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Destructive Effects of Constructive Ambiguity in Risky Times

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DESTRUCTIVE EFFECTS OF CONSTRUCTIVE AMBIGUITY IN RISKY TIMES

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Abstract

Unclear bailout policy, underinvestment and calls for bankers' responsibility are some of the observations from the recent financial crisis. The paper explains underinvestment as an inefficient equilibrium. Under ambiguous bailout policy agents suffer from a lack of information with regards to the insolvency resolution methods. Beliefs of bankers regarding whether an insolvent bank is liquidated, may differ from those of depositors even if bankers and depositors possess absolutely symmetric information about the economy. It is shown that such an asymmetry in beliefs results in underinvestment if the investment climate is characterized by high aggregate risk. The paper suggests policy implications aimed at the reduction of anxiety of agents and at aligning their beliefs to restore efficiency.

JEL Classification: G28, D80

Keywords: bank bailouts; constructive ambiguity

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"Central banks have pumped a vast amount of money into the financial system this year – but so far there is little evidence that this liquidity has found its way into the broader economy" - Financial Times[1]

"...our call to commercial banks in general ... [is] to ship to the real economy the extraordinary efforts that we are making ourselves. We call for their full responsibility when they provide credit" - J.-C. Trichet[2]

1 Introduction

Despite unprecedented efforts of central banks to bail economies out of the recent financial crisis the revival is slow and banking systems around the world are reported not channel the liquidity provided by central banks further to the real sector. Along with this breakage of the monetary transmission mechanism, the crisis leads to two other important observations: (1) regulations with regards to insolvency resolutions in banking (and non-banking) sectors have changed in major economies, and (2) there is a sharp increase in efforts to make bankers more responsible for the (negative) events in the banking sector. Although the two latter are meant to improve the soundness of the financial system and thus contribute to the smooth channelling of funds to the real sector, this is not the case. This paper suggests an explanation to this phenomenon based on the uncertainty (ambiguity) about the policy response to bank failures.

Central Bankers often follow a policy of "constructive ambiguity", which means that the bailout policy is not announced ex-ante (Goodhart and Schoenmaker [1995], Santomero and Hoffman [1998], Bennett [2001] provide empirical evidence). This is mostly justified by the objective of avoiding excessive risk-taking by banks (see a review

[1] "Money struggles to pass through banking pipe" by D.Oakley, R.Atkins and G.Tett, *Financial Times*, July 21 2009

[2] Jean-Claude Trichet, President of the ECB, Press conference, Luxembourg, 2 July 2009

by Enoch et al. [1997]) or by social benefits (see Freixas [2000] for a costs-benefits analysis). Researchers address the issue of constructive ambiguity by assuming that banks may be bailed out with some probability, which is known to the public. In general, however, there is no reason to assume that this piece of information is available to the agents.

Cukierman and Meltzer [1986] present one of the first models to encompass political ambiguity, in which they assume that the public forms rational expectations about the policy indicators on the basis of the historical path of signals. However if the macroeconomic environment and/or regulation change, such a path of signals from the past can not be used in the expectation formation mechanism. In the models of Freixas [2000] and Shim [2006] bankers are supposed to know the probability of bailouts. If the policy of the regulator suddenly changes and there is no historical path of signals to estimate the "true" probability distribution, they would still form homogenous expectations (beliefs) about the policy outcomes and there will be no significant change in results (except for replacing objective expectations with subjective beliefs). Introducing depositors into the model makes the public heterogenous, which implies that beliefs may differ among agents and implications of this are in the focus of the current paper.

The paper studies an economy with agents (depositors) wishing to invest their fixed endowment into a risky asset which dominates the risk-free one. However, they have no access to the market of the risky asset, which justifies the existence of banks in the economy. Banks are assumed to be completely financed through [uninsured] deposits. Banks act as the second group of decision-makers in the economy, whose investment decision is explicitly modelled. Finally, there exists a regulator which intervenes if banks are insolvent. As usual, the regulator maximizes social welfare, which in this paper's setting means selecting such an intervention policy that the whole endowment of depositors is invested through banks into the risky asset. Depositors and bankers are unaware of the policy of the regulator who follows constructive ambiguity but are able to identify the set of policies that are optimal from the point of view of the regulator. Since there is no unique solution to the regulator's optimization problem beliefs of depositors and bankers can differ and as a result the model produces underinvestment in risky asset and overinvestment in the safe one.

It is not unusual to assume that banks have exclusive access to the superior investment technology. A classical explanation for that follows Benston and Smith [1976], who derive the existence of banks through their role in transaction cost reduction. The model in the current paper is built upon a similar assumption that captures the general idea of incomplete market participation. The results would hold if the interactions are embedded into a framework with a more sophisticated *raison d'être* for banks. Section 6 of the paper provides a discussion of possible applications of the model to different settings, including delegated monitoring (Diamond, 1984) and liquidity provision (Diamond and Dybvig, 1983) frameworks.

There exists some recent finance literature that takes a similar view on ambiguity as here. The study of Caballero and Krishnamurthy (2008) is the closest to the current paper in that they consider a liquidity crisis and underinvestment that arises through the inability of investors to rely on past data in building expectations. An interesting feature in Caballero and Krishnamurthy (2008) is that the aggregate probability distribution of liquidity shocks is known to agents and can be derived from the past data, however it is impossible to derive the probabilities with which each individual agent would be hit by a particular liquidity shock. Other authors like Easley and O'Hara (2009a) focus on price effects of ambiguity arising from agents' preferences. A review of the recent studies on ambiguity in finance can be found in Easley and O'Hara (2009b). Contrast to these studies, ambiguity in the current paper arises from the decision of the regulator and the multiplicity of optimal regulatory policies, which does not allow market participants to anticipate the action of the regulator.

This also leads to policy implications that are qualitatively different from the previous studies. Caballero and Krishnamurthy (2008), for example, derive that adverse outcomes of ambiguity can be avoided if central banks credibly commit to provide agents with liquidity if the worst scenario is realized. Easley and O'Hara (2009a) come to a similar conclusion that a regulatory intervention should be conditioned on the realization of the worst scenario: this reduces the anxiety of agents. Importantly, these studies assume ambiguity aversion or pessimistic agents who overweight the worst outcome. On the technical side, in the current paper agents can exhibit optimism as well as pessimism, which makes the results applicable to a more general case than only pessimistic agents. On the qualitative side, the optimal policy design here aims rather at the alignment of expectations of the heterogenous public than at the improvement of the worst case for each agent. Conditioning interventions on the realization of macroeconomic events is a convenient tool for this. This novel effect of the macroeconomic conditioning is due to the fact that, like in Caballero and Krishnamurthy (2008), there is no ambiguity about the aggregate macroeconomy (which still can be risky) and macroeconomic indicators can be used as an objective publicly observed randomizer that aligns expectations about the regulatory interventions.

The rest of the paper explores the above ideas formally. Section 2 introduces the economic environment which is risky but not ambiguous. In a risky environment, it is possible that banks are insolvent, therefore insolvency resolution is discussed in Section 3. Section 4 determines the market equilibrium and demonstrates multiplicity of regulatory policies that maximize social welfare, which generates ambiguity about the choice of the regulator. Section 5 studies beliefs of agents and the market equilibrium under ambiguity about the regulatory policy. Policy implications and possible extensions of the model are discussed in Section 6. The paper concludes with a summary of results.

2 The Model

Consider an economy with a continuum of risk-neutral agents distributed at $[0;1]$ and two types of financial assets, one risky[3] and one risk-free. The model describes two periods: in the first period decisions and investments are made, and in the second period a state of nature $\mathbf{s} \in \{H, L\}$ is realized and investment gains reaped. Each household is endowed with one unit of wealth in the beginning of the first period.

2.1 Markets

The markets of both risky and risk-free assets are characterized by an absolutely elastic supply of assets. The risky asset yields a gross rate of return of $r^{\mathbf{s}}$ in state of nature $\mathbf{s}$, the risk-free asset yields r^F in each state of nature. The probability of state $\mathbf{s} = H$ is p, and the probability of state $\mathbf{s} = L$ is $1 - p$. It is assumed that

$$r^H > r^F > r^L \tag{A-1}$$

and

$$pr^H + (1-p)r^L > r^F \tag{A-2}$$

[3] It may be convenient to think of the risky asset as of an investment project like a production technology, which yields different outcomes in two different states of nature.

Short sales are not allowed, hence the amount invested in financial assets is non-negative. Assumptions A-1 and A-2 guarantee that a financial portfolio of a risk-neutral agent would only contain the risky asset. Since the supply of the asset is perfectly elastic, market equilibrium would result in the allocation of funds entirely in the risky asset.

Since this is the reference point for the analysis, the regulatory policy would be aimed at the provision of this risky allocation of funds. At teh first glance, this somewhat contradicts the logic of the banking regulation, which is mostly aimed at the reduction of risks. However, productive investment is usually associated with higher risks than unproductive allocation of funds, and thus a regulatory policy that would result in a safe allocation of funds is not realistic either.[4] Such a policy of supporting risky investment can also be found in the recent financial crisis (e.g. governments had to intervene to prevent a sharp fall in mortgage lending, which banks considered a highly risky investment.) The current paper focuses on such episodes when risky investment is economically optimal and thus a regulatory policy that aims at the provision of such an optimal risky outcome is natural in this setting.[5]

2.2 Banks

Assume, transaction costs prevent agents from entering the market for the risky asset. They still have an access to the market of the risk-free asset. Transaction costs justify the existence of banks, which offer a deposit contract with a duration of one period and without a premature withdrawal option. The banking sector is assumed to be of a unit size, perfectly competitive and homogenous. Banks belong to a small part

[4] For example, narrow banking, though believed to be an example of a perfectly safe financial system, is never implemented in practice.

[5] In the discussion part we will show that a similar result could be obtained in a Diamond-Dybvig (1983) setting, where the issue of such a risky policy objective does not arise.

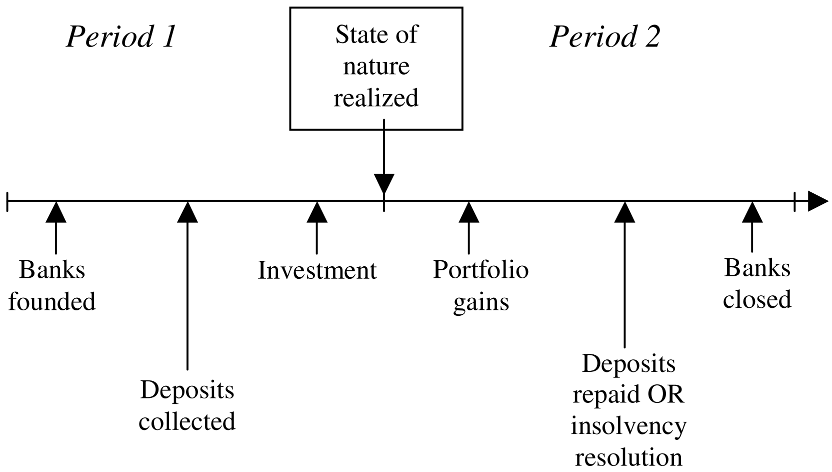

Figure 1. Sequence of events

of agents, who manage banks and are called bankers.[6]

The sequence of interactions between banks and depositors is shown in Fig. 1. In the first period, three actions take place: first, banks are created, then deposits are collected and, finally, banks invest. In the beginning of the second period, the state of nature is realized. Other three actions take place in the second period: first, banks reap portfolio gains, then deposits are repaid, and the banks are closed. The economy terminates at the end of the second period.

There exists also a regulatory authority (regulator), which chooses in the first period to either liquidate or bail out insolvent banks. The term "liquidation" is used to describe the insolvency resolution, as opposed to the duly closure of each bank at the end of the second period, when the economy terminates.

3 Insolvency Resolution

In the first period, banks collect deposits in the amount of D and invest them in a portfolio with share x of the risky asset and share $(1 - x)$ of the risk-free one. In the

[6] Throughout this paper, banks and bankers are synonyms. Bankers are infinitesimal in the population.

second period, if the state of nature $\mathbf{s} \in \{H, L\}$ is realized, the value $V^{\mathbf{s}}$ of a bank is

$$V^{\mathbf{s}} = \left[xr^{\mathbf{s}} + (1-x)\, r^F\right] D \tag{1}$$

The bank is insolvent if $V^{\mathbf{s}} < r^D D$. If the insolvent bank is liquidated, each depositor receives $\frac{V^{\mathbf{s}}}{D}$ per unit of the initial deposit and thus faces the state-contingent rate of return $xr^{\mathbf{s}} + (1-x)\, r^F$. If the insolvent bank is bailed out, the regulator injects liquidity in the amount of

$$\max\left(r^D D - V^{\mathbf{s}}; 0\right) = \max\left(r^D - \left(xr^{\mathbf{s}} + (1-x)\, r^F\right); 0\right) D > 0 \tag{2}$$

and depositors are repaid in full.[7]

Bankers are assumed to internalize the costs of liquidation/bailout proportionally to the gap between the value of the bank and the amount due to depositors. Hoggarth et al. [2003] stress that government liquidity injections are mostly conditional on changes in senior management, who lose their jobs[8]; at the same time, shareholders bear some losses as well. Although management's losing jobs is not relevant for the one-period setting in this paper, the losses of shareholders still play an important role. Specifically, in order to prevent moral hazard, government can mandate an infusion of private sector capital, when performing an open bank assistance. Although there is no moral hazard in the model, costs internalization prevents negative effects of the limited liability (which is then a special case with zero costs internalization). Brown and Dinç [2005] provide an empirical evidence on costs internalization for bank failures in emerging markets. They report, in particular, that if a failed bank is taken over by the state, pre-failure owners and top management lose the most; depositors tend

[7] For the sake of brevity, the source of such a subsidy is not discussed here. It may be thought as taxes collected by the Regulator from future generations, which are not considered in the two-period setting here.

[8] They say that Paul Volcker, asked once by a bank's CEO, what would he reply to a banker requesting a bailout, answered that he would be glad to discuss the issue with the banker's successor. ("Smach the glass", *Economist*, Oct. 18th, 2007)

to lose much less, if anything. These ideas (job/reputation loss by management and private capital infusions) are captured by the internalization of costs.

The internalization of costs need not be symmetric in the liquidation and in the bailout case, therefore we assume that bankers internalize fraction $\lambda \in [0;1]$ of the portfolio-deposits gap if the bank is liquidated and fraction $\mu \in [0;1]$ if it is bailed out. The payoff of bankers in the liquidation case is hence

$$\left[\max\left(xr^{\mathbf{s}} + (1-x)\, r^F - r^D; 0\right) - \lambda \max\left(r^D - \left(xr^{\mathbf{s}} + (1-x)\, r^F\right); 0\right)\right] D \tag{3}$$

and in the bailout case it is

$$\left[\max\left(xr^{\mathbf{s}} + (1-x)\, r^F - r^D; 0\right) - \mu \max\left(r^D - \left(xr^{\mathbf{s}} + (1-x)\, r^F\right); 0\right)\right] D \tag{4}$$

If the costs internalization is symmetric, $\lambda = \mu$, the payoff of bankers if liquidated is the same as if bailed out, and as a result, bankers' choice does not depend on the regulatory policy. The asymmetric case can serve as a metaphor for other distortions in the decision-making by bankers, which can be caused by the regulatory policy. If $\lambda = \mu = 1$, we obtain complete internalization of costs by bankers, which corresponds to "unlimited liability".[9] If $\lambda = \mu = 0$, bankers enjoy limited liability. To rule out the limited liability effects, we assume from this point that $\lambda, \mu > 0$.

No moral hazard issues arise here as no asymmetry of information is assumed. If bankers wish to collect deposits and declare bankruptcy after reaping the investment gains, the proceeds of the investment are fully verifiable and the above described insolvency resolution procedure presumes that they are used to repay to depositors. Therefore bankers have no incentives to declare themselves insolvent. Furthermore,

[9] To avoid possible negative consumption in the second period, we might assume that agents obtain in the second period a lump-sum payment additionally to the investment payoff. In this case the penalty on bankers (internalized bailout costs) is deducted from this amount. This additional payment does not change the decision-making in the first period, this is why it is superfluous for the analysis and not considered in the text.

portfolio selection is costless and does not require any [potentially unverifiable] efforts. With regards to unfair pricing, positive penalties ensure that bankers have no incentives to establish excessively high interest rate on deposit. Although constructive ambiguity cannot be justified here through moral hazard, it will arise in the next section as multiple optima of the social welfare function.

The focus on bailouts and liquidations is mainly due to the simple setting of the model which however suffices to demonstrate the effects of political ambiguity. In general we only need to require that the regulator has several policy options which might have asymmetric effects on the public. As we will see below, the result does not require that $\lambda \neq \mu$. To obtain the inefficiency result in Section 5 it will suffice that the policy options available to the regulator create asymmetric outcomes at least for one group of agents. Bailouts and liquidations capture this property.

4 Optimal Bailouts

In this section, we derive the optimal bailout policy of the regulator. As usual, the regulator maximizes social welfare. Since the public strictly prefers the risky asset to the risk-free one (see Section 2), the public is better off if the total endowment of depositors is invested in the risky asset. Therefore, the Regulator chooses the probability of bailout to ensure that in the resulting equilibrium (1) agents deposit their entire endowment with banks, and (2) bank portfolios consist entirely of the risky asset.

In period 1, the Regulator decides upon bailout probability z. This section studies the effect of z on the equilibrium by assuming that depositors and bankers are aware of z.

4.1 Households

Households decide upon the composition of their portfolio with share a of deposits and $(1-a)$ of the safe asset and search for $\max_a G^e$, s.t. $0 \leq a \leq 1$, with G^e- expected gains of households:

$$\begin{aligned} G^e &= zar^D + p(1-z)\,a\min\left\{r^D; xr^H + (1-x)\,r^F\right\} \\ &\quad + (1-p)(1-z)\,a\min\left\{r^D; xr^L + (1-x)\,r^F\right\} + (1-a)\,r^F \end{aligned} \tag{5}$$

In (5), the first term corresponds to the deposit payoff in the bailout case: a units of deposit are repaid in full with interest rate r^D no matter whether the bank is solvent or not. The second and the third terms correspond to state-contingent deposit payoffs in the liquidation case: if the bank is insolvent, depositors only obtain $xr^{\mathbf{s}} + (1-x)\,r^F$ pro unit of deposit in each state of nature $\mathbf{s}$. The fourth term describes the payoff through investment in the safe asset, which depends neither on the state of the nature nor on the liquidation/bailout decision of the regulator.

Since there is a unit mass continuum of households possessing a unit endowment, a solution of the individual optimization problem above determines the aggregate supply of deposits:

$$D^s = a^* \in \arg\max_a G^e \tag{6}$$

Solving for a^* is straightforward due to the linearity of G^e in a: depositors place their entire endowment as deposits with banks, as soon as the expected return from depositing is higher than the risk-free rate of interest. If the expected deposit payoff equals to the risk-free return, households are assumed to invest in the deposit contract. This assumption simplifies the exposition. A possible interpretation of it could be infinitesimal transaction costs, induced by a purchase of the risk-free asset. From the straightforward solution of the optimization problem it follows that for a given probability of bailouts z, aggregate deposit supply is given by

$$D^s\left(r^D, x\right) = \begin{cases} 1 & \text{if } \ r^D \geq r_D^D \\ 0 & \text{if } \ r^D < r_D^D \end{cases} \tag{7}$$

$$\text{with } r_D^D = r^F + \frac{(1-p)(1-z)}{p+z(1-p)} x\left(r^F - r^L\right) \tag{8}$$

Note that the demand for deposits depends on the deposit interest rate r^D and on the financial quality of the bank x, and is parametrized on the bailout policy z. Term $\frac{(1-p)(1-z)}{p+z(1-p)}x\left(r^F - r^L\right)$ represents the interest margin, which depositors require in order to switch from risk-free assets to deposits. It is distinct from the risk premium, which is zero since agents are risk-neutral.

4.2 Banks

In period 1, each bank decides upon its portfolio composition x and the amount of deposits D to be collected. The banks are aware of two possible actions of the Regulator: bailout with probability z, and liquidation with probability $1-z$. The state contingent payoff of banks is conditioned on the state of nature **s** and on the action of the regulator and discussed in Section 3. The expected payoff function of bankers takes the following form:

$$\begin{aligned} \Pi^e = \; & p \max\left[xr^H + (1-x)r^F - r^D; 0\right] D + \\ & (1-p)\max\left[xr^L + (1-x)r^F - r^D; 0\right] D - \\ & p\left(z\mu + (1-z)\lambda\right)\max\left[r^D - \left(xr^H + (1-x)r^F\right); 0\right] D - \\ & (1-p)\left(z\mu + (1-z)\lambda\right)\max\left[r^D - \left(xr^L + (1-x)r^F\right); 0\right] D \end{aligned} \tag{9}$$

The first two terms correspond to the expected profit of banks under limited liability. The third and fourth terms stand for the costs internalization. Note that with no internalization, the probability of bailout would vanish from the expected payoff of banks.

Each bank seeks for $\max\limits_{x,D}\Pi^e$ subject to $D \geq 0$ and $0 \leq x \leq 1$. The solution of this optimization problem is again straightforward due to its linearity in both D and x. As a result, if the Regulator bails out insolvent banks with probability $z \in (0,1]$, and if banks internalize the cost of bailouts $(\lambda, \mu > 0)$, the optimal choice $\left(x^*, D^d\right)$ of each competitive bank is:

$$x^* \in \begin{cases} [0;1] & \text{if } r^D > r_B^D \\ \{1\} & \text{if } r^D \leq r_B^D \end{cases} \tag{10}$$

$$D^d \in \begin{cases} \{0\} & \text{if } r^D > r_B^D \\ [0,\infty) & \text{if } r^D = r_B^D \\ \{\infty\} & \text{if } r^D < r_B^D \end{cases} \tag{11}$$

$$\text{with } r_B^D = \frac{pr^H + (z\mu + (1-z)\lambda)(1-p)r^L}{p + (z\mu + (1-z)\lambda)(1-p)}$$

Note that in a banking sector of a unit size, D^d above describes the aggregate demand for deposits.

4.3 Equilibrium and Optimal Bailout Rule

Now we need to define the deposit market equilibrium and find the optimal bailout policy. If we denote with X^* equilibrium aggregate investment in the risky asset, and with D^* - equilibrium aggregate amount of deposits, then the optimal policy of the regulator is the one, for which $X^* = D^* = 1$ as this allocation maximizes social welfare: for risk neutral depositors utility is higher when the whole endowment is invested in the risky asset.

Definition 1 *For a given bailout policy z, competitive equilibrium is the allocation of funds (X^*, D^*) and the interest rate r_c^D, which provides*

1. $X^* = x^* D^d$ *with* $\left(x^*\left(r_c^D\right), D^d\left(r_c^D\right)\right) \in \arg\max \Pi^e$
2. $D^s\left(r_c^D, x^*\right) = a^* \in \arg\max G^e$
3. $D^* = D^s\left(r_c^D, x^*\right) = D^d\left(r_c^D\right)$

The definition of equilibrium requires that deposit supply equals deposit demand. Note that equilibrium is parametrized on the bailout policy of the regulator. The portfolio choice x^* by banks is uniquely determined by the equilibrium interest rate r_c^D and the regulator's choice of z. Given x^* and D^*, the equilibrium investment in the risky asset is determined by $X^* = x^* D^*$.

Proposition 1 *The competitive equilibrium is:*

$$X^* = D^* = 1 \tag{12}$$

$$r_c^D = \frac{pr^H + (z\mu + (1-z)\lambda)(1-p)r^L}{p + (z\mu + (1-z)\lambda)(1-p)}$$

for any bailout policy $z \in [\max(\underline{z}, 0); 1]$ *with*

$$\underline{z} = \frac{\lambda(1-p)\left(r^F - r^L\right) - p\left(pr^H + (1-p)r^L - r^F\right)}{(1-p)p\left(r^H - r^L\right) - (\mu - \lambda)(1-p)\left(r^F - r^L\right)} \tag{13}$$

The proposition straightforwardly follows from equating deposit supply and demand functions (7 and 11). Fig. 2 illustrates the proposition. Bailout policy threshold $\underline{z}$ is determined from the condition $r_D^D < r_B^D$ which ensures socially optimal investment $X^* = D^* = 1$. It is easy to check that $\underline{z} < 1$.[10]

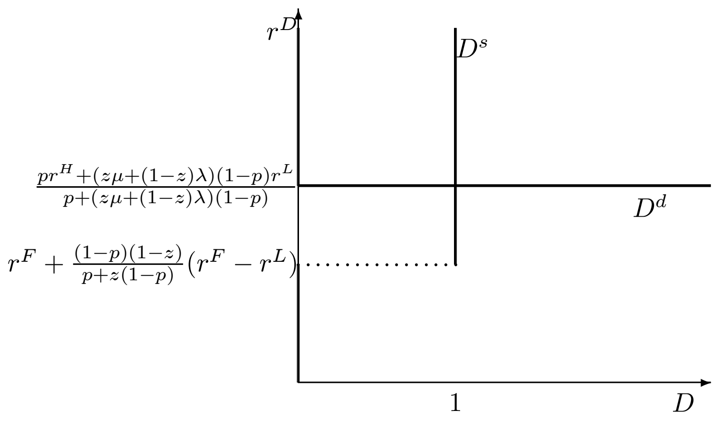

Figure 2. Equilibrium with known bailout/liquidation policy z

[10] The nominator is smaller than the denominator if and only if $\mu < \frac{p}{1-p}\frac{r^H - r^F}{r^F - r^L}$, with the right-hand side strictly greater than unity due to Assumption A-2.

As an additional result we observe that penalties on bankers (internalization of bailout/liquidation costs) can require that the regulator avoids commitment to liquidation. In particular, if λ is high and greater than μ, regulator should avoid bailout policies with too low z, otherwise banks' behavior is too cautious and the efficient allocation cannot be achieved in equilibrium.

This issue of agents exhibiting cautious behavior receives a greater importance as soon as we assume that the regulator follows the policy of constructive ambiguity and/or cannot credibly communicate z to the public. Depositors and bankers are aware of objectives of the regulator and know the solution of the regulators optimization problem. However the multiplicity of optima makes the policy ambiguous. The next section studies the efficiency of the equilibrium allocation if bankers and depositors make decisions under ambiguity.

5 Ambiguous Bailouts

Assume the regulator does not commit to any bailout rule. Without loss of generality we consider the range of potentially optimal bailout policies $z \in [\underline{z}; 1]$, and substitute for $\underline{z} = 0$ wherever $\lambda < \frac{p}{1-p} \frac{pr^H + (1-p)r^L - r^F}{r^F - r^L}$. Uncertainty about the regulatory policy induces uncertainty about the payoff structure in the model. Note that the analysis above does include uncertainty in form of a possible mixed strategy of the regulator, i.e. a stochastic bailout-liquidation rule. Now it is assumed that depositors and bankers possess less information than before, but still are symmetrically informed about the economy. To be precise, depositors and bankers are informed about the following: (1) the set of players in the economy, (2) set of strategies of each player, and (3) payoff functions of all players. Payoff functions are stochastic and determined by the realization of the random variable $\mathbf{s}$, which determines the state of nature, and consequently, the realization of the return of the risky asset.[11] As shown above, under uncertainty in terms of stochasticity (Arrovian uncertainty) the equilibrium allocation is efficient, if the bailout policy is chosen from a suitable range. Ambiguity (Knightian uncertainty) is distinct from stochasticity.

5.1 Nature of Ambiguity and Decision-making

Under assumption of rationality, agents should be able to predict, which policy the regulator chooses, if they know the payoff function of the latter. Since it was assumed that the objective of the regulator is to provide for efficiency of the equilibrium allocation, both depositors and bankers can identify that this objective can be achieved through *any* policy in the range $z \in [\underline{z}; 1]$. There is no reason, why *both* depositors and bankers should count for the *same* probability of bailouts. Clearly, depositors and bankers operate under uncertainty, which is represented by a continuum of probability distributions over the regulatory policy. This kind of uncertainty is a special case of ambiguity.

One of the relevant concepts for decisions under ambiguity is the notion of pessimism and optimism. Wakker [2001] defines optimism and pessimism on the basis of choices, which agents would make, if their actions lead to different outcomes in different states of the world, probabilities of which are unknown. For example, if households in the current paper have access to the market of the risky asset, but are not aware of the probability distribution p, they would also face ambiguity. Knowing that two states of nature are possible, they might prefer to invest in the risky asset (which corresponds to optimism) or to invest in the risk-free asset (which corresponds to pessimism). The

[11] One might wish to see nature as a fourth player in the game. This would require additional discussion, which is not in the focus of the current paper.

reason for that is that for an optimist, the best possible outcome overweighs the worst one, and for a pessimist the opposite is true.[12]

There are several ways to capture optimism and pessimism in the decision-making.[13] Same agents can exhibit both optimistic and pessimistic behaviors in different situations or even take into account both best and worst outcomes in their decisions. To show that an equilibrium outcome under ambiguity may differ from the one under a stochastic bailout rule, we assume that agents weigh best and worst. If we denote the degree of pessimism with α, then depositors maximize the following functional:

$$\alpha \min_{z\in[\underline{z};1]} G^e(z) + (1-\alpha) \max_{z\in[\underline{z};1]} G^e(z) \tag{14}$$

with $G^e(z)$ denoting the expected gains of depositors (5) for a given bailout policy z. We can also interpret α as the fraction of depositors that exhibits pessimistic behavior and $1-\alpha$ as the optimistic fraction. The above functional then represents an average depositor.

The first term in (14) corresponds to pessimism and counts for the worst outcome, and the second term corresponds to optimism and counts for the best outcome. Extreme pessimism corresponds to $\alpha = 1$. The ambiguity itself is captured by the fact that bailouts may follow any probability distribution $z \in [\underline{z}; 1]$. More generally, $z \in \Delta_z \subseteq [0;1]$ with Δ_z capturing the degree to which agents are informed about the regulatory policy. If $\Delta_z = \{\widehat{z}\}$ then (14) turns into $G^e(\widehat{z})$, and we obtain the above discussed case without ambiguity.

Differentiating (5) with respect to z yields $\frac{\partial G^e}{\partial z} = 0$ if $r^D > xr^H + (1-x) r^F$, or

[12] Gneezy et al. (2006) provide a paradoxical experimental evidence that a lottery over the best and the worst may be valued significantly lower than the worst outcome itself. Decisions under ambiguity, as described in the text, are not related to such behavioral effects.

[13] Chateauneuf et al. (2007) introduce non-extreme outcome additive capacities (neo-additive capacities) to represent the CEU as a weighted sum of the EU-term, a pessimistic term, and an optimistic term. Simple capacities (see, e.g. Eichberger and Kelsey, 2000) also capture the same possibility.

$\frac{\partial G^e}{\partial z} > 0$ in all other cases. Therefore, the worst expected outcome for depositors is associated with liquidation of banks: $\min_{z\in[\underline{z};1]} G^e(z) = G^e(\underline{z})$. The best expected outcome takes place if the regulator bails out insolvent banks: $\max_{z\in[\underline{z};1]} G^e(z) = G^e(1)$. This implies that under ambiguity depositors maximize

$$\alpha \min_{z\in[\underline{z};1]} G^e(z) + (1-\alpha) \max_{z\in[\underline{z};1]} G^e(z) = \tag{15}$$
$$(1-\alpha(1-\underline{z}))\, ar^D + (1-\alpha)\, ar^D + \alpha p (1-\underline{z})\, a \min\left\{r^D; xr^H + (1-x)\, r^F\right\} +$$
$$\alpha(1-p)(1-\underline{z})\, a \min\left\{r^D; xr^L + (1-x)\, r^F\right\} + (1-a)\, r^F$$

Note that technically (15) repeats (5) if we replace $z := 1-\alpha(1-\underline{z})$.

We can do the same exercise for banks, by replacing $G^e(z)$ in functional (14) with expected payoff of bankers $\Pi^e(z)$ from (9). Assume that the degree of pessimism of bankers is given by β, which is not necessarily equal to α. Again, we need to identify, what is the worst outcome for bankers, who internalize bailout costs:

$$\begin{aligned}\frac{\partial \Pi^e}{\partial z} &= -p(\mu-\lambda)\max\left[r^D - \left(xr^H + (1-x)\, r^F\right); 0\right] D - \\ &\quad -(1-p)(\mu-\lambda)\max\left[r^D - \left(xr^L + (1-x)\, r^F\right); 0\right] D\end{aligned}$$

For positive values of D we obtain $\frac{\partial \Pi^e}{\partial z} < 0$ if $\mu > \lambda$ ($\frac{\partial \Pi^e}{\partial z} > 0$ if $\mu < \lambda$) for all r^D, except $r^D < xr^L + (1-x)\, r^F$, in which case $\frac{\partial \Pi^e}{\partial z} = 0$. If bankers internalize insolvency costs equally in liquidation and bailout case, $\mu = \lambda$, their choice is independent of bailout policy.

If $\mu > \lambda$, the worst expected outcome for bankers is associated with bailouts: $\min_{z\in[\underline{z};1]} \Pi^e(z) = \Pi^e(1)$. The best expected outcome is associated with liquidation: $\max_{z\in[\underline{z};1]} \Pi^e(z) = \Pi^e(\underline{z})$ (it is vice versa, if $\mu < \lambda$). Similarly to depositors, bankers maximize the functional:

$$\beta \min_{z\in[\underline{z};1]} \Pi^e(z) + (1-\beta) \max_{z\in[\underline{z};1]} \Pi^e(z) = \tag{16}$$
$$= \begin{cases} \beta\Pi^e(1) + (1-\beta)\Pi^e(\underline{z}) & \text{if} \quad \mu \geq \lambda \\ \beta\Pi^e(\underline{z}) + (1-\beta)\Pi^e(1) & \text{if} \quad \mu < \lambda \end{cases}$$

Terms $\Pi^e(1)$ and $\Pi^e(\underline{z})$ differ only with regards to the internalization of bailout/liquidation costs. Denote

$$\theta = \begin{cases} \beta\mu + (1-\beta)(\underline{z}\mu + (1-\underline{z})\lambda) & \text{if} \quad \mu \geq \lambda \\ (1-\beta)\mu + \beta(\underline{z}\mu + (1-\underline{z})\lambda) & \text{if} \quad \mu < \lambda \end{cases}. \tag{17}$$

Functional (16) takes now the form

$$\begin{aligned} & p \max\left[xr^H + (1-x)r^F - r^D; 0\right] D + \\ & (1-p)\max\left[\left(xr^L + (1-x)r^F - r^D\right); 0\right] D - \\ & \theta p \max\left[xr^H + (1-x)r^F - r^D; 0\right] D - \\ & \theta(1-p)\max\left[\left(xr^L + (1-x)r^F - r^D\right); 0\right] D, \end{aligned} \tag{18}$$

which technically repeats (9) with $z\mu + (1-z)\lambda := \theta$.

Note that similarity between (15) and (5) as well as between (18) and (9) is only technical and does not arise through substitution of z with some perceived probability of bailouts. The latter would be the case if we consider asymmetric information leading to different degenerated priors $\Delta_z = \{\widehat{z}\}$ for depositors and bankers. Instead, the information is symmetric, and both face the same prior $\Delta_z = [\underline{z}; 1]$ for the bailout policy. Even more, depositors and bankers treat the missing information in the same way, and as a special case we can obtain equal degrees of pessimism $\alpha = \beta$. It is the combination of the degree of optimism/pessimism and the worst/best outcomes that technically replaces z in the objective functions.

5.2 Equilibrium under Ambiguity

As noticed above, technically the objective function of depositors (15) under ambiguous bailout policy repeats their objective function (5) with $z := 1 - \alpha(1 - \underline{z})$. Their optimization problem is the same as before. To determine the supply of deposits, it suffices to substitute for $z := 1 - \alpha(1 - \underline{z})$ in (7):

$$\begin{aligned} D^s\left(r^D, x\right) &= \begin{cases} 1 & \text{if } r^D \geq r^D_D \\ 0 & \text{if } r^D < r^D_D \end{cases} \\ \text{with } r^D_D &= r^F + \frac{(1-p)\alpha(1-\underline{z})}{p + (1 - \alpha(1-\underline{z}))(1-p)} x\left(r^F - r^L\right) \end{aligned} \tag{19}$$

The same applies to banks. To determine their optimal choice, it suffices to substitute for $z\mu + (1-z)\lambda := \theta$ in (11):

$$\begin{aligned} x^* &\in \begin{cases} [0;1] & \text{if } r^D > r^D_B \\ \{1\} & \text{if } r^D \leq r^D_B \end{cases} \\ D^d &\in \begin{cases} \{0\} & \text{if } r^D > r^D_B \\ [0,\infty) & \text{if } r^D = r^D_B \\ \{\infty\} & \text{if } r^D < r^D_B \end{cases} \\ \text{with } r^D_B &= \frac{pr^H + \theta(1-p)r^L}{p + \theta(1-p)} \end{aligned} \tag{20}$$

We can define an equilibrium in a similar way as before:

Definition 2 *For given degrees of pessimism α and β, the equilibrium under ambiguity is the allocation of funds (X^*, D^*) and the interest rate r^D_a, which provide*

1. $X^* = x^* D^d$
2. $D^s\left(r^D_a, x^*\right) = a^*$
3. $D^* = D^s\left(r^D_a, x^*\right) = D^d\left(r^D_c\right)$

   where $\left(x^*\left(r^D_a\right), D^d\left(r^D_a\right)\right)$ *maximizes* $\beta \cdot \min\limits_{z\in[\underline{z};1]} \Pi^e(z) + (1-\beta) \cdot \max\limits_{z\in[\underline{z};1]} \Pi^e(z)$
   and a^* *maximizes* $\alpha \cdot \min\limits_{z\in[\underline{z};1]} G^e(z) + (1-\alpha) \cdot \max\limits_{z\in[\underline{z};1]} G^e(z)$.

Note that the equilibrium is not anymore parametrized on the bailout policy, since the latter is not announced. Instead, the equilibrium is parametrized on the degree of pessimism of the agents. The following proposition establishes that the economy can settle in an inefficient equilibrium.

Proposition 2 *The equilibrium under ambiguity is given by:*

$$X^* = D^* = \begin{cases} 1 & \text{if } \; p \cdot \frac{p+(1-\alpha(1-\underline{z}))(1-p)}{p+\theta(1-p)} \geq \frac{r^F - r^L}{r^H - r^L} \\ 0 & \text{if } \; p \cdot \frac{p+(1-\alpha(1-\underline{z}))(1-p)}{p+\theta(1-p)} < \frac{r^F - r^L}{r^H - r^L} \end{cases}$$

$$r_a^D \in \begin{cases} \left\{ r_B^D \right\} & \text{if } \; p \cdot \frac{p+(1-\alpha(1-\underline{z}))(1-p)}{p+\theta(1-p)} \geq \frac{r^F - r^L}{r^H - r^L} \\ \left[r_B^D ; r_D^D \right] & \text{if } \; p \cdot \frac{p+(1-\alpha(1-\underline{z}))(1-p)}{p+\theta(1-p)} < \frac{r^F - r^L}{r^H - r^L} \end{cases}$$

$$\text{with } r_B^D = \frac{pr^H + \theta (1-p) r^L}{p + \theta (1-p)},$$

$$r_D^D = r^F + \frac{(1-p)\alpha (1-\underline{z})}{p + (1 - \alpha (1-\underline{z}))(1-p)} \left(r^F - r^L \right),$$

$$\text{and } \theta = \begin{cases} \beta\mu + (1-\beta)(\underline{z}\mu + (1-\underline{z})\lambda) & \text{if } \; \mu > \lambda \\ \mu & \text{if } \; \mu = \lambda \\ (1-\beta)\mu + \beta(\underline{z}\mu + (1-\underline{z})\lambda) & \text{if } \; \mu < \lambda \end{cases} .$$

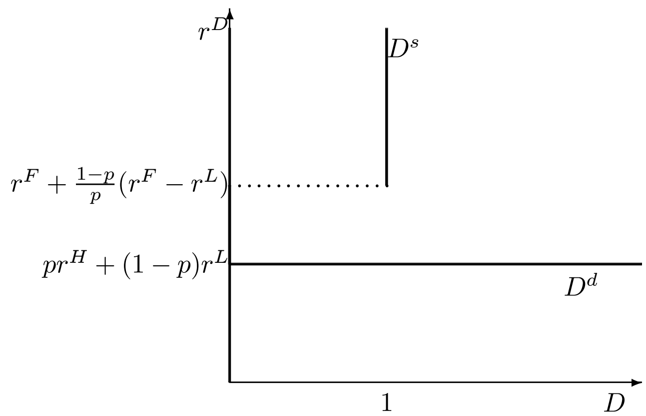

Figure 3. Equilibrium under ambiguity: an example

Condition $p \cdot \frac{p+(1-\alpha(1-\underline{z}))(1-p)}{p+\theta(1-p)} \geq \frac{r^F - r^L}{r^H - r^L}$ characterizes the investment climate in the economy: it relates risk, pessimism and rates of return. Figure 3 highlights the intuition behind the proposition, assuming $\alpha = \theta = 1$ and $\underline{z} = 0$. Competitive banks choose $x^* = 1$ and set the deposit rate so that their expected profit is zero. If $D > 0$, this implies deposit interest rate of $pr^H + (1-p) r^L$, which should exceed or be equal to the rate $r^F + \frac{1-p}{p}\left(r^F - r^L\right)$, required by depositors. This is only possible if $p^2 \geq \frac{r^F - r^L}{r^H - r^L}$. In fact, inefficient equilibria appear because bankers exhibit cautious behavior and avoid acquiring deposits at high interest rates. At the same time, pessimistic depositors exhibit cautious behavior as well, and avoid depositing at interest rates which make the expected return on deposits lower than the risk-free rate.[14] It is important that bankers do not need to exhibit pessimism or optimism (which is the case if $\mu = \lambda$): the equilibrium can be inefficient due to the cautious behavior of depositors solely.

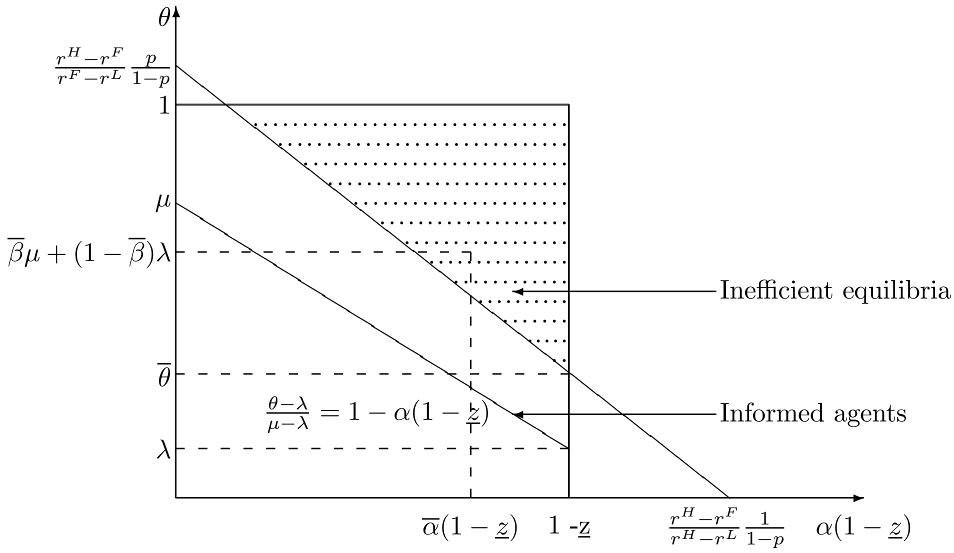

Figure 4. Degrees of pessimism, costs internalization and inefficient equilibria

Figure 4 provides an illustration of the result for arbitrary degrees of pessimism and costs internalization. Condition $p \cdot \frac{p+(1-\alpha(1-\underline{z}))(1-p)}{p+\theta(1-p)} \geq \frac{r^F-r^L}{r^H-r^L}$ corresponds to the area below the threshold line $\theta = \frac{p}{1-p}\frac{r^H-r^F}{r^F-r^L} - \alpha\left(1-\underline{z}\right)p\frac{r^H-r^L}{r^F-r^L}$, which intersects the axes in points $\frac{p}{1-p}\frac{r^H-r^F}{r^F-r^L} > 1$ and $\frac{1}{1-p}\frac{r^H-r^F}{r^H-r^L} > 1$ (both are above unity due to Assumption A-2). For some given level of θ, the dotted area in the picture represents inefficient

[14] The expected return as given by the probability of the states of nature, not by the bailout policy.

equilibria. Threshold $\overline{\theta}$ represents the highest level of θ which precludes existence of inefficient equilibria even for highest possible degree of pessimism of depositors and the toughest possible liquidation policy, i.e. for $\alpha(1-\underline{z})=1$:

$$\overline{\theta}=\frac{p}{1-p}\frac{pr^H+(1-p)\,r^L-r^F}{r^F-r^L}. \tag{21}$$

Inefficient equilibria can only appear if $\theta>\overline{\theta}$, which implies that the necessary condition for them to appear is $\overline{\theta}<1 \Leftrightarrow p^2<\frac{r^F-r^L}{r^H-r^L}$. Recalling that the risky project is characterized by the expected return of $\overline{r}=pr^H+(1-p)\,r^L$ and by the variance of $\sigma^2=p\,(1-p)\left(r^H-r^L\right)^2$ yields the following interpretation of the necessary condition for inefficiency of equilibria:

$$\sigma^2>\left(r^H-r^L\right)\left(\overline{r}-r^F\right). \tag{22}$$

According to (22), an ambiguous bailout policy is more likely to lead to the inefficiency of financial intermediation in economies with relatively high investment risk. On the contrary, if the investment risk is relatively low ($\sigma^2\leq\left(r^H-r^L\right)\left(\overline{r}-r^F\right)$), then ambiguity in the bailout policy does not have any effect on the efficiency of equilibrium, for any uncertainty attitude of the public.

Recall that objective functions of depositors (15) and bankers (16) under ambiguity technically coincide with their objective functions (5) and (9) under announced bailouts if $z:=1-\alpha(1-\underline{z})$ for depositors and $z\mu+(1-z)\,\lambda:=\theta$ for bankers. If the regulator can make the public aware that bailout policy z is chosen then beliefs of depositors and bankers align along the line $\frac{\theta-\lambda}{\mu-\lambda}=1-\alpha(1-\underline{z})$ in Figure 4, which lies entirely in the area of efficient equilibria, no matter how (un)favorable the investment climate is in the economy and what degree of costs internalization is imposed by the insolvency regulation.

6 Policy implications and discussion

The model above justified the existence of banks by their exclusive access to the market of risky assets. In spirit of Benston and Smith [1976] this could be explained by high transaction costs and by the ability of banks to reduce them. Although the system of financial markets in the economy is complete, depositors only have access to one of them, and this incomplete participation problem prevents them from achieving the efficient allocation of resources. Banks re-establish efficiency. The regulation in this paper concerns insolvency resolution rules. If these rules are unclear, the efficient outcome can be destroyed. This section first considers some policy implications of the model and then discusses possible extensions to capture other functions of banks.

Translating the above inefficiency condition $\theta > \overline{\theta}$ in terms of costs internalization μ and λ would give a policy implication in spirit of Caballero and Krishnamurthy (2008), i.e. aiming at reducing the anxiety of the agents. Inefficiency condition $\theta > \overline{\theta}$ turns into $\mu > \lambda > \frac{\overline{\theta}}{(1-\beta)(1-\underline{z})} - \frac{\beta+(1-\beta)\underline{z}}{(1-\beta)(1-\underline{z})}\mu$ or $\lambda > \mu > \frac{\overline{\theta}}{1-\beta(1-\underline{z})} - \frac{\beta(1-\underline{z})}{1-\beta(1-\underline{z})}\lambda$ depending on which of the policy options brings higher penalties to bankers, or into $\mu = \lambda > \overline{\theta}$ in the case of symmetric penalties. Recall that $\overline{\theta}$ is fully described by the macroeconomic parameters such as risk and expected return of the risky asset as well as the risk-free rate of return. Thus the regulator can avoid inefficient outcome by reducing the penalties imposed on bankers below the threshold value given by macroeconomic conditions. If the regulator wishes to maintain asymmetric penalty effects of the two policy options then the degree of bankers' pessimism/optimism β should also be taken into account. Both μ and λ can be reduced to ensure efficiency. Reducing the higher of the two measures μ and λ shrinks the inefficiency intervals above and thus makes it easier for the regulator to ensure efficiency for any β. By reducing the lower one the regulator can abandon the inefficiency interval straightforwardly. None of these actions will preclude depositors' cautious behavior but they will reduce the anxiety of bankers who will go for a higher interest rate demanded by depositors.

A completely different policy implication relies on the ability of the regulator to align the beliefs of the public instead of reducing their anxiety. If the regulator can credibly commit to either of the policy options then inefficiency never occurs. However, as mentioned in the introduction, there can be reasons that make such a commitment undesirable, in which case the regulator would prefer some mix of the two options. The question is therefore whether some non-degenerate probability distribution z can be credibly communicated to the public. If this is possible then public beliefs are homogenous and Proposition 1 guarantees an efficient allocation of resources in equilibrium. If the regulator can use an external publicly observed randomizer than the problem is solved.

The conclusions of the model seem robust to the definition of banks and the role they play. A more sophisticated justification of banks would appear if asymmetric information is introduced into the model, and banks act as delegated monitors (Diamond, 1984). This could be done by assuming that there are many borrowers i who all have access to identical risky production technology described by p, r^H and r^L as in the above model but have different managerial skills and thus generate projects characterized by different r_i^L and r_i^H. Banks can improve the quality of the projects through active monitoring and thus achieve the parameters r^H and r^L of the risky investment, which is superior to the distributions available without monitoring. The rest of the analysis is unchanged. Delegated monitoring function of banks provides ground for insolvency and competition regulation: (1) bank failures should be costly to create incentives for bankers to monitor properly, and (2) restrictions on diversification would reduce the efficiency of monitoring cost reduction (Diamond, 1996). Again, the role of the regulator in application to the model above consists in the determination of a clear insolvency resolution rule and penalties for bankers.

To provide an additional reason for the bailout policy, a framework with bank runs could be used. This would require a complete reformulation of the model. In the bank run model of Diamond and Dybvig [1983], the liquidity provision role of banks arises because the system of available financial markets is incomplete, and banks create a market that allows agents to insure against idiosyncratic liquidity shocks (the incomplete markets setting complements the incomplete participation setting that is used in the current paper). However, patient depositors have incentives to mimic impatient depositors and withdraw their funds early, if they expect the bank to be unable to cover all early withdrawals. A deposit insurance financed through taxes on depositors (who are owners of mutual banks) prevents bank runs. Since banks offer deposit contracts that implement the ex-ante optimal allocation (c_1, c_2) with consumption by early withdrawal strictly less than consumption by late withdrawal, $c_1 < c_2$, deposit guarantees need not be promised with certainty. Indeed, any bailout probability $z \in \left[\frac{c_1}{c_2}, 1\right]$ would prevent a bank run, since the expected payoff of patient depositors is at least c_1 in case of a bank run and strictly greater without bank runs. This multiplicity of regulatory optima would create the same ambiguity problem as in the model in the current paper. The rest of the analysis would then be built upon a similar reasoning as in the model above: if bankers internalize bailout/liquidation costs and the conditions of the deposit contract are negotiated in the market, where depositors and bankers have different beliefs with regards to failure resolutions, then inefficient allocation of resources can appear as an equilibrium outcome. The inefficiency in this case would mean that the resulting deposit contract would be strictly dominated by investment opportunities available in existing markets.

7 Conclusions

Regulatory ambiguity and political opacity have been for a long time being in the center of economic debates. The common approach to the issue is representing an opaque regulatory policy with a probability distribution over its possible realizations. This approach fails to capture possible heterogeneity of beliefs of uninformed agents. If the policy of the regulator is not announced, the public estimates the likelihood of the future outcomes according to their degrees of pessimism or optimism. Even if the public are homogenous in their ambiguity attitude, they can form different beliefs, if the regulation has an asymmetric impact on them.

In the current paper, regulatory ambiguity is studied in the market equilibrium framework. It is shown that even if agents are perfectly rational and symmetrically informed about each other, as well as about the macroeconomic environment, some missing piece of information can play a crucial role in determining the equilibrium outcome. The fact that the regulator is better informed about his policy than the public, does not create a problem of asymmetric information, since the regulator does not participate in the market interactions. If the perfectly rational public are informed about the objective function of the regulator, they may wish to find the optimal regulatory policy, which they would count for in their decision-making. However, if there are multiple optima, the public have to make decisions under ambiguity.

Regulatory ambiguity is studied here in application to the deposit market. An ambiguous bailout policy creates an asymmetry in beliefs of depositors and bankers with regards to the action of the regulator in case of banks' insolvency. This may result in a suboptimal allocation of funds as compared with the market outcome. Informing agents about the probability of bailouts eliminates the asymmetry in beliefs and restores the optimal allocation of funds. This result provides a reason for limiting the "constructive ambiguity" to a stochastic bailout rule with a probability of bailouts known to both bankers and depositors. A possible way to achieve this is to condition the bailout policy on a publicly observed macroeconomic parameter with known probability distribution. This parameter then plays the role of a publicly observed randomizer that aligns beliefs of the public.

The inefficiency result is more likely for economies (or time periods) with high aggregate investment risk and high internalization of bailout/liquidation costs by banks (penalty on bankers). If the regulator cannot credibly signal about his policy, and as a result the beliefs of the public cannot align, efficient equilibria still can be ensured, if the internalization of bailout costs by banks is low and aggregate investment risk is low. This comparative static exercise is in line with the observations from the recent financial crisis. In the pre-crisis environment with lower aggregate risk underinvestment was not an issue and constructive ambiguity did not seem to create a problem. The crisis has contributed to the aggregate investment risk and generated a wave of debates on "social responsibility" of bankers leading to increased penalties for bankers. As the model predicts, these two factors combined with an ambiguous bailout policy lead to underinvestment in the real sector. Although there are many other factors that contribute to underinvestment, the objective of the current paper was to draw attention to the one which importance seemingly has been underestimated in the "goldilocks economy": some negative effects of political ambiguity can only be seen in times of high aggregate risk.

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