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Lender of last resort and the moral hazard problem

Suomen Pankin keskustelualoitteita
Finlands Banks diskussionsunderlag

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Lender of last resort and the moral hazard problem

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Abstract

The paper considers a modelin which limited liability causes an asset substitution problem for banks. The problem can at times become so severe that the current regulatory framework – based on a combination of effectively full deposit insurance, minimum capital requirements and prudential supervision – proves inadequate for mitigating the moral hazard. Against this background, consideration is given to the question of how, and at what cost, an increase in market discipline would improve incentives. Finally, the additional microeconomic incentive effects of lender of last resort (LOLR) arrangements in the various alternatives is discussed. In conclusion, it is argued that LOLR arrangements in which the terms of liquidity support depend on the bank's risk profile can be effective in improving the bank's incentives to make the desired risk choice in the first place.

Key words: central bank, liquidity provision, lender of last resort, moral hazard

JEL classification numbers: E5, G0, G2

Keskuspankkien tarjoama hätärahoitus ja moral hazard -ongelma

Suomen Pankin keskustelualoitteita 17/2002

Mikko Niskanen
Tutkimusosasto

Tiivistelmä

Tutkimuksessa tarkastellaan ongelmaa, jossa osakkeenomistajien rajoitettu vastuuvelvollisuus synnyttää epäyhteneväisyyttä pankin ja tallettajien riskinottoa koskevissa tavoitteissa. Tästä aiheutuva moral hazard -ongelma voi muodostua niin vakavaksi, että sitä ei nykymuotoilla lakisääteisiin vakavaraisuusvaatimuksiin ja viranomaisvalvontaan sekä käytännössä hyvin pitkälle vietyyn tallettajansuojaan perustuvalla sääntelyjärjestelmällä enää kyetä tehokkaasti purkamaan. Tutkimuksessa pohditaan, voisiko tällaisessa tilanteessa pelkästään markkinakurin kasvattaminen tällöin johtaa yhteiskunnallisesti parempaan lopputulokseen. Erityisesti arvioidaan keskuspankkien mahdollisesti antaman hätärahoituksen merkitystä ja esitetään, että hätärahoitus, jonka ehdot voisivat olla riippuvaisia pankkien alun perin ottamista riskeistä, saattaisi kaikkein parhaiten täydentää muuta viranomaissääntelyä sekä markkinakuria oikeansuuntaisten kannustimien muodostuksessa.

Asiasanat: keskuspankit, likviditeetin tarjonta, hätärahoitus, moral hazard

JEL-luokittelu: E5, G0, G2

Contents

1 Introduction

Discussion of the pros and cons of central banks acting as lender of last resort (LOLR), ie providing banks and other financial institutions with liquidity when other institutions will not do so, has now continued for about 200 years. A vast literature, from Thornton (1802) and Bagehot (1873) in the early days, to as recently as eg Goodhart (1999), has supported the view that an LOLR is needed, primarily because otherwise there would remain a risk that small liquidity problems develop into widespread financial crises and lead ultimately to even more serious social consequences.[1] And almost as vast an opposition, with the loudest voices often from central banks themselves, has maintained that the LOLR is not needed mainly because its presence would, at worst, be outright detrimental. Specifically, it has been argued that this facility, just like any other public safety net, would give rise to a moral hazard problem as it makes banks more susceptible to excessive risk-taking. Moreover, once depositors realize that they are in effect guaranteed by the central bank, they would cease to provide market discipline through the monitoring of banks. As a result, the argument goes, bank losses would become even more probable and the financial system more fragile than would be the case without a lender of last resort.

As the previous discussion reveals, central banks are, in the final analysis, faced with a time consistency problem. Even if an LLR facility were beneficial ex post, ie after a liquidity shortage has occured, expectations of support from such a facility may weaken the banks' incentives ex ante in a way that makes the occurence of a liquidity shock even more probable. Having recognized this problem, central banks have in recent years aimed their rhetoric at the dampening of such expectations, either by remaining ambiguous about their role as lender of last resort in the first place (eg the European Central Bank) or by emphasizing that decisions are always made ex post on a discretionary basis (US Federal Reserve).[2]

However, despite the central banks' apparent attempts to efface all expectations concerning the LOLR, it still remains an open question what precisely are the effects, both in terms of banks' and their depositors' incentives, of such arrangements in the first place. Moreover, given all the new regulatory innovations that were introduced during the 20th century, are those effects still as strong as they were perhaps before. In this paper, we intend to address these questions. We examine the incentive effects of LOLR arrangements, both alongside and without deposit protection schemes, against the backdrop that banks are susceptible to a particularly severe moral hazard problem. In particular, we

[1] See Freixas et al (1999) for an extensive review of LOLR literature.

[2] Goodfriend and Lacker (1999) provide a recent discussion of the central bank's commitment problem in LOLR arrangements.

develop a framework which builds on a traditional asset substitution problem where moral hazard would occur, unless proper protective mechanisms are in place, because the bank can make its risk choice only after it has received deposits and because its equity holders are protected by limited liability.[3] Within this framework, if the moral hazard problem were not too severe, and the bank's cost of equity not too high, requiring the bank to keep a certain minimum amount of equity capital would be sufficient for mitigating moral hazard. However, we assume that the moral hazard problem is so severe that resorting to minimum capital requirements alone (as a means of aligning the bank's incentives with those of depositors) would lead to an unreasonably high equity ratio, not only in terms of increasing the bank's capital costs, but also as it reduces the supply of deposit-related services to the public, particularly in view of the social importance of deposits in facilitating payments and as a source of liquidity. Therefore, other means of discipline are needed as well.

Because of these reasons, we allow for the possibility that, depending on the safety net in place, the depositors can, either as a reaction to the bank's risk-taking or for purely exogenous reasons, refrain prematurely from the bank's refinancing. However, a central feature is that, while the depositors can substitute for excessively high equity requirements by providing market discipline in this way, limited transparency of the bank's risk profile has the effect that this type of market discipline would never be optimal (in the first-best sense) even ex post. After acknowledging this, we examine the various trade-offs that result in different institutional settings and consider different LOLR arrangements against this background. In this regard, our emphasis is on mechanisms where ex post contingencies, provided by the central bank in its role as LOLR, can be used as a

[3] More specifically, the asset substitution problem follows because limited liability in effect provides the shareholders with an option to limit their own losses to the initial amount of their equity capital. In order to maximize the value of this option, it is in the shareholders' interest to take more risk than is socially preferable. This idea was originally introduced by Jensen and Meckling (1976) in a general corporate finance setting that was applicable to all firms and not only to banks. However, it can be argued that it applies to banks particularly well, even if the effects of deposit insurance and other safety nets in further deteriorating the situation are not taken into account, because banks have many characteristics, especially their high leverage, the opacity of their assets, and their debt held by mainly small depositors, which make the moral hazard problem particularly relevant to them.

complement for market discipline and/or other regulatory requirements in inducing the bank for the desired risk choice.[4]

The structure of the paper is as follows. In section 2, we briefly review the relevant recent literature. In section 3, we present our general framework. In section 4, we make the characterization of a severe moral hazard problem. First-best solutions, which are assumed infeasible elsewhere in our paper, are discussed in section 5. In section 6, we discuss the various tradeoffs related to the introduction of market discipline when there is no LOLR. The effects of LOLR arrangements are then discussed in more detail in section 7. Section 8 concludes.

Things that are omitted in this paper but are certainly important in terms of banks' incentive formation are issues related to market structure. Moreover, we do not consider managerial incentives either.

2 Related literature

To a large extent, this paper has been inspired by two different strands of literature. First, there is a vast literature which builds on the idea that the financial system, for one reason or another, is inherently unstable and that banks therefore become occasionally subject to unnecessary bank runs. In recent years, most of these treatments have built on the model developed by Diamond and Dybvig (1983) where it was shown that at the same time when bank deposits are useful in improving intertemporal risk-sharing, they also make the economy more fragile by allowing multiple equilibria. In this regard, it has been suggested that the LOLR and other financial safety nets are useful as they prevent the unnecessary social costs that arise in the bad equilibria. For example, it was shown in Allen and Gale (1998) that some deadweight costs can indeed be removed with the existence of an LOLR. In our discussion, we consider situations where depositors

[4] Here, ex post contingencies are properties in the contractual relationship between the bank and the depositors (or the provider of deposit insurance), or between the bank and the LOLR, which allow for the utilization of possible ex post information about the bank's risk-taking in a way that can be used to induce the bank for making the desired choice already in the first place. For example, the feature that bank deposits can be withdrawn on demand is one such contingency because the awareness that the bank's depositors, in case of becoming informed about the bank's improper risk-taking, would react by withdrawing their funds (or by declining to roll over their existing short-term deposits), which would then force the bank to liquidate its assets in the amount of the liquidity shock (Calomiris and Kahn, 1991). Similarly, the awareness that banking supervisors may come to inspect the bank, and that this inspection would lead to an early closure if evidence concerning excessive risk-taking is found out, would also restrain the bank's willingness to take excessive risk. However, our main focus is on situations where ex post contingencies are related to LOLR arrangements and their specific features.

refrain from refinancing, though exogenous, to be realizations of bad equilibria similar to those modelled explicitly Diamond and Dybvig.

Second, there has emerged over the last 25 years an equally important literature, first applied in corporate finance but increasingly to the field of banking as well, which has increased the awareness of how certain institutional structures may have evolved as solutions to some problems caused initially by asymmetric information. More specifically, financial fragility may not just be an inherent problem within the banking system, but instead the institutional structures and contractual forms that cause it, ie the existence of banks and bank deposits in particular, may have developed as a rational response to more profound problems, such as relieving moral hazard inherent in all debtor-creditor relationships. Thus, the framework used in this paper is based on Jensen and Meckling (1976), perhaps the best-known incentive paper in corporate finance, and which has already earlier been adapted to banking framework by eg John, John and Senbet (1991). Recent examples of how this literature has developed towards optimal contracts are eg Diamond (1991), Rey and Stiglitz (1993) and Repullo and Suarez (1998). The role of bank deposits as an optimal contract has been discussed in Calomiris and Kahn (1991) and Calomiris, Kahn and Krasa (1991).

A recent survey of the economic literature on the LOLR can be found in Freixas et al (1999). The first serious discussion on the subject was in Bagehot (1873). A survey of the historical debate regarding the connection between the LOLR and moral hazard is found in Moore (1999). A recent more general survey of the economics of bank regulation, including how incentive effects are taken into account in the more contemporary literature, can be found in Bhattacharya et al (1998). The particular role of market discipline in this regard has recently been discussed in many papers. For example, one of the strongest proponents of market discipline is found in Calomiris (1999) and its limitations are discussed in Blum (2000). A discussion of the commitment problem faced by the central banks when acting as an LOLR is found in Goodfriend and Lacker (1999).

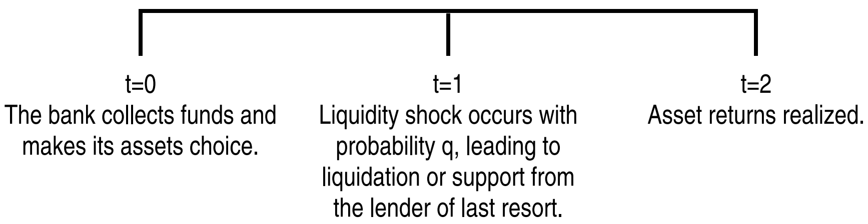
3 The general framework

We consider a model with depositors and/or public authorities acting jointly as principal and the bank's risk-neutral equity holders as agent and where the latter, because they are protected by limited liability, are susceptible to a moral hazard problem.[5] Therefore, proper ex ante incentives are needed for aligning the equity

[5] It is assumed that there is no coordination problem between depositors. Moreover, there are no agency problems between the bank's owners and its management. In other words, the bank's choices are entirely controlled by its equity holders, whose objective is to maximize their own expected return on equity.

holders' objective with the objectives of the depositors (and/or society at large) and for inducing the bank to make the desired choice. There are three periods in the model (t = 0,1,2). At t = 0, after collecting deposits (with their total amount normalized to one), the bank makes its asset choice. In making that choice, the bank assigns a certain probability, q, for an external liquidity shock to occur at t = 1, meaning that the depositors would refrain from renewing their deposits. This probability is first assumed to be independent and in later analysis dependent on the depositors' incentives to monitor the bank (the intensity of which depends again on the type of a possible safety net in place) and on the bank's initial risk choice. As a consequence, given the occurrence of the liquidity shock, unless there is an LOLR arrangement in place, the bank would be forced to liquidate prematurely and inefficiently asset holdings equal in amount to the size of the shock. We assume re-capitalisation of the bank with equity is not possible at such short notice. Finally at t = 2, if the bank has been able to continue its operations, asset returns would be finally realized. See figure 1 for a graphical illustration of the timing of the events.

Figure 1. **Timeline of events**



In making its asset choice at t = 0, the bank chooses between the following strategies:

1. A good (low-risk) strategy, denoted with subscript G, which returns x_G with certainty at t = 2 and L in case of a premature liquidation at t = 1.

2. A bad (high-risk) strategy, denoted with subscript B, which returns x_B with probability p_B (and zero with probability $1–p_B$) at t = 2 and L in case of a premature liquidation at t = 1.

3. A safe strategy, denoted with subscript S, which returns r with certainty both at t = 1 and t = 2.

The ultimate returns at t = 2 from the various strategies, and their expected values at t = 0, are assumed to differ as follows: $x_B > x_G > r > 1$; $x_G > r > 1 > p_B x_B$. Thus all strategies, when successful, provide positive returns at t = 2. However, while the good and the safe strategy each have a positive return with certainty, the bad strategy involves risk. Taking this into account, the present value of the bad strategy turns out negative.

The various strategies differ also in terms of their liquidation value at t = 1. The good and bad strategies are both assumed to be illiquid and promise a certain gross return of $L \leq p_B x_B$ per unit invested if liquidated prematurely. In other words, it is known already at t = 0 that the liquidation value of either strategy, in the event of forced liquidation, would not exceed the going concern value of the bad strategy. The idea that both strategies would have equal liquidation values reflects the lack of transparency, from which it follows that the bank's initial risk choice would also remain indistinguishable to outsiders at t = 1. On the contrary, had the bank chosen the safe strategy, which is assumed to be perfectly liquid and transparent, it would return the whole invested capital already at t = 1.

4 Characterization of a severe moral hazard problem

To start with, we consider as a reference point the case where effectively all bank liabilities are insured by deposit insurance. In such case, the bank knows that the depositors would be compensated if the bank is about to face a liquidity shock (ie is unable to service deposit withdrawals) at t = 1. As a consequence, since the depositors need not worry about the safety of their deposits, they have no reason either to refrain from making those deposits in the first place or to monitor the bank (and use the threat of early withdrawals as a means for providing discipline) while having the deposits in the bank. Therefore, the depositors' participation constraint is not binding and the bank knows that the probability of the liquidity shock would not be dependent on its initial risk choice (ie $q_G = q_B = q$).[6] This makes the bank's moral hazard problem particularly severe.

Another distinguishing feature which is relevant here, is that the bank knows that possible insurance compensation is paid directly to depositors, and not to the bank. Specifically, given the occurrence of the liquidity shock, deposit insurance would only be used for to the remaining amount which is not serviced through liquidation of the bank's assets. As a consequence, the need for insurance

[6] Because of these reasons, we just assume an exogenous q here.

compensation to arise would als mean that the bank is closed down.[7] When the above features are taken into account, the bank's expected profits for different strategies can be described follows:

$$\Pi_G = q\max(L - D, 0) + (1-q)(x_G - D), \tag{1a}$$

$$\Pi_B = q\max(L - D, 0) + (1-q)p_B(x_B - D), \tag{1b}$$

$$\Pi_S = q(r - D) + (1-q)(r - D). \tag{1c}$$

It can be seen from (1a)–(1c) that expected profits are non-negative if $\Pi_i > E$, $i = G,B,S$. As this would not hold only in those cases where both the bank's initial equity E is very high and liquidation value L is very low, we assume that the bank's participation constraint is never binding. As a consequence, we concentrate on the bank's incentives to choose the good strategy. To achieve this, the following two incentive constraints must hold:

$$\Pi_G > \Pi_B, \tag{2a}$$

$$\Pi_G > \Pi_S, \tag{2b}$$

Inequalities (2a) and (2b) are the conditions which must be satisfied for the bank to choose the good instead of bad or safe strategy. Utilizing the definitions (1a)–(1c), and employing the balance sheet identity $E \equiv 1 - D$, (2a) can be expressed as an incentive-compatible equity requirement:

$$E > \frac{p_B(x_B - 1) - (x_G - 1)}{1 - p_B} \equiv \overline{E}_0 \tag{3a}$$

Respectively, inequality (2b) reduces to the following form:

$$\begin{cases} qL + (1-q)x_G > r & \text{if} \quad E \geq 1 - L \\ E < 1 - \left(\dfrac{r - (1-q)x_G}{q}\right) & \text{if} \quad E < 1 - L \end{cases} \tag{3b}$$

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[7] Alternatively, it can be assumed that the provider of deposit insurance would in the event of a liquidity shock be the first claimant on the bank's assets and would never allow the bank to continue its operations with its initial equity holders still in place.

Notice also that a situation where the bank is unable to repay may also develop at $t = 2$, if the bank's investments in the end turn out to be a failure. However, our focus is only in the effects of a pure liquidity shock which occurs at $t = 1$, not in insolvencies at $t = 2$.

Thus, in comparison to the case where $q = 0$, a liquidity shock occurring with a positive probability does not alter the conditions under which the bank chooses the good instead of bad strategy.[8] Moreover, the bank chooses the good over the safe strategy only as long as its expected profits from the former are higher after allowing for the possible liquidity shock. In case where $E \geq 1–L$ (in other words $D \leq L$), this would hold whenever the unconditional present value of the good strategy (which takes into account that this strategy may need to be liquidated prematurely if the bank meets a liquidity shock) is greater than present value of the certain returns from the safe strategy. However, in case where the proceeds from the liquidation were inadequate for servicing deposit withdrawals in full (ie $E < 1–L$), it would also have to hold that the bank's equity capital is below some threshold value.

To see the implications of (3a) and (3b) in practice, consider a numerical example where the parameters are given the following values: $p_B = 0.5$, $x_G = 1.2$, $x_B = 2$, $r = 1.1$ and $q = 0.2$. It follows from (3a) that the bank would be induced to choose the good instead of a bad strategy only if the amount of its equity capital (E) exceeds 0.6. Moreover, relative to a base case with $q = 0$, there would be an additional constraint that it would choose the good over the safe strategy only if the value of the bank's assets in premature liquidation (L) is greater than 0.7.[9]

In this regard, our focus in the rest of the paper is on environments where the moral hazard problem is so severe that, with equity requirements as the only means for aligning incentives, mitigating it would require unreasonably high equity ratios, especially as high equity reduces the amount of socially valuable deposit-related services that banks provide. Moreover, given that even high equity requirements would not necessarily induce the bank to choose the good strategy, but may instead lead to situation where it prefers the safe strategy, other alternatives are needed to complement equity requirements as measures that provide proper incentives. However, before turning to the discussion of these other measures, few remarks are in place for certain candidates as potential solutions to the moral hazard problem but which are nevertheless inadequate in our context.

First, it is often argued that the moral hazard problem can be mitigated if the depositors charge a risk premium, or the provider of deposit insurance charges an insurance premium, which correctly reflects the amount of risk the bank has

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[8] In fact, the case where $q = 0$ is quite relevant here because deposit insurance does not only eliminate the depositors' incentives to monitor banks but it also eliminates bank runs which result because depositors cannot coordinate their activities (as is explained in Diamond and Dybvig, 1983).

[9] Notice that in order to choose the good over the save strategy in case where $L \leq 0.7$, the bank's equity would need to be so low that it would also choose the bad ever the good strategy.

taken. However, in our set-up, which we believe corresponds better to the actual sequence of events, this type of fair pricing is not possible because the bank makes its risk choice only after it has already collected the deposits (or received the insurance). In fact, Blum (2000) has shown that if depositors in such a context tried to anticipate that the bank is about to choose a bad strategy, and would charge an insurance premium which reflects this anticipation, it would only aggravate the moral hazard problem. This follows because, facing a higher premium, the bank would have an even greater incentive to increase risk as the option to go bankrupt would be in such case more valuable to it. Correspondingly, if the provider of deposit insurance sets the insurance premium in anticipation of excessive risk-taking, it would also make the moral hazard problem only more severe than initially.

Second, it may also be argued that the minimum equity requirement can be significantly lowered if it is complemented with a regulatory framework where banking supervisors continuously monitor that banks meet this lower requirement. An example of this might be the widely adopted requirement, based on BIS recommendations, that banks must have own capital at least 8 per cent of their risk-weighted assets, and where supervisory authorities monitor that this level is indeed achieved. However, if the minimum capital requirement is clearly less than what would be an incentive-compatible equity requirement it is quite a possible that the supervisors' statutory role in monitoring banks would not harden enough the bank's incentive constraint. In fact, even if the supervisors were able to perfectly distinguish the bank's initial risk choice (which is obviously not the case) and to accurately estimate the present value of the chosen strategy at $t = 1$, a bank supervision philosophy that only focuses on the assessment of banks' statutory capital adequacy would not provide sufficient incentives for inducing banks to make the desired risk choice.

Thus, in the case where we have deposit insurance in place and allow for a prematurely occurring exogenous liquidity shock, the bank's incentives to choose the good instead of a bad strategy are not much different from what they would be if the liquidity shock were not possible at all. However, it may have the effect that instead of the good but illiquid strategy the bank would prefer more liquid strategy which might yield somewhat less but is safer in terms of providing higher return in case of a premature liquidation. In this regard, the bank would become to resemble more of a narrow bank.

5 Ex post contingencies as an effective solution

In this section, we temporarily deviate from the assumption that the bank's initial risk choice is not observable and examine procedures that would effectively mitigate moral hazard in cases where this choice were observable. Furthermore, what is essential here is that the risk choice is verifiable in a sense that further measures can be made contingent on it.[10] These measures can be based either on market- or regulation-based mechanisms.

We also deviate from the earlier assumption that the bank would perceive the liquidity shock to occur with the same probability regardless of its risk choice. Instead, since all information concerning the bank's initial risk choice would become immediately observable to the depositors, we assume here that they would in any case want to make use of it.

Assume that the bank's risk choice becomes observable at $t = 1$ and the bank offers short-term deposits (which are denoted with D). If depositors are risk-neutral, they would provide refinancing in a competitive environment only if their risk-adjusted expected return is equal to the equilibrium rate of return. As a consequence, the bank at $t = 0$ would have to take into account that its asset choice be reflected in the forthcoming refinancing cost at $t = 1$. For example, if the depositors found out that the bank had chosen the bad strategy, they would demand a refinancing rate of $1/p_B$. Correspondingly, if they found out that the bank has chosen the good or the safe strategy, they would demand a refinancing rate of 1. As a result, the bank's expected profits would be x_G–D if it chooses the good strategy, r–D in case of the safe strategy and $p_B(x_B–(D/p_B))$ in case of the bad strategy. Under these conditions, the bank's two incentive constraints become as follows:

$$x_G - D > p_B\left(x_B - \frac{D}{p_B}\right), \tag{4a}$$

$$x_G - D > r - D. \tag{4b}$$

After rearranging, it can be seen that both inequalities hold for all values of $D \in [0,1]$. Therefore, we conclude that whenever the refinancing rate can be made contingent on the bank's initial risk choice, short-term deposits alone are effective

[10] Standard references of models where the refinancing decision is used for providing better ex ante incentives are eg Diamond (1991), Stigliz and Rey (1993) and Repullo and Suarez (1998) in corporate finance settings and Calomiris, Kahn, and Krasa (1991) and Flannery (1994) in a banking context. See also Calomiris and Kahn (1991) for a model where the threat of deposit withdrawals serves as providing incentives for bank managers to abstain from fraudal activities.

in providing the necessary discipline, without that one needs to resort to the equity requirements (or LOLR for that matter).

Consider now the case where depositors are risk-averse, or for some other reason accept to refinance only in cases where they remain confident that their deposits will be repaid with certainty. In other words, the depositors would always refrain from refinancing if they observe that the bank has chosen the bad strategy. In order that the deposit contract in such case were accepted in the first place, it would have to be that the proceeds from a premature liquidation of the bank's assets (L) are greater than the amount of deposits. Moreover, whenever the depositors' participation constraint is not binding and they accept the deposit contract, the bank's incentive constraint to choose the good instead of bad strategy would become as follows

$$x_G - D > p_B x_B \left(1 - \frac{D}{L}\right). \tag{5}$$

After rearranging, it can be seen that this inequality holds for all D because $L \leq p_B x_B$ by definition. In other words, when information about the bank's initial risk-taking becomes fully observable by $t = 1$, even risk-averse depositors can provide proper incentives by threatening to refrain from refinancing without that minimum equity requirements would be needed. However, for depositors to participate in such a contract, it has to be that $D \leq L$.

Another way to effectively constrain the bank's risk-taking would be to charge a deposit insurance premium at $t = 1$ that is dependent on the bank's risk choice at $t = 0$. Just as in the case where risk-neutral depositors can charge a premium that reflects these risks, if the provider of deposit insurance is capable at $t = 1$ to observe the same risks, it can charge an insurance premium that reflects them. In such case, if the bank has chosen the good strategy, which obviously would not contain any risk, the price of the premium would be zero. On the contrary, if the bank has chosen the bad strategy, the fair price of the insurance premium would be $(1-p_B)D$. Therefore, being aware that the size of the insurance premium would be contingent on the amount of risk taken, the bank's incentive constraint would receive the following form:

$$x_G - D > p_B[x_B(1-(1-p_B)D) - D], \tag{6a}$$

$$x_G - D > r - D. \tag{6b}$$

Since (6b) holds generally, it follows from (6a) that the condition under which the bank would choose the good strategy, becomes as follows

$$E > \frac{p_B(p_B x_B - 1) - (x_G - 1)}{(1 - p_B)(1 - p_B x_B)}. \tag{7}$$

From (7), we can see that, with our assumptions, the numerator would always be negative. Therefore, it follows that a fairly priced insurance premium would by itself solve the moral hazard problem.

In summary, if the bank's risk choice is transparent ex post in a sense that it becomes observable either to the depositors at large, or only to the provider of deposit insurance, then the bank's susceptibility to moral hazard can be mitigated without that minimum equity requirements are needed at all. Naturally, in such case, also the LOLR could perfectly distinguish banks according to their initial risk choice.

6 Towards a more realistic view of market discipline

Consider now a situation where the lack of transparency still prevents the depositors, or the provider of deposit insurance, from providing the necessary discipline though contractual contingencies. However, unlike in section 4, where depositors remained totally uninformed about the bank's initial risk choice, it is now assumed that this choice is partially observable in a sense that the bank knows that depositors can refrain from refinancing whenever they receive a signal which indicates that the bank has chosen a bad strategy. Furthermore, the bank knows that its depositors may, or may not, receive a signal that would make it to bear the consequences of its bad strategy choice. Moreover, the bank also knows that, with certain probability, the depositors may receive an erroneous signal that leads them to refrain from refinancing even if it has not initially chosen the bad strategy. Therefore, the bank's perceived probability of depositors receiving the signal would be higher when it has actually chosen the bad strategy, but positive also in case where it has chosen the good strategy (in other words $q_B > q_G > 0$).

Again, the depositors accept to make short-term deposits in the first place only if $D \leq L$. In such case, the bank's expected profits for a given strategy can be expressed as

$$\begin{aligned} \Pi_G^{MD} &= q_G x_G \left(1 - \frac{D}{L}\right) + (1 - q_G)(x_G - D) \\ &= x_G - \left[1 + q_G\left(\frac{x_G}{L} - 1\right)\right]D, \end{aligned} \tag{8a}$$

$$\Pi_B^{MD} = q_B p_B x_B\left(1-\frac{D}{L}\right)+(1-q_B)p_B(x_B-D)$$
$$= p_B x_B - p_B\left[1+q_B\left(\frac{x_B}{L}-1\right)\right]D, \tag{8b}$$

$$\Pi_S^{MD} = q_S(r-D)+(1-q_S)(r-D)$$
$$= r-D. \tag{8c}$$

In other words, expected profits are determined as a weighted combination of the perceived probabilities of the liquidity shock in the different cases. After rearranging, incentive constraints (2a) and (2b) receive the following form:

$$E > \frac{p_B(x_B-1)-(x_G-1)+q_G\left(\frac{x_G}{L}-1\right)-q_B p_B\left(\frac{x_B}{L}-1\right)}{\left[1+q_G\left(\frac{x_G}{L}-1\right)\right]-p_B\left[1+q_B\left(\frac{x_B}{L}-1\right)\right]} \equiv \overline{E}_1. \tag{9a}$$

$$E > 1-\frac{x_G-r}{q_G\left(\frac{x_G}{L}-1\right)} \tag{9b}$$

Next, consider how changes in both q_G and q_B affect the bank's incentives. First derivatives of (9a) are as follows:

$$\frac{\partial\overline{E}_1}{\partial q_G} = \frac{\left(\frac{x_G}{L}-1\right)(x_G-p_B x_B)}{\left\{1+q_G\left(\frac{x_G}{L}-1\right)-p_B\left[1+q_B\left(\frac{x_B}{L}-1\right)\right]\right\}^2} < 0 \tag{10a}$$

$$\frac{\partial\overline{E}_1}{\partial q_B} = \frac{-p_B\left(\frac{x_B}{L}-1\right)(x_G-p_B x_B)}{\left\{1+q_G\left(\frac{x_G}{L}-1\right)-p_B\left[1+q_B\left(\frac{x_B}{L}-1\right)\right]\right\}^2} > 0 \tag{10b}$$

We see from (10a) that an increase in q_G, *ceteris paribus*, would unambiguously decrease the incentive-compatible minimum equity requirement needed for inducing the bank to make the good over the bad risk choice. Similarly, we see from (10b) that an increase in q_B would increase it, respectively.

At first sight it looks that the net effect of an equal change in both q_G and q_B would be ambiguous. However, a closer inspection reveals that the net effect is positive only if $L < \frac{x_G - p_B x_B}{1-p_B}$, which incidentally equals $L < 1 - \bar{E}_0$ (ie the region where the depositor's participation constraint is always binding). Therefore, we can conclude that the sign of the first derivative is negative in all feasible regions. This is illustrated in Figure 2 where the right end of the solid graph turns clockwise to the right as q increases.

Consider next how an increase in q_G affects the bank's incentives between the good and the safe strategy. First derivative of (9b) is as follows:

$$\frac{x_G - r}{q^2\left(\frac{x_G}{L} - r\right)} > 0 \tag{11}$$

First, given that $q_G = 0$, it follows that the incentive constraint is not binding anywhere. In other words, if the possibility of a liquidity shock is nonexistent, the bank would never have an incentive to choose the safe instead of the good strategy. However, as q_G becomes positive, the safe strategy would gradually become more preferable, first for the highest equity ratios, but as q increases further, increasingly more generally. This can also be seen from (11) where the sign of the first derivative is unambiguously positive.

To see the joint implications of (10) and (11), together with the relevant participation constraints, consider the graphical exposition in Figures 2 through 6 based on the numerical example of section 4.[11] In these figures, the bolded curve represents the minimum equity value that is needed under different liquidation values for inducing the bank to choose the good strategy.

In Figure 2, the bank's incentive to choose the good over the bad strategy is described. It can be seen that for low values of L the depositors' participation constraint E ≥ 1–L is the binding constraint. However, for sufficiently high values of L, (9a) becomes the binding constraint (represented by a thin dotted line). The point where the two constraints intersect is the incentive-compatibility requirement in our base case (Equation (3a)):

$$E = \frac{p_B(x_B - 1) - (x_G - 1)}{1 - p_B} \equiv \overline{E}_0.$$

In other words, in cases of sufficiently high liquidation values, liquidity shocks that occur with positive probability lead to a situation where less equity is needed (for aligning the bank's incentives with those of its depositors) than in environments where liquidity shocks do not occur at all. Notice that this result

[11] Analytic exposition would be too complicated here.

holds regardless of whether the liquidity shocks would contain information or not. Instead, this positive incentive effect arises essentially because, after the deposits have already been prematurely serviced in case of the liquidity shock, all proceeds from the remaining assets would always accrue entirely to the equity holders (awareness of which would provide already ex ante an additional carrot for the bank).

Finally, it can be seen from Figure 2 that, for any sufficiently high liquidation value (ie. those with the incentive compatibility constraint being the most binding one), as both q_G and q_B increase in equal amounts, even less equity is needed for any given liquidation value L in order to provide proper incentives.[12] This follows because the good strategy becomes relatively the more attractive as q increases since it is, as was explained above, more valuable to have all the remaining assets after liquidity shock invested in the good strategy.

In Figure 3, the area outside the solid graph represents the equity values for different levels of L under which the bank would be induced to choose the good over the safe strategy. It can be seen that for any given probability q, the liquidation value has to exceed a certain threshold value or otherwise the bank is better off in choosing the safe strategy. Moreover, as q increases, more equity is needed for a given liquidation value L for inducing the bank to choose the good over the safe strategy. This result follows because if there is a sufficiently high amount of equity capital, it simultaneously means relatively few deposits. In such circumstances, it may be worthwhile to choose the better-yielding good strategy as there would not be so much to loose in case of a liquidity shock. Naturally, as q increases, it also increases this threshold equity level.

In Figure 4, where Figures 2 and 3 are combined, it can be seen what is needed overall for the bank to choose the good strategy. First, in those cases where the bank's proceeds from the premature liquidation of its assets would not cover deposit withdrawals entirely, the depositors' participation constraint would prevent them from making the deposits in the first place. However, it may just as well be the case that the depositors' participation constraint is never the most binding one. In fact, as shown in Figure 4, it would be typical that for sufficiently low values of L considerably more equity capital would be needed for inducing the bank to make the right risk choice than in the case with no liquidity shock. However, as L increases, the positive incentive effect starts to dominate and eventually less equity capital is needed for making the correct choice.

We also see in Figure 4 that as q increases the conditions under which the bank would choose the good strategy would become increasingly rare. Thus, in conclusion, while an increase in q reduces the amount of equity needed for inducing the bank to choose the good instead of the bad strategy, there is a trade-

[12] Ultimately, as q converges towards 1, (9a) converge towards $E = 1–L$, in which case the incentive constraint becomes identical with the depositors' participation constraint.

off in the sense that a higher q also induces the bank to choose the safe strategy instead of the good one.

Figure 2. **The effect of an increase of q on (3a)**

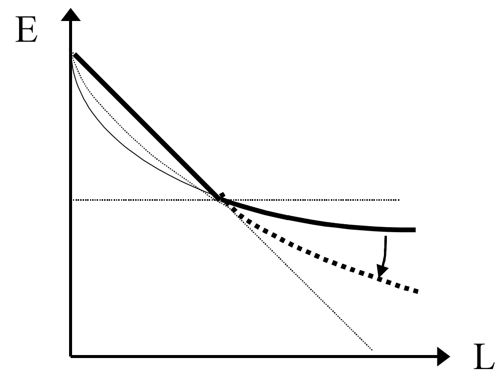


Figure 3. **The effect of an increase of q on (3b)**

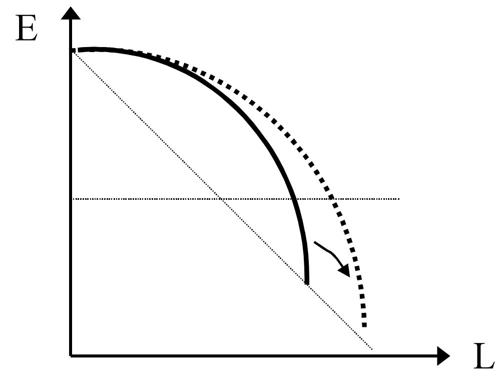


Figure 4. **The combined effect of an increase in q on the bank's incentive to choose the good strategy**

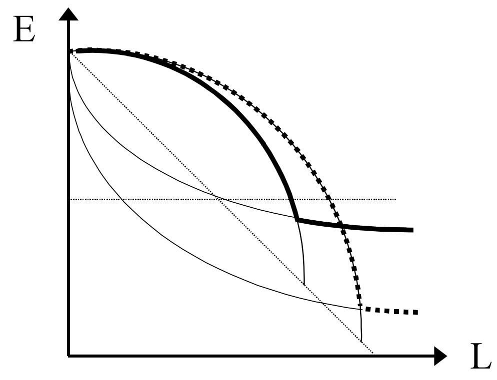


Figure 5. **The effect of a divergence of q_B from q_A on (3a)**

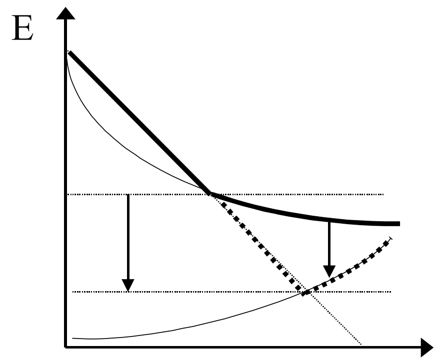
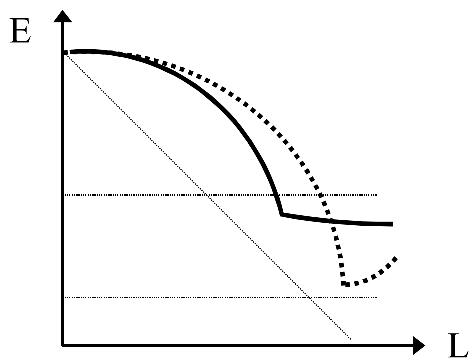


Figure 6. **The combined effect of a divergence of q_B from q_A on the banks incentive to choose the good strategy**



Thus far, we have shown that a liquidity shock, even if the bank's perceived probability of its occurrence would not be dependent on its initial risk choice, would clearly affect the bank's incentives. Finally let us consider how those incentives would be affected if the bank's perceived probability of liquidity shock were dependent on its initial risk choice, ie $q_G < q_B$. This is illustrated in Figures 5 and 6, where it can be seen that the higher the divergence of q_B from q_G, the less equity capital is needed initially for inducing the bank to make the good risk choice in the first place. However, this effect would be at its greatest for low liquidation values of L (which are not, however, feasible as the depositors' participation constraint is binding there). For sufficiently high liquidation values (where the depositors' participation constraint is not any more binding) this effect starts gradually to decrease. This follows because, while the bank perceives that the probability of liquidity shock is dependent on its initial risk, it would not have to bear the full consequences of its occurrence if it can be expected that the final liquidation value L is not dependent of its initial risk choice (ie L remains the same despite the chosen strategy).

To sum up the story so far, we have examined how ex post liquidity shocks that contain noisy information about the bank's chosen strategy would affect the bank's incentives to choose its strategy in the first place. First, it was observed that the possibility of a liquidity shock leads to a situation where the depositors would not make any deposits in the first place unless they are convinced that the bank can repay them in full even if the liquidity shock were to occur. Next, it was shown that when the depositors' participation constraint is not binding, the bank's incentive to choose the good over a bad strategy is somewhat better than in case with no liquidity shock at all. This result was not, though, entirely obvious as the bank may also choose another strategy which is safer in short run but yields less in the longer run and is thus sub-optimal. Nevertheless, incentives to choose a good strategy would be somewhat improved if the bank knew that the probability of a liquidity shock would be greater after it chooses a bad strategy than in case of a good strategy. Finally, in order that the incentives were even better, the liquidation value L should also need to reflect the chosen strategy. However, as it was assumed that this distinction cannot be made privately by the depositors due to incomplete verification, it provides a reason for a consideration of the role of a lender of last resort in the next chapter.

7 Lender of last resort

In previous chapters we have examined how the bank's risk-taking incentives would be affected if the depositors may prematurely withdraw their deposits. This was discussed in a framework where the depositors observe the bank's initial risk choice only indistinctly. It was shown that where banks must take into consideration that liquidity shocks may occur, their incentive to make a good risk choice is somewhat better (in comparison to environments where liquidity shocks do not occur), particularly (but not necessarily) if their perceived probability of liquidity shock is at least to some extent dependent on the initial risk choice. However, the drawback was that establishing market discipline in this way would also lead to other costs, particularly if the value of the bank's assets in case of a premature liquidation were sufficiently low. Given the new trade-off, it was discussed that sometimes it may still not be socially worthwhile to rely solely on market discipline in order to create better ex ante incentives. This would only be more sensible in case where the depositors would also expect already at the outset that the bank might not be able to fully repay in the event of a liquidity shock, which would of course lead to a situation where the depositors would not accept to make deposits in the first place.

Thus, on the basis of the previous discussion it seems equally difficult to eliminate both the wrong incentives and the costly premature liquidation by relying solely either on market discipline or on full deposit insurance that would eliminate the occurrence of liquidity shocks altogether. So other alternative arrangements that would better compromise between the two goals may need to be discussed. In this section, we discuss how the various lender of last resort (LOLR) arrangements would alter the bank's and the depositors' incentives from those of previous chapters. In the most general form, equations (1a)–(1c) are reformulated as follows:

$$\begin{aligned}\Pi_G^{LOLR} &= q_G\left[s(x_G - mD) + (1-s)x_G(1-\tfrac{D}{L})\right] + (1-q_G)(x_G - D)\\ &= x_G - \left[1 + q_G(s(m - \tfrac{x_G}{L}) + \tfrac{x_G}{L} - 1)\right]D\end{aligned} \tag{12a}$$

$$\begin{aligned}\Pi_B^{LOLR} &= q_B p_B\left[s(x_B - mD) + (1-s)x_B(1-\tfrac{D}{L})\right] + (1-q_B)p_B(x_B - D)\\ &= p_B x_B - p_B\left[1 + q_B(s(m - \tfrac{x_B}{L}) + \tfrac{x_B}{L} - 1)\right]D\end{aligned} \tag{12b}$$

$$\Pi_S^{LOLR} = r - D \tag{12c}$$

where

s = probability that the LOLR would, in the event of a liquidity shock, decide to grant liquidity support,
m = cost of liquidity support.

In examining how the existence of an LOLR arrangement would alter the bank's (and the depositors') incentive constraints, we first determine the conditions under which the bank would, in the event of a liquidity shock and given that emergency support is always available, choose to accept support in the first place. After determining those conditions, we proceed to the other effects of the LOLR's decision rule on the bank's ex ante incentives. In order that the support were worth taking, the following condition must hold:

$$\Pi_i^{LOLR} > \Pi_i^{MD} \quad i = G, B, S. \tag{13}$$

By comparing (8a) and (12a) we can determine the highest possible rate charged by the LOLR for liquidity support under which the bank, after having chosen the good strategy, would be willing to accept support instead of a liquidation of its assets:

$$m < \frac{x_G}{L}. \tag{14}$$

Respectively, by comparing (8b) and (12b) we receive a similar condition under which the bank, after having chosen the bad strategy, would accept support instead of a liquidation of its own assets:

$$m < \frac{x_B}{L}. \tag{15}$$

We see from (14) and (15) that, after having chosen the bad strategy, the bank would always accept liquidity support at a higher interest rate than after having chosen the good strategy. However, such a high interest rate would not be meaningful from the LOLR's perspective as it would always know that a bank which would accept to pay a higher interest than (14) would also have chosen a bad strategy. Therefore, (14) must hold generally.

Finally, by comparing (8c) and (12c) it can be seen that, after having chosen the safe strategy, the bank would not accept liquidity support at any interest rate which exceeds the equilibrium rate promised to the depositors in the first place. This follows, because in case of a safe strategy the bank does not have any reason to pay anything extra for keeping the assets until the final period.

Next, we discuss how the LOLR's policy rule, ie. the conditions under which support would be granted or not, is reflected in the probability *s* that the bank assigns for the probability that support would be given in the face of a liquidity shock. We consider three different cases in more detail and discuss a fourth one more briefly.

First, consider the most liberal case where LOLR support is always granted unconditionally. That is, whenever the bank faces a liquidity shock, it could turn to the LOLR and support would be automatically granted. In such case, *s* would equal 1. Naturally, it follows that the depositors would not have any incentive left to monitor the bank, in which case $q_G = q_B = q$. Thus, incentive constraints (2a) and (2b) are reduced to the following form:

$$E > \frac{p_B(x_B - 1) - (x_G - 1) + q(1 - p_B)(m - 1)}{\left[1 + q(m - 1)\right](1 - p_B)} \equiv \overline{E}_2 \tag{16a}$$

$$E > 1 - \left[\frac{x_G - r}{q(m - 1)}\right]. \tag{16b}$$

We see from (16a) and (16b) that when the interest rate charged by the LOLR, *m*, equals 1, ie the equilibrium rate charged by the depositors when the bank is induced to choose the good (or the safe) strategy, our incentive constraints become identical with the case where there is no liquidity shock at all. In other words, after allowing for the possibility of an exogenous liquidity shock, it is possible to ascertain with an existence of an LOLR, without that the bank's incentives are radically altered, both that the depositors accept to make deposits in the first place (which would not be possible if the liquidation value of the bank's assets is insufficient for repaying those deposits) and that costly and premature liquidation of the bank's assets is avoided. Moreover, it would also have the consequence that the bank would better accept the good strategy instead of relying on the safe one. Naturally, however, this would not relax the severity of our moral hazard problem (ie incentive to choose the good over the bad strategy), as was discussed in earlier sections.

We also see from (16a) and (16b) that as the interest rate *m* charged by the LOLR increases, it has the consequence that the incentive-compatible equity requirement (which induces the bank to choose the good over the bad strategy) becomes higher as well. In other words, if *m* is set higher than the equilibrium rate initially charged by the depositors, this can in fact make the bank's susceptibility to moral hazard even more severe than in the case with no liquidity shock at all. Obviously, this is in contradiction with the Bagehot's first recommendation that an LOLR should make it clear that a higher than prevailing market interest rate would always be charged on any liquidity support.[13]

Second, consider a somewhat more restrictive policy where the LOLR would provide support only if the bank can post assets as eligible collateral in the amount of liquidity it needs. However, we assume first that the LOLR does not have any better means than depositors at large to assess the true value of the bank's assets, so it would need to rely on their liquidation value (which was assumed to be commonly known). In other words, the LOLR would assign the following policy rule:

$s = 1$ if $E \geq 1-L$
$s = 0$ if $E < 1-L$

In such case, incentive constraints would be written as follows:

[13] However, a higher *m* may be justified if its role is (particularly in cases where the liquidity shock would concern only a reasonably low proportion of the bank's liabilities) either to encourage banks to hold a sufficient amount of liquid reserves (in order to shelter such minor shocks), or to seek refinancing primarily from outside private sources. However, if the size of liquidity shock can be so high that for sheltering it the bank would need a considerable amount of liquid reserves, we are back in our earlier discussion where it was maintained that being a narrow bank would also prevent banks from providing many of their socially most valuable services (ie. liquidity creation).

$$\begin{cases} E > \dfrac{p_B(x_B-1)-(x_G-1)+\left(q_G-q_Bp_B\right)(m-1)}{1-p_B+\left(q_G-q_Bp_B\right)(m-1)} & \text{if } L \geq D \\ E > \dfrac{p_B(x_B-1)-(x_G-1)+q_G\left(\dfrac{x_G}{L}-1\right)-q_Bp_B\left(\dfrac{x_B}{L}-1\right)}{\left[1+q_G\left(\dfrac{x_G}{L}-1\right)\right]-p_B\left[1+q_B\left(\dfrac{x_B}{L}-1\right)\right]} & \text{if } L < D \end{cases} \tag{17a}$$

$$\begin{cases} E > 1-\left[\dfrac{x_G-r}{q_G(m-1)}\right] & \text{if } L \geq D \\ E > 1-\dfrac{x_G-r}{q_G\left(\frac{x_G}{L}-1\right)} & \text{if } L < D \end{cases} \tag{17b}$$

Third, consider the most restrictive case where the LOLR, in contrast to depositors, would have the means at its disposal at the time of the liquidity shock to distinguish the bank's initial risk choice. This might be reasonable even if central banks and other public authorities are not able to monitor asset quality continuously in all banks. However, they might instead be capable for examining only that limited amount of banks which have not passed the scrutiny of depositors and have therefore faced a liquidity shock. Additionally, assume that the presence of such LOLR facility would lead to a situation where the depositors would cease to monitor banks in a sense that $q_B > q_G$ (in other words, it would be that $q_B = q_G = q$). In such case, the LOLR would be able to assign an interest rate *p* that reflects the quality of the bank's assets, ie $m=1/p_i$, where i=G,B. The bank's incentive constraint between the good and bad strategy choice would then become as follows

$$E > \frac{p_B(x_B-1)-(x_G-1)-q(1-p_B)}{(1-q)(1-p_B)} \tag{18}$$

On the basis of (18), a conclusion can be made that an effective way to mitigate the bank's moral hazard is to assign an interest rate that is dependent on the risks that the bank has taken. In other words, even if the bank's risk choice is not revealed to private sources, if the LOLR can make such a distinction, then this type of an LOLR arrangement would certainly improve the bank's incentives. In addition, if the LOLR acted in this manner, carrying out this role would not even lead to any financial losses.

An alternative way to make the costs of LOLR support positively dependent on the bank's initial risk choice would be to assign a collateral requirement for the liquidity support. According to this policy rule, support would be provided only against sufficient amount of eligible collateral. This requirement could also be further augmented with safety margins, according to which there is an additional requirement that less support would be granted against those eligible assets that contain more risk. In fact, this type of a policy rule would correspond to the Bagehot's other criterion that LOLR support should be provided only against sound collateral. However, in comparison to our previous suggestion that the interest charged for the liquidity support should be the separating factor, a system based on different types of eligible collateral would be somewhat more restrictive. In particular, it leaves open the question of how a bank in need of liquidity would be treated if it is not able to provide a sufficient amount of eligible collateral. Specifically, after acknowledging the time inconsistency problem inherent in all LOLR arrangements, it might be easier for central banks to implement arrangements where the question of whether or not to grant liquidity support in the first place can be avoided, and where instead the interest rate charged on it would vary according to the perceived risk profile of the applying bank.

It should be noted that if liquidity support were provided only against the safest possible collateral, banks would then be encouraged to choose the safe strategy in the first place. In such case, the LOLR arrangement itself would obviously become redundant in that banks would then have the possibility to receive refinancing against these safe assets just as well from the private sources.

Finally, brief remarks are in place about the significance of the doctrine of ”constructive ambiguity”. In a strict sense, such policy would mean that the LOLR's decision of whether to provide liquidity support, ie whether s equals 0 or 1, is always a result of randomisation. Obviously, the main challenge is to prove that constructive ambiguity in such sense is indeed a credible policy rule and not just empty words behind which one wants to conceal the discretionary approach which typically suffers from the time inconsistency problem. In this regard, this strategy would be efficient in terms of incentive formation if it really contains the idea that banks cannot take the access to liquidity support for granted, particularly if they have chosen a high-risk strategy. However, it would also mean that the depositors can never know how the LOLR is going to behave, in which case their participation constraint might also be binding.

8 Conclusion

Discussion of whether the existence of LOLR arrangements cause moral hazard in banks has continued now for about 200 years. During that period, there has been a tremendous change all over the world in the way how financial systems work, and how the choices that banks make are influenced. In particular, in Bagehot's time it was mainly the central banks, in their role as a monetary authority and possibly an LOLR, that were virtually the only public authorities acting as financial regulators. Instead, in today's world, the banks' choices are influenced by a multitude of different regulatory mechanisms, with deposit insurance, statutory capital adequacy requirements and bank supervision being the most important.

The objective in this paper was primarily to assess whether the central bank's role, or lack of it, as an LOLR has any influence left on bank incentives. In other words, could there still be a possible connection between LOLR and moral hazard, given all other regulations that prevail nowadays. All along, it was taken as granted that the main rationale for LOLR's existence in today's world is elsewhere, mainly in preventing widespread systemic crises. The focus here was just to find out what might be the effects of such arrangements on the level of an individual bank.

Our default case was a situation where effectively complete deposit insurance causes a severe moral hazard problem that cannot be prevented by capital adequacy requirements alone. Therefore, additional discipline is needed, but as was discussed, statutory bank supervision might be inadequate, mainly because its proper implementation is either too costly or would be prevented by political and other considerations. Moreover, it was discussed why one cannot rely solely on market discipline either, mainly because one of the preconditions for banks to survive, and to have a significant role in the economy, requires that their risk choice remains opaque. It was also discussed that high social costs of liquidating banks does not speak for relying on market discipline alone. Therefore, it was concluded that the LOLR arrangements may still today have a positive role in improving bank incentives. However, as LOLR arrangements would at best complement other regulatory mechanisms, it would be best to consider them as one component in a wider regulatory structure. Finally, LOLR arrangements would be most beneficial if central banks could commit to a policy where the price of liquidity support would always be dependent on an assessment of risks that the applying bank has taken.

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