected to prevail in period 1. In general equilibrium both of these rates, as well as the rates at which financial intermediaries borrow from lenders, depend on financial markets participants' perceptions about the likelihood of bailout as summarized by their multiple priors set. Hence, by affecting equilibrium interest rates, perceptions about the likelihood of bailout in period 0 affect the volume of leverage in financial markets.

This section investigates the impact of period's 0 permanent beliefs about governmental bailout policy, as summarized by the parameter π_0 , on the volume and the cost of period's 0 loans to Bs as well as on expected future rates. By affecting interest levels expected to prevail in period 1, the period's 0 perceived levels of bailout uncertainty and of aversion to this uncertainty affect, in turn, the volume of Bs leverage in period 0. The following proposition presents the various impacts of π_0 given, overly restrictive, sufficient conditions.

Proposition 14. *For model consistent expectations and provided F_s risk aversion, δ , is small, $P_F < 1$ and $(1 - \theta_{UB})^2(1 + r_{B1} - r_{L1}) > 1$, higher permanent values of π_0 (lower levels of bailout uncertainty or of uncertainty aversion) are associated with*

- (i) Overall larger levels of credit by intermediaries to borrowers and by lenders to financial intermediaries in period 0;
- (ii) Lower levels of r_{B2}^E and of r_{L2}^E ;
- (iii) A higher level of r_{B1} .

The results of Proposition 14 arise through several interconnected channels. Propositions 8–10 imply that perceptions of a more generous bailout policy directly raises the fraction of the portfolio that lenders are expected to invest in risky loans to financial intermediaries in period 1. This effect exerts downward pressures on the expected future rates, r_{B2}^E and r_{L2}^E . Since

$$L_B^* = \frac{1}{(1 + r_{B1})(1 + r_{B2}^E) - 1} \quad (33)$$

this raises, given r_{B1} , the demand for leverage by Bs. In turn, this higher demand for leverage raises r_{B1} and this reduces the demand for leverage by Bs. However, as suggested by part (i) of Proposition 14, the first effect always dominates implying that, ultimately, lower ex ante bailout uncertainty perceived for period 1 induces a credit expansion already in period 0.

Clearly, the belief that government may repay the debt of some delinquent financial intermediaries creates a moral hazard

problem. An important implication of Proposition 14 is that, by raising leverage in the economy, the perception of a more generous bailout policy, aggravates this problem and increases the likelihood and the severity of a potential financial crisis in period 1. Note that this moral hazard problem is more important either when individuals are more confident about their probability assessments (lower ambiguity) or when they are less averse to uncertainty (lower ambiguity aversion).

8.2. The impact of a temporary expansionary monetary policy

Within the context of the model a temporary expansionary monetary policy in period 0 takes the form of a decrease in r_f , holding the expected borrowing rate r_{B2}^E constant. The following proposition summarizes the impact of such a policy.

Proposition 15. *A temporary decrease in the risk free policy rate, r_f , leads to a decrease in both r_{B1} and r_{L1} , and to an increase in leverage within both the financial and the real sectors, i.e., both $L_F^*(r_{B1}, r_{L1})$ and $L_B^*(r_{B1}, r_{B2}^E)$ go up.*

When the decrease in period's 0 r_f is permanent, in the sense that it is expected to last also through period 1, there is a further expansionary effect on the equilibrium volume of credit in period 0. This effect operates through the same channels that a decrease in π_0 does. That is, by reducing expected future rates, a lower expected future policy rate induces further increases in the current volume of credit.

Broad interpretation of Propositions 14 and 15: The subprime crisis counterpart of period 0 in the model can be thought of as the buildup phase of the crisis. During this phase market participants believed that the set of bailout probabilities with positive mass is concentrated in a range with relatively high values of p and were relatively insensitive to the consequent uncertainty. In addition, monetary policy was loose by historical standards. Propositions 14 and 15 imply that both factors contributed to the ex ante expansion of credit and to a real investment boom, making the system more fragile to a sudden downward revision of perceptions about the likelihood of governmental bailouts.

9. Should government commit to a bailout policy?

This section briefly reflects on the desirability (or undesirability) of bailout uncertainty. The discussion in the previous section suggests that higher ex ante bailout uncertainty and/or aversion to it reduces the volume of leverage and with it the level of real investment activity undertaken by borrowers. The discussion in Section 7 suggests that higher ex post (after long term investment decisions have been made) bailout uncertainty or aversion to it lead to higher levels of defaults and, in parallel, to the destruction of existing investments by borrowers. The first result opens the door for the conclusion that some ex ante bailout uncertainty or aversion to it may be desirable since it keeps the buildup of credit in check thereby alleviating potential future burdens on taxpayers as well as potential defaults. But, in the spirit of the "lender of last resort" view, the second result provides an argument for reducing bailout uncertainty and the (possibly associated aversion to it) ex post in order to avoid bankruptcies and the associated destruction of capital and economic activity. It would therefore appear at first blush that, although higher bailout uncertainty is disruptive ex post, it may be desirable ex ante.

This begs the question of whether the optimal level of bailout uncertainty (or ambiguity) may be internal. Although answering this important question is largely beyond the scope of this paper it is briefly touched upon at the end of this section. But the analysis in the two previous sections does imply that, whatever the optimal

level of bailout uncertainty, over time changes in both directions in this level are inefficient. This statement is based upon the view that welfare in the economy is higher the lower is the volume of investments destroyed or missed due to errors in evaluating bailout uncertainty. As shown in the previous two sections an increase in bailout uncertainty or aversion to it between periods 0 and 1 induces period's 0 investment and leverage levels in excess of the levels that would have been chosen had it been known in period 0 that bailout uncertainty will increase in period 1. As a consequence defaults and capital destruction in period 1 are in excess of their levels in the absence of the change. Thus, given the initial levels of bailout uncertainty and of aversion to it, welfare is higher in the absence of the change. When bailout uncertainty goes down, period's 0 investments by borrowers are lower than what they would have been, had they known in advance that period's 1 bailout uncertainty will be lower, and the level of investments in the economy is suboptimally low.

We now come back to the question regarding the desirability of bailout uncertainty. One way to reduce this uncertainty is to have government (reliably) commit to a particular probability of bailout. Such a policy, if successful, eliminates multiple priors beliefs from the minds of individuals and, in parallel, may reduce the impact of uncertainty aversion. A firm commitment to a unique probability of bailout that is not higher than the minimal probability entertained by individuals prior to the commitment, has the beneficial effect of reducing ex ante excessive leverage buildups.

10. Related literature

There are two traditional, not necessarily mutually exclusive, views regarding financial crises. One is that crises reflect mainly liquidity problems (Kindleberger and Aliber, 2011; Friedman and Schwartz, 1963). The other is that crises occur when bank depositors or holders of other banks obligations have reason to believe that fundamentals are poor (Mitchell, 1941). The origins of the modern theory of banking crises can be traced to the pioneering papers of Bryant (1980) and Diamond and Dybvig (1983). A lucid and comprehensive account of the vast literature that developed since the publication of those papers till the onset of the recent global financial crisis appears in Allen and Gale (2009) and is not replicated here. Instead, the literature review that follows focuses mainly on studies that were largely triggered by the subprime crisis.

A basic empirical reference strongly supporting the view that financial crises are preceded by high credit and leverage buildups is Schularick and Taylor (2012). In much of the theoretical literature, including our paper, a basic origin for financial crises is excessive credit creation prior to the crisis. But the mechanisms through which such buildups occur often vary substantially across papers and historical episodes. Two strands of literature emerge in recent studies on financial crises. One discusses the implications of the inability of policymakers to commit ex ante to "no bailout" policies. The other investigates the effects of changes in the value of existing assets on the demand for liquidity. We start with a discussion of the first group of papers.

Using a variant of the Diamond and Dybvig (1983) framework, Ennis and Keister (2009) show that in the presence of ex ante credible freezes on deposit withdrawals, bank runs would not have occurred in the first place. But in the absence of such a commitment ex post, efficient policies may involve both bailouts and runs on the bank. Noting that, in practice, commitments are usually dynamically inconsistent, Ennis and Keister (2010) show that such ex post efficient policies induce waves of partial runs.

Farhi and Tirole (2012) develop the idea that banks tend to invest their portfolios in correlated risky assets when they believe

that easy money policies are more likely. They attribute such banks beliefs to the tendency of governments to behave in a time inconsistent manner in the face of potential economy-wide financial failures. Such beliefs about policies also induce banks to raise their share of short term leverage. Both of those outcomes increase systemic risks. In a related paper, Ratnovski (2009) notes that the tendency of central banks to provide liquidity once a systemic crisis materializes diminishes the ex ante liquidity held by banks and creates bailout rents.

The second strand of literature on pricing of assets and the demand for liquidity includes a variety of papers. Acharya and Viswanathan (2011) argue that, when prior to a crisis expectations are optimistic, the disruptions caused by a crisis when it materializes are larger. This occurs through a higher ex ante willingness of lenders to grant credit when they believe the distribution of shocks to the value of borrowers assets is better in a first order stochastic dominance sense. Our paper features a similar effect albeit through a different mechanism. In our paper a lower ex ante bailout uncertainty induces lower rates of interest throughout the financial system inducing higher levels of leverage and, consequently, more difficulties of refinancing once bailout uncertainty increases. Unlike their paper, in which the shocks to the prices of assets are exogenous, our paper relates the trigger to the crisis to a change in beliefs due to the realization of an observable event.

Acharya et al. (2011) develop the idea that demand for liquidity is driven by a strategic acquisition motive due to the hope that fire sales by other institutions in the future will make it possible to buy assets at bargain prices. They find that banks demand for liquidity is countercyclical and that the expectation of bailouts decrease the ex ante incentives of banks to hold liquidity. We implicitly have a broadly similar effect in that ex ante lower bailout uncertainty induces higher leverage which, given the structure of our model, is akin to a reduction in liquidity. Diamond and Rajan (2011) argue that financial institutions, whose assets are currently depressed, have a strong incentive to hold these assets even at the risk that if the prices of these assets go down further they will default. The logic of this "demand for illiquidity is as follows. By holding depressed assets the bank acquires the option to recover in states of nature in which it is solvent even at the cost of having to maintain them by short term loans. Selling the depressed assets at currently low market prices amounts to throwing away the option to recover in the future if the market turns around. Diamond and Rajan (2011) argue that this mechanism creates a negative externality and suggest that the problem could be eased by government buying some of those assets.

A detailed analysis of such a policy appears in Tirole (2012). Assuming that market freezes are due to adverse selection regarding the quality of legacy assets, Tirole investigates the benefits and costs to government of buying those assets at a prefixed price in order to rejuvenate the market. The model features firms that, due to agency costs do not have enough cash to finance new investment projects but own legacy assets whose value is unknown to a competitive financial market. The agency costs take the form of private information by each firm about the likelihood that its project will succeed. Government moves first and proposes a price at which it is willing to buy legacy assets from firms. Since it maximizes a mixture of firms and taxpayers welfare, government aims to offer a price that rejuvenates trade in private legacy assets without leaving too large rents to firms. Tirole (2012) shows that the optimal intervention involves a full purchase of the weakest legacy assets by government, leaving the strongest legacy assets to the market and financing intermediate quality assets while leaving them on the firms balance sheets. Although intervention is costly to taxpayers and always produces moral hazard, it may be desirable under conditions identified in the paper.

Gorton (2010) distinguishes between collaterals that are information sensitive and collaterals that are information insensitive. Using this distinction, Gorton and Ordonez (2014) develop a model in which the fraction of collateral that is of the first type changes endogenously over time in response to the realization of exogenous shocks. They show that when most of the collaterals are of the second type the quality of collateral gradually decreases due to the entry of borrowers with successively lower quality collateral into the market. After a while the realization of a (possibly small) shock raises the incentive to examine the collateral, and with it the fraction of information sensitive collateral. When this happens, more lenders gradually discover the poor quality of the collateral inducing a run and implying that small shocks can lead to a panic after a sufficiently long period of benign neglect. Empirical motivation for this approach from the 2007–8 repo market appears in Gorton and Metrick (2012).

In our model, the stochastic government bailout guarantee plays a role similar to the stochastic value of collaterals in Gorton and Ordonez (2014). As long as government keeps bailing out financial institutions, financial operators consider bailout uncertainty to be moderate. But, following a dramatic public event like not rescuing Lehman, bailout uncertainty increases and triggers the general equilibrium changes described in our paper. Furthermore, due to the fact that it is a public signal, the impact of such an event on beliefs (and through them on financial markets) is magnified à la Morris and Shin (1998). In terms of the Gorton and Ordonez (2014) conceptual framework, this can be thought of as a revelation that governments collateral through bailouts is not as good as previously believed.

Motivated by the Irish experience Acharya, Acharya et al. (2014) model a vicious circle between sovereign and banking credit risk. Their main idea is that, when government engages in excessive bailouts financing them to a large extent with larger sovereign debt, the credit rating of government eventually decreases, reducing the future ability of the government to provide bailouts. In turn, this increases the risk of lending to banks since the likelihood of bailouts is lower. There is also reverse causality, from risky sovereign debt to banks balance sheets that is due to the fact that banks hold sovereign debt. As a consequence, a higher sovereign risk weakens the balance sheets in the banking sector.

Like Uhlig (2010), we attribute market freezes to the existence of uncertainty (or ambiguity) and aversion to it, modeled by the Gilboa and Schmeidler (1989b) maximin criterion. In Uhlig's paper potential buyers of asset backed securities are uncertain about the quality of the assets offered on the market. By contrast, in our paper all market participants are uncertain about governments bailout policy and this uncertainty rises following events such as the downfall of Lehman Brothers. Diamond and Dybvig (1983), Cooper and John (1988) and others view a financial crisis as a move from a good to a bad equilibrium. By contrast, in our paper, given perceptions about the set of bailout probabilities, equilibrium is unique. Correspondingly, a shift from a good to a bad equilibrium occurs, due to a change in beliefs, following a widely observed dramatic events like not bailing out Lehman Brothers.

One distinctive feature of our paper is that it analyzes how a change in beliefs regarding government policy in one part of the financial system (the lenders segment) impacts through general equilibrium links all the other parts of the system (financial intermediaries and borrowers). Although the analysis in the paper is purely positive it is useful to recall that tracing out the impact of bailouts in one segment of the system on the entire financial system is a precondition for answering normative questions such as: How should a given amount of bailout money be distributed over the various segments of the financial system?

11. Concluding remarks

A major result of our analysis is that the larger the change in bailout uncertainty, and the potentially associated change in aversion to this uncertainty, the stronger the pre-crisis buildup and the deeper the ensuing crisis. The detailed mechanics of this result can be appreciated by thinking of period 0 as the pre-crisis phase during which the lowest perceived likelihood of bailout is high and monetary policy relatively loose leading to credit expansion and to an investment boom. Taylor (2009) argues that loose monetary policy caused, prolonged and worsened the financial crisis. Period 1 can be thought of as the phase in which, due to the arrival of some major public signal – like not rescuing Lehman – financial market operators adjust their worst scenario perceptions about the likelihood of bailout downward. This adjustment induces a general increase in market interest rates, a rise in the proportion of insolvent borrowers along with the destruction of real investments and, for some realizations of real returns, a complete drying up of short term credit markets – or in Caballero's (2010) terminology – a sudden financial arrest.

The paper shows that the pre-crisis bubbly credit boom is larger the larger the perceived probability of bailout π_0 and that the magnitudes of deleveraging and of insolvencies (real and financial) is larger the lower is the post-crisis perceived probability of bailout π_1 . Since it measures the extent to which the subjective set of possible bailout distributions widened between periods 0 and 1 the difference $\pi_0 - \pi_1$ is a natural proxy for the increase in bailout uncertainty cum aversion. Combining this proxy with Propositions 14 and 12 yields the conclusion that higher changes in bailout uncertainty cum uncertainty aversion are associated with larger pre-crisis bubbles as well as with higher levels of insolvencies and destruction of real economic activity when the bubble bursts. The crucial variable through which those effects operate is leverage. It expands more during periods of optimism about the likelihood of bailouts but, by the same token, it shrinks more violently during periods of pessimism about the likelihood of bailouts.³² Given π_1 , the deleveraging process during period 1 involves a larger volume of insolvencies the higher is π_0 . The reason is that a higher π_0 raises the ex ante leverage buildup in comparison to what market operators would have engaged in, had they known already in period 0 that the probability of bailout in period 1 will drop to π_1 . The larger this “excessive” credit buildup, the larger the ex post volume of insolvencies in the real economy.

The paper shows that the perceptions of market participants about systemic risks as captured by the aggregate covariance between the returns on different loans within the fully diversified portfolio of lenders is systematically related to bailout uncertainty and ambiguity aversion. In particular, even within a fully rational world, a higher level of bailout uncertainty or uncertainty aversion is associated with a higher level of perceived systemic risks (Propositions 10 and 12). A novel broader implication of this analysis is that, in the presence of bailout uncertainty, the level of systemic risk may increase just because of an increase in ambiguity aversion following a traumatic event such as Lehman's collapse, implying that systemic risk levels depend on preferences. Furthermore, the effect of increasing systemic risk due to changes in preferences for ambiguity is likely to be persistent.

A main result of Diamond and Dybvig (1983) classic model of bank runs is that deposit insurance eliminates runs on the banks. Although there is an analogy between the role of deposit insurance in Diamond and Dybvig (1983) and bailouts in our framework, a crucial difference between them is that, up to a given limit, deposit

³² In terms of the multiple priors framework periods of optimism can be thought as being characterized by low ambiguity aversion and period of pessimism by high levels of ambiguity aversion.

insurance is backed by the ex ante certainty of a legal act while the availability (and scope) of the generalized bailouts considered here is shrouded in uncertainty and is likely to remain in this state also in the future. Besides other obvious differences two additional difference worth emphasizing are: (i) In [Diamond and Dybvig \(1983\)](#) liquidity shocks are exogenous while here they are related to an increase in uncertainty due to the arrival of new information about government policy. (ii) Our framework features a more detailed picture of the financial sector and is designed to make statements about the impact of monetary policy on leverage and the aggregate economy.

Like [Caballero and Krishnamurthy \(2008\)](#) this paper relates flight to quality episodes to the existence of Knightian uncertainty. But we argue that flight to quality episodes are likely to reflect increases in both uncertainty as well as aversion to uncertainty following traumatic largely unanticipated events, like the downfall of Lehman's Brothers. Although, in practice, individuals may find it hard to disentangle uncertainty from uncertainty aversion, the [Gilboa and Schmeidler \(1989\)](#) maxmin expected utility with multiple priors framework utilized in this paper does not require the separation between these factors in order to optimally react to such changes. More broadly decreases in uncertainty and in uncertainty aversion provide a structured way to understand some of the factors that lie behind Keynes "animal spirits" and to link them to abrupt changes in government policy and other exogenous events.

[Reinhart and Rogoff \(2009\)](#) present broad evidence supporting the view that private financial crises are often followed by substantial reductions in tax collections and defaults on sovereign debt. Motivated by this findings and some of the results in this paper, we speculate in what follows on an additional channel through which higher ex ante leverage buildups possibly makes the economy more crisis prone when new information arrives. Higher leverage raises the probability as well as the magnitude of potential defaults, and with it the cost of potential bailouts. The more costly is a bailout to taxpayers, the more reluctant is government to engage in such bailouts. As a consequence, the higher is leverage, the higher bailout uncertainty making beliefs more sensitive to news.

The upshot is that the sensitivity of expectations to various news becomes larger the larger is leverage. In terms of the multiple priors framework this means that the range of bailout probability distributions entertained by individuals becomes more sensitive to news. As a consequence, the same pessimistic new information about the likelihood of bailout is more likely to puncture a bubble the higher is leverage.

Appendix A

A.1. Supportive lemmata

Lemma 4. *Provided δ is positive but close to zero, $P_F < 1$ and $(1 - \theta_{UB})^2(1 + r_{B1} - r_{L1}) > 1$ the impact of a general equilibrium change in r_{B2}^E on r_{B1} (i.e., $\frac{dr_{B1}}{dr_{B2}^E}$) is relatively small.*

A.2. Proofs

Proof of Lemma 1. For regular borrowers, and given $r_{B2} = r_{B2}^E$, the condition in Eq. (4) is identical to the condition in Eq. (3). But, by [Assumption 1](#), the last condition is satisfied for all $L_B \geq 0$. Hence, regular borrowers are solvent at any level of leverage. Since the expected return of a lucky borrower is larger than that of a regular borrower this is afortiori true for lucky borrowers. The proof for unlucky borrowers follows by using Eq. (5) in solvency condition (4) and by rearranging terms. QED

Proof of Lemma 2. The proof of parts (i) and (ii) is obtained by substituting $\tilde{Y}_p = -2y$ and $\tilde{Y}_p = 0$ respectively into Equation (8) and by rearranging terms. The proof of part (iii) follows by inserting $\tilde{Y}_p = 2y$ into Eq. (8) and by utilizing [Assumption 1](#). QED

Proof of Lemma 3. Part (i) is a direct consequence of [Lemma 1](#). To prove part (ii) note that, since $\frac{1}{2} < q < 1$, $L_B^L < L_B^C < L_B^H$. The ultimate payoff of an UB is either 0 in case of expansion or $-2y$ in case of contraction. By [Lemma 2](#), and since $L_B^C < L_B^H$, this borrower is solvent in the first case. By [Lemma 2](#), and since $L_B^L < L_B^C$, this borrower is insolvent in the second case. Part (iii) is a direct consequence of [Assumption 1](#) in conjunction with condition (7). QED

Proof of Lemma 4. Noting that $\gamma_{11} = (1 - \theta_{UB})^2$ and differentiating Eq. (18) with respect to r_{B1}

$$\frac{\partial L_{F1}^*}{\partial r_B} = \frac{1 - \delta}{\delta} \left(\frac{1}{P_F} \frac{(1 - \theta_{UB})^2}{1 - (1 - \theta_{UB})^2} (r_{B1} - r_{L1})^{1-2\delta} \right)^{\frac{1}{\delta}} + \frac{1 + r_{L1}}{(r_{B1} - r_{L1})^2}.$$

Under the conditions of the proposition the term in parenthesis on the right hand side of this equation is larger than one. Consequently, when δ tends to zero from above $\frac{\partial L_{F1}^*}{\partial r_B}$ tends to infinity implying, by Eq. (50), that $\frac{dr_{B1}}{dr_{B2}^E}$ becomes very small. This completes the proof of the claim and of the proposition. QED

Proof of Proposition 1. The first two default probabilities follow directly from [Lemmas 1](#) through 3. The third probability is derived by noting that, when leverage is larger than L_B^C default may occur in period 1 if the borrower turns out to be unlucky (with probability θ_{UB}). Default may also occur in period 2 if she turns out to be a regular borrower and $\tilde{Y}_p = -2y$ (with probability $\theta_{RB}(1 - q)^2$). The last probability follows by noting that, in addition to the states in which she defaults in the previous case, the borrower defaults also in the following two cases: (i) If she is a LB and there is a contraction, (ii) If she is a regular borrower and $\tilde{Y}_p = 0$. QED

Proof of Proposition 2. To show that L_B^H is the optimal level of leverage it suffices to establish that

$$V(L_B^H) > V(L_B^C) > V(L_B^L) > V(L_B = 0), \\ V(L_B^H) > V(L_B^M).$$

The proof is implemented by using Eq. (12) to form explicit expressions for the differences $V(L_B^L) - V(L_B = 0)$, $V(L_B^C) - V(L_B^L)$, $V(L_B^H) - V(L_B^C)$, $V(L_B^M) - V(L_B^H)$ and by showing that they are all positive.

- (i) $V(L_B^L) - V(L_B = 0) = q^2(2y - r_B^E)L_B^L - 2q(1 - q)r_B^E L_B^L$.
By [Assumption 1](#), and since q is sufficiently close to one, this difference is positive.
- (ii) $V(L_B^C) - V(L_B^L) = (q^2(2y - r_B^E) - 2q(1 - q)r_B^E)(L_B^C - L_B^L) - (1 - q)^2 P_B L_B^C$.
Since $(L_B^C - L_B^L) > 0$, this expression is positive for q sufficiently close to one.
- (iii) Let θ_{LB} approach q from below and θ_{UB} approach zero from above, then
 $V(L_B^H) - V(L_B^C) = q^2(2y - r_B^E)(L_B^H - L_B^C) - 2q(1 - q)(1 - r_B^E L_B^C) - (1 - q)^2 P_B ((1 - q)L_B^H - L_B^C)$. Since $(L_B^H - L_B^C) > 0$, this expression is positive for q sufficiently close to one.

- (iv) The condition $V(L_B^M) - V(L_B^H) > 0$ is equivalent to
 $((\theta_{RB}2q(1-q) + \theta_{LB}(1-q))P_B - (\theta_{LB}q + \theta_{RB}q^2)(2y - r_B^E))$
 $(L_B^M - L_B^H) > 0$.
 Since $(L_B^H - L_B^C) > 0$, this expression is positive if and only if
 $P_B > \frac{(\theta_{LB}q + \theta_{RB}q^2)(2y - r_B^E)}{(2\theta_{RB}q + \theta_{LB})(1-q)}$. QED

Proof of Proposition 3. The proof is a direct consequence of the fact that all three types of agents are risk averse and that leverage levels are positive. Consequently, financial intermediaries require a markup over their leverage costs as compensation for investing in risky loans to investors implying that $r_B > r_L$. Similarly, lenders demand a risk premium when they invest in risky loans to financial intermediaries rather than in the risk free asset. Hence, $r_L \geq r_f$.³³ QED

Proof of Proposition 4. By construction, since $r_f < r_L$, an F with positive short term leverage and some fraction of the portfolio invested in risk free assets can increase her profits by reducing short term leverage and, in parallel, decreasing the investment in risk free assets. Consequently, a configuration with both positive leverage and some investment in risk free assets cannot be a financial intermediary's optimum. Hence $z_f = 1$. QED

Proof of Proposition 5. Eq. (18) is obtained by maximizing the expected utility of F with respect to L_F for $z_f = 1$ under the assumption that F's optimal leverage is above L_F^C . Conditions (ii) and (iii) are needed to rule out the possibility that optimal leverage is at L_F^C or at zero. To derive those conditions let L_F^M be any leverage level above L_F^C and let

$$E[V_F(L_F)] \equiv E[u(W_F(L_F))]. \quad (34)$$

Then necessary conditions for the optimal level of leverage to be above L_F^C are

$$E[V_F(L_F^M)] > E[V_F(L_F = 0)] \quad (35)$$

and

$$E[V_F(L_F^M)] > E[V_F(L_F^C)]. \quad (36)$$

Conditions (i) and (ii) are obtained by using Eqs. (13) and (15) to express F's utility in terms of the appropriate levels of leverage. Substitution of the resulting expression into Eqs. (35) and (36) and rearrangement of terms provides the result. To complete the proof it remains to show that, when γ_{1t}/γ_{2t} is sufficiently small, $E[V_F(L_F^S)] < E[V_F(L_F^C)]$ for any $0 < L_F^S < L_F^C$. Since $E[V_F(L_F^C)] < E[V_F(L_F^M)]$, then $E[V_F(L_F^M)]$ is also larger than $E[V_F(L_F^S)]$. When γ_{1t}/γ_{2t} is small, the only two terms that could potentially make $E[V_F(L_F^S)]$ larger than $E[V_F(L_F^C)]$ involve γ_{1t} , while the terms that operate to reverse this inequality involve γ_{2t} . In the extreme case, where $\gamma_{1t}/\gamma_{2t} = 0$, it is unambiguously the case that $E[V_F(L_F^S)] < E[V_F(L_F^C)]$. By continuity this is also true for the case for γ_{1t}/γ_{2t} positive but sufficiently small. QED

³³ As elaborated later in the general equilibrium section, the equality sign is allowed to accommodate a special case in which, due to full diversification, lenders face no risk in period 0.

Proof of Proposition 6. The condition in Eq. (16) implies that, when $L_{Ft}^* > L_{Ft}^C$, F is solvent if and only if both of her debtors are solvent. Recalling that $r_{Bt} - r_{Lt} > 0$ and inspecting Eq. (18) reveals that L_{Ft}^* is a monotonically increasing function of δ and that it tends to infinity when δ tends to zero. It follows that, for sufficiently small but positive values of δ , $L_{Ft}^* > L_{Ft}^C$ implying that F is solvent if and only if both of her borrowers are solvent. QED

Proof of Proposition 7. The first four parts follow directly from inspection of Eq. (18). Part (v) is established by differentiating this equation with respect to r_{Bt} . QED

Proof of Proposition 8. Calculation of the expected value is relatively straightforward. Derivation of the variance utilizes the fact that the variance of a fully diversified risky portfolio, composed of (equally weighted) infinitely many identically distributed assets, is equal to the covariance between any two assets within the portfolio. Calculation of this covariance simplifies the derivation of an explicit expression for $\text{Var}[\tilde{R}_{L2}]$ but still involves some messy intermediate algebra. The expression for L's portfolio variance in Proposition 8 is obtained by using the joint distribution of \tilde{R}_{L2}^i and \tilde{R}_{L2}^j in the definition of the covariance between \tilde{R}_{L2}^i and \tilde{R}_{L2}^j and by simplifying the resulting algebraic expressions. QED

Proof of Proposition 9. Recall that, the symbol \tilde{R}_L denotes the payoff from a portfolio that consist of an infinite number of loans. The notation $R_f = 1 + r_f$ stands for the gross risk free rate. A typical lender's maximization problem is given by

$$\max_{z_L} E[u(z_L(\tilde{R}_L - R_f) + R_f)],$$

where $u(\cdot)$ stands for the utility function. The first order condition implies

$$E[u'(z_L^*(\tilde{R}_L - R_f) + R_f)(\tilde{R}_L - R_f)] = 0.$$

Taking a Taylor approximation of the marginal utility with respect to \tilde{R}_L around R_f yields

$$E[u'(R_f)(\tilde{R}_L - R_f)] + E[u''(R_f)(\tilde{R}_L - R_f)(\tilde{R}_L - R_f)z_L^*] \cong 0.$$

For a sufficiently small risk premium

$$z_L^* \cong -\frac{u'(R_f)(E[\tilde{R}_L] - R_f)}{u''(R_f)E[(\tilde{R}_L - R_f)^2]} = \frac{(E[\tilde{R}_L] - R_f)}{-\frac{u''(R_f)}{u'(R_f)}\text{Var}[\tilde{R}_L]},$$

but for constant absolute risk aversion, $u(x) = -e^{-\alpha x}$, the coefficient of absolute risk aversion is $-\frac{u''(R_f)}{u'(R_f)} = \alpha$. QED

Proof of Proposition 10. Part (i) follows immediately from Eq. (21).

Parts (ii) and (iii): The first derivative of $\text{Var}[\tilde{R}_{L2}]$ with respect to π_t is

$$\frac{\partial \text{Var}[\tilde{R}_{L2}]}{\partial \pi_t} = -2(1 - \pi_t)(1 - q)(1 - q_{RB1})^2(q + 2qq_{RB1} + q_{RB1}^2),$$

which is negative since $\pi_t, q \in [0, 1]$ are probabilities. QED

Proof of Proposition 11. Rewriting Eq. (26) (by means of Proposition 8) as

$$z_L^*(\pi, \tilde{R}_L, q, q_{RB1}) \cong \frac{E[\tilde{R}_L] - (1 + r_f)}{\alpha \text{Var}[\tilde{R}_L]} = \frac{\lambda_1(1 + r_L) - (1 + r_f)}{\alpha \lambda_2(1 + r_L)^2}, \quad (37)$$

where

$$\lambda_1 = (\pi_1 + (q(1 - q_{RB1}^2) + q_{RB1}^2)(1 - \pi_1)) \quad (38)$$

and

$$\lambda_2 = (1 - \pi_1)^2(1 - q)(1 - q_{RB1})^2(q + 2qq_{RB1} + q_{RB1}^2). \quad (39)$$

Differentiating z_L^* with respect to r_L yields

$$\begin{aligned} \frac{\partial z_L^*}{\partial r_L} &= \frac{\lambda_1(1 + r_L)^2 - 2(1 + r_L)(\lambda_1(1 + r_L) - (1 + r_f))}{\alpha\lambda_2(1 + r_L)^4} \\ &= \frac{-\lambda_1(1 + r_L) + 2(1 + r_f)}{\alpha\lambda_2(1 + r_L)^3}. \end{aligned}$$

Since it is a probability $\lambda_1 \in [0, 1]$ and $\lambda_2 \geq 0$. Hence, the derivative is positive for $r_f \geq \frac{r_L}{2} - \frac{1}{2}$, which is true for $r_L \leq \frac{1}{2}$. QED

Proof of Proposition 12. Part (i) is an immediate consequence of Proposition 10.

Part (ii): Differentiating Eqs. (31) and (32) totally with respect to π_1 yields

$$0 = (1 - \theta_{UB})M_F \left(\frac{\partial L_F^*}{\partial r_B} \frac{dr_{B2}}{d\pi_1} + \frac{\partial L_F^*}{\partial r_L} \frac{dr_{L2}}{d\pi_1} \right) \quad (40)$$

and

$$\begin{aligned} (1 - \theta_{UB})^2 M_F \left(\frac{\partial L_{F2}^*}{\partial r_B} \frac{dr_{B2}}{d\pi_1} + \frac{\partial L_{F2}^*}{\partial r_L} \frac{dr_{L2}}{d\pi_1} \right) \\ = (1 + r_f + z_{L1}^*(r_{L1} - r_f))M_L \left(\frac{\partial z_{L2}^*}{\partial r_L} \frac{dr_{B2}}{d\pi_1} + \frac{\partial z_{L2}^*}{\partial \pi_1} \right). \end{aligned} \quad (41)$$

Solving this two equations system for $\frac{dr_{B2}}{d\pi_1}$ and $\frac{dr_{L2}}{d\pi_1}$ yields

$$\frac{dr_{B2}}{d\pi_1} = -\frac{\frac{\partial z_{L2}^*}{\partial \pi_1}}{\frac{\partial z_{L2}^*}{\partial r_L}} \quad (42)$$

and

$$\frac{dr_{L2}}{d\pi_1} = \frac{\frac{\partial L_{F2}^*}{\partial r_B} \frac{\partial z_{L2}^*}{\partial \pi_1}}{\frac{\partial L_{F2}^*}{\partial r_L} \frac{\partial z_{L2}^*}{\partial r_L}}. \quad (43)$$

By Proposition 7, $\frac{\partial L_{F2}^*}{\partial r_B} > 0$ and $\frac{\partial L_{F2}^*}{\partial r_L} < 0$. By Propositions 10 and 11, $\frac{\partial z_{L2}^*}{\partial \pi_1}$ and $\frac{\partial z_{L2}^*}{\partial r_L}$ are both positive. Utilization of those sign restrictions in Eqs. (43) and (42) implies that the general equilibrium effects of a surprise decrease in π_1 is to raise both r_{B2} and r_{L2} above what those rates had been expected to be in period 0 (r_{B2}^E and r_{L2}^E).

Part (iii): Although Assumption 2 requires that $E[\tilde{Y}_P|I_1, RB] = 2y((q + q_{RB1} - 1) > r_B^E \equiv (1 + r_{B1})(1 + r_{B2}^E) - 1$, the condition in part (iii) of this proposition implies that it is violated when r_B^E is replaced with r_B , or in explicit notation

$$E[\tilde{Y}_P|I_1, RB] = 2y(q + q_{RB1} - 1) < r_B \equiv (1 + r_{B1})(1 + r_{B2}) - 1. \quad (44)$$

By Eq. (4) adapted to actual period's 1 information a RB is solvent in period 1 if and only if

$$L_B(1 + r_B^E) \leq (1 + L_B) \left(1 + E[\tilde{Y}_P|I_1, RB] \right),$$

which is equivalent to

$$L_B \leq \frac{1 + 2y(q + q_{RB1} - 1)}{r_B - 2y(q + q_{RB1} - 1)} \equiv L_B^C(r_{B1}), \quad (45)$$

where the denominator is positive by condition (44). It follows that regular borrowers do not get refinancing in period 1 if

$$L_B^* = L_B^H = \frac{1}{r_B^E} > \frac{1 + 2y(q + q_{RB1} - 1)}{r_B - 2y(q + q_{RB1} - 1)} \equiv L_B^C(r_{B1}). \quad (46)$$

Rearrangement of this inequality reveals that it is equivalent to the condition in part (iii) of the proposition establishing that RB default. Given that RB default under r_{B2} UB default afortiori.

Part (iv) When r_{B2} increases sufficiently beyond the bound in part (ii) even LB are denied access to credit inducing a total drying up of refinancing to borrowers. QED.

Proof of Proposition 13. Part (i): The banking spread in period 2 is

$$S_2 \equiv r_{B2} - r_{L2}. \quad (47)$$

Differentiating the spread totally with respect to π_1

$$\frac{dS_2}{d\pi_1} = \frac{dr_{B2}}{d\pi_1} - \frac{dr_{L2}}{d\pi_1} = \left(1 - \frac{\frac{\partial L_{F2}^*}{\partial r_L}}{\frac{\partial L_{F2}^*}{\partial r_B}} \right) \frac{dr_{L2}}{d\pi_1}, \quad (48)$$

where the second equality follows by using Eqs. (43) and (42). Since $\frac{\partial L_{F2}^*}{\partial r_B} > 0$, $\frac{dS_2}{d\pi_1}$ is negative or positive depending on whether $\left| \frac{\partial L_{F2}^*}{\partial r_L} \right|$ is larger or smaller than $\frac{\partial L_{F2}^*}{\partial r_B}$. Hence an increase in bailout uncertainty (a decrease in π_1) raises the spread in the first case and reduces it in the second.

Part (ii): Examination of the expression for L_{F2}^* in Proposition 5 reveals that $\left| \frac{\partial L_{F2}^*}{\partial r_L} \right|$ and $\frac{\partial L_{F2}^*}{\partial r_B}$ may differ only because of the second term on the right hand side of Eq. (18). Using this fact along with that equation yields after some algebra that the sign of $r_{B2} - r_{L2}$ is equal to the sign of $\left| \frac{\partial L_{F2}^*}{\partial r_L} \right| - \frac{\partial L_{F2}^*}{\partial r_B}$. Since $r_{B2} - r_{L2} > 0$, $\left| \frac{\partial L_{F2}^*}{\partial r_L} \right| > \frac{\partial L_{F2}^*}{\partial r_B}$ implying, by part (i), that an increase in bailout uncertainty raises the banking spread. QED.

Proof of Proposition 14. The Equation system in (28), (29) and (30) determines r_{B2}^E , r_{L2}^E and r_{B1} as functions of π_0 and other exogenous variables. Differentiating this system totally with respect to π_0 and using the total differential of the first of those equations to express $\frac{dr_{B1}}{d\pi_0}$ in terms of $\frac{dr_{B2}}{d\pi_0}$ yields

$$\frac{dr_{B1}}{d\pi_0} = \frac{dr_{B1}}{dr_{B2}^E} \frac{dr_{B2}^E}{d\pi_0} \quad (49)$$

where

$$\frac{dr_{B1}}{dr_{B2}^E} = -\frac{M_B \frac{\partial L_B^*}{\partial r_B^E}}{M_B \frac{\partial L_B^*}{\partial r_B} - M_F \frac{\partial L_{F1}^*}{\partial r_B}}. \quad (50)$$

Eq. (33) implies $\frac{\partial L_B^*}{\partial r_B^E} < 0$, $\frac{\partial L_B^*}{\partial r_B} < 0$ and, from Proposition 7 $\frac{\partial L_{F1}^*}{\partial r_B} > 0$. Hence, $\frac{dr_{B1}}{dr_{B2}^E}$ is negative implying that $\frac{dr_{B1}}{d\pi_0}$ and $\frac{dr_{B2}}{d\pi_0}$ have opposite signs. Differentiating L_B^* totally with respect to π_0 and using Eq. (50)

$$\frac{dL_B^*}{d\pi_0} = -\frac{M_F \frac{\partial L_{F1}^*}{\partial r_B} \frac{\partial L_B^*}{\partial r_B^E}}{M_B \frac{\partial L_B^*}{\partial r_B} - M_F \frac{\partial L_{F1}^*}{\partial r_B}} \times \frac{dr_{B2}^E}{d\pi_0}. \quad (51)$$

Inspection reveals that the left term on the right hand side of this equation is negative, implying that

$$\text{Sign} \left(\frac{dL_B^*}{d\pi_0} \right) = -\text{Sign} \left(\frac{dr_{B2}^E}{d\pi_0} \right). \quad (52)$$

Substituting Eq. (50) into the total differentials of Equations (29) and (30) and rearranging yields the following two equations system for the determination of $\frac{dr_{B2}^E}{d\pi_0}$ and of $\frac{dr_{L2}^E}{d\pi_0}$:

$$M_F(1 - \theta_{UB})^2 \frac{\partial L_{F2}^E}{\partial r_B^E} \frac{dr_{B2}^E}{d\pi_0} + \left(M_F(1 - \theta_{UB})^2 \frac{\partial L_{F2}^E}{\partial r_L^E} - M_L(1 + r_f) \frac{\partial z_{L2}^E}{\partial r_L^E} \right) \frac{dr_{L2}^E}{d\pi_0} = M_L(1 + r_f) \frac{\partial z_{L2}^E}{\partial \pi_0}$$

and

$$\left(M_F(1 - \theta_{UB}) \left(W_{r_{B1}} \frac{dr_{B1}}{dr_{B2}^E} + \frac{\partial L_{F2}^E}{\partial r_B^E} \right) - M_B \left(\frac{\partial L_B}{\partial r_B} \frac{dr_{B1}}{dr_{B2}^E} + \frac{\partial L_B}{\partial r_B^E} \right) \right) \frac{dr_{B2}^E}{d\pi_0} + M_F(1 - \theta_{UB}) \frac{\partial L_{F2}^E}{\partial r_L^E} \frac{dr_{L2}^E}{d\pi_0} = 0, \tag{53}$$

where L_{F2}^E and z_{L2}^E are the model consistent expectations of those variables given the information set of period 1 and $W_{r_{B1}}$ is the derivative of $(1 + r_{B1} + (r_{B1} - r_{L1})L_F^*(r_{B1}, r_{L1}))$ with respect to r_{B1} . To evaluate the signs of $\frac{dr_{B2}^E}{d\pi_0}$ and of $\frac{dr_{L2}^E}{d\pi_0}$ it is convenient to utilize Lemma 4.

Applying this lemma to Eq. (53) and solving for $\frac{dr_{B2}^E}{d\pi_0}$ and $\frac{dr_{L2}^E}{d\pi_0}$ provides

$$\frac{dr_{B2}^E}{d\pi_0} \cong \frac{\frac{\partial L_{F2}^E}{\partial r_B^E} \frac{\partial z_{L2}^E}{\partial \pi_0}}{\frac{\partial z_{L2}^E}{\partial r_L^E} \frac{\partial L_{F2}^E}{\partial r_B^E}} < 0 \tag{54}$$

and

$$\frac{dr_{L2}^E}{d\pi_0} \cong - \frac{\left(M_F(1 - \theta_{UB}) \frac{\partial L_{F2}^E}{\partial r_B^E} - M_B \frac{\partial L_B}{\partial r_B^E} \right) \frac{\partial z_{L2}^E}{\partial \pi_0}}{M_F(1 - \theta_{UB}) \frac{\partial z_{L2}^E}{\partial r_L^E} \frac{\partial L_{F2}^E}{\partial r_B^E}} < 0. \tag{55}$$

The negative signs of those expressions follow by noting that, from Proposition 7, $\frac{\partial L_{F2}^E}{\partial r_B^E} > 0$, $\frac{\partial L_{F2}^E}{\partial r_L^E} < 0$; from Propositions 10 and 11 we get that $\frac{\partial z_{L2}^E}{\partial \pi_0}$ and $\frac{\partial z_{L2}^E}{\partial r_L^E}$ are both positive; and from Eq. (33) $\frac{\partial L_B}{\partial r_B^E} < 0$. This establishes part (ii). The fact that L_B^* is higher follows from Eq. (52) in conjunction with the fact that $\frac{dr_{B2}^E}{d\pi_0} < 0$. This implies via Eqs. (29) and (28) that $L_F^*(r_{B1}, r_{L1})$ and z_{L1} are also higher when π_0 is higher establishing part (i). Part (iii) follows from part (ii) and Eq. (49) by noting that $\frac{dr_{B1}}{dr_{B2}^E}$ is negative. QED

Proof of Proposition 15. Translated into the model's timing framework a temporary decrease in the risk free rate means that r_f goes down without any change in the expected risk free rate for the second period. The decrease in r_f triggers, via Eq. (20), a decrease in r_{L1} , and by part (ii) of Proposition 7, an increase in $L_F^*(r_{B1}, r_{L1})$. This increase translates through equilibrium condition (27) into an increase in z_{L1} . Furthermore, the increase in $L_F^*(r_{B1}, r_{L1})$ induces, via equilibrium condition (28), a decrease in r_{B1} and an increase in L_B^* . QED

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Glossary of symbols

We use the convention X_{jt}^i , where X is a variable, $j = \{B, F, L, LB, RB, UB\}$ designates agent type, $t = \{0, 1, 2\}$ designates time period and $i = \{L, C, M, H\}$ designates leverage level.
 B: Borrower, 4
 D: Default, 7

- F : Financial intermediary, 4
 FR : Financial requirements, 5
 L : Lender, 7
 LB : Lucky borrower, 6
 L_j^* : Optimal leverage of agent j , 5
 L_i^j : Leverage level i of agent j , 4
 M : Agent's mass, 4
 P : Default's penalty, 7
 RB : Regular borrower, 6
 UB : Unlucky borrower, 6
 $V(\cdot)$: Expected utility, 7
 $W(\cdot)$: Wealth, 6
 $Pr[\cdot]$: Probability, 2
 α : Lender's absolute risk aversion, 9
 δ : Financial intermediary's relative risk aversion, 10
 $E[\cdot]$: Expectation, 4
 γ_{nt} : Probability of payoff in time t conditional on n solvent borrowers, 8
 \mathcal{P} : Set of plausible probability distributions of bailout, 9
 π : Lowest probability of bailout, 9
 θ_{LB} : Proportion of lucky borrowers, 6
 θ_{RB} : Proportion of regular borrowers, 6
 θ_{UB} : Proportion of unlucky borrowers, 6
 $Var[\cdot]$: Variance, 10
 \tilde{R} : Gross payoff, 8
 \tilde{Y}_A : Economy yield, 4
 \tilde{Y}_i : Idiosyncratic yield, 4
 \tilde{Y}_p : Project yield, 4
 p : Probability of bailout, 9
 q : Probability of positive outcome, 5
 r_B : Two-period compounded borrowing interest rate, 12
 r_{Bt} : Borrowing rate at time t , 4
 r_{Lt} : Lending rate at time t , 4
 r_f : Risk-free rate, 4
 $u(\cdot)$: Utility, 7
 x : Project size, 5
 y : Component of investment outcome, 5
 z : Allocation to uncertain assets, 4