Optimal Lender of Last Resort Policy in Different Financial Systems*

Falko Fecht
Deutsche Bundesbank
falko.fecht@bundesbank.de

Marcel Tyrell
University of Trier
tyrell@uni-trier.de

December 1, 2003

Abstract

In a framework closely related to Diamond and Rajan (2001) we characterize different financial systems and analyze the welfare implications of different LOLR-policies in these financial systems.

We show that in a bank-dominated financial system it is less likely that a LOLR-policy that follows the Bagehot rules is preferable. In financial systems with rather illiquid assets a discretionary individual liquidity assistance might be welfare improving, while in market-based financial systems, with rather liquid assets in the banks balance sheets, emergency liquidity assistance provided freely to the market at a penalty rate is likely to be efficient.

Thus, a "one size fits all"-approach that does not take the differences of financial systems into account is misguiding.

*We would like to thank Jean-Charles Rochet for a stimulating discussion and very helpful comments. The views expressed herein are those of the authors and not those of the Deutsche Bundesbank.

1 Introduction

In the last two decades financial crises, a phenomenon that most observers in the 1970's thought to be a relict of the past, has reawakened the interest of academics and practitioners. Following the collapse of the Bretton Woods agreement in 1973 and the subsequent wave of deregulation in many countries, financial crises reemerged. For instance, Lindgren and Saal (1996) found that about three quarter of the IMF's member countries suffered some form of banking crises, though panics in the traditional sense were avoided either by central bank interventions or by explicit or implicit government guarantees. Nevertheless the experience with crises in Scandinavian countries like Norway, Finland and Sweden in the 1980's and more recently in East-Asian and Latin-American countries shows that crises were particularly disruptive in terms of the depth of ensuing recessions. This explains why the question of how to prevent or handle financial crises is one of the most lively debated policy and research issues in the financial community.

In this debate, largely unanimity prevails that the maintenance of financial stability is facilitated by well-designed "safety net" arrangements aimed at both limiting the risk of disruption in the financial system (crisis prevention) and the consequences of disruption if it arises (crisis management). A central element of these arrangements is the lender of last resort. There is considerable agreement on the need of a lender of last resort to provide *discretionary* liquidity assistance to a financial institution or to the market as a whole in reaction to an adverse shock which causes an abnormal increase in demand for liquidity that cannot be met from an alternative source.[1] Usually the role of a lender of last resort (LOLR) is assigned to the central bank.

However, the question arises what are the *principles* that a lender of last resort is supposed to follow. As far back as 1873, Bagehot (1873), based on the work by Thornton (1802), formulated rules of a lender of last resort policy. He suggested that *in a crisis, the lender of last resort should lend freely, at a penalty rate, on the basis of collateral that is marketable in the ordinary cause of business when there is no panic.*[2] Especially, to discourage risk taking by individual institutions the view holds that the lender of last

[1] See for a discussion of the lender of last resort function(s) Freixas, X. et al. (November 1999). Thus we do not want to touch the discussion if there should (and could) be an institutional separation between a central bank which is responsible for the conduct of monetary policy and a lender of last resort; on this topic see Goodhart (1995).

[2] See for instance Fischer (1999), Giannini (1999) and Goodhart (1999) for a discussion of these rules.

resort should lend whenever possible only to the market at penalty rate and only against good collateral. By this maxim the doctrine of what a lender of last resort *should* do today is still well-captured besides coming under some criticism by authors like Goodhart (1999) or Giannini (1999).[3]

In this paper, we take a first step to investigate if such a "one size fits all"-approach with respect to lender of last resort policy makes much sense having in mind the differences between financial systems of various countries. This issue while very important is highly complex because as the literature on comparative financial systems shows, there are many dimensions in which financial systems differ.[4] However, we focus our very simple analysis on one dimension, namely the differences in the importance of relationship banking in market-oriented and bank-dominated financial systems. Our research question is the following: Given that financial structures differ in this aspect across countries, shouldn't also the lender of last resort policies with respect to the form of liquidity assistance to the financial system be different?

More specifically, we build our analysis on the Diamond/Rajan-framework and use this modelling structure as our starting point to incorporate certain stylized facts on differences between bank- and market-based financial systems.[5] The approach will be extended to explore what happens to the functioning of a financial system if there is an aggregate shortage of liquidity - if the supply of liquid assets is small relative to aggregate demand. We are able to define different cases for the resulting equilibrium on the market for liquidity and thus develop a taxonomy of crises situations. This gives us some hints on the probabilities and welfare consequences of certain crises situations in the respective financial systems. In turn this allows us to give a first assessment of type of interventions a lender of last resort should follow. Especially, the question when - if at all - the lender of last resort should charge a penalty interest rate and if the lender of last resort should lend only to the market or to individual institutions, will be analyzed with regard to the different financial systems. Our main result is that under reasonable assumptions individual liquidity assistance to banks is preferable in bank-dominated financial system while in market-oriented systems a policy

[3]For instance, the Report on Financial Stability in Emerging Market Economies by the Group of Ten (1997) and Calomiris/Meltzer (1998) argue strongly in favor of an national respectively international Lender of Last Resort-Policy under Bagehot rules.

[4]See Allen and Gale (2001) for a recent survey. This literature includes theoretical analysis, e.g.Allen and Gale (2000), as well as more empirically oriented work such as Franks and Mayer (1995) and Hackethal, Schmidt, and Tyrell (2002)

[5]See Diamond and Rajan (2001) for the basic framework and Diamond and Rajan (2002) for an application to banking crises.

following Bagehot's rules should be pursued.

Of course, we are not the first who discuss optimal lender of last resort policy and especially the classical market doctrine of the lender of last resort.[6] But to our knowledge we are the first who analyze in a theoretical framework the interrelationship between characteristic differences of financial system configurations and adequate lender of last resort policies.

The remainder of the paper is organized as follows. Section 2 presents our framework. In section 3 the stability of an individual bank will be investigated. It follows an analysis of the equilibrium in the liquidity market in section 4. In section 5 we describe the optimal lender of last resort policy. Section 6 concludes.

2 The framework

2.1 The setup

Following Diamond and Rajan (2001) we consider an economy with three dates ($t = 0, 1, 2$) and a large number of entrepreneurs, bankers and investors. Entrepreneurs are wealthless, however each of them has a project at his disposal which requires an investment $I = 1$ at $t = 0$. Each investor is endowed with a small amount of consumption good in comparison to the required investment size, hence we need many investors to fund a project. In addition, we assume that the aggregate endowment of all investors in the economy is lower than the total investment possibilities. Because of this shortage of investment capital at date 0 entrepreneurs and bankers must offer an expected return as high as possible to attract funding. Entrepreneurs, investors and bankers, whose role will be clarified below, are risk-neutral but differ in their preferences: Investors and bankers have a strong preference for consumption at date 1, i.e. they have a very high discount rate for consumption at date 2, whereas entrepreneurs value consumption at each date equally. Investors can storage their initial endowment earning a return of 1 for every unit invested, or they can invest it in the project.

Financing the projects includes some difficulties which have to be overcome. Entrepreneurs have specific abilities vis-a-vis their projects, i.e. the cash flow each entrepreneur can generate from his project exceed what anyone else can get out of it. But entrepreneurs cannot commit their human capital to the project, except on a spot basis. From this it follows that a

[6] See for instance Rochet and Vives (2002) for a very interesting model that shows how a lender of last resort can avoid inefficient liquidation of banks.

lender can extract future repayment only by threatening to take away the project from the initial entrepreneur. The project returns C generated by the initial entrepreneur are uncertain in terms of their time structure. The project pays out C either at t_1 if the project produces *early* or ant t_2 if the project is delayed. All uncertainty about projects is resolved at date 1.

We consider two alternatives when taking away the project from an entrepreneur. The project can be *restructured* at any time until date 1 which will yield a payoff c_1 immediately and nothing at date 2, or the entrepreneur can be *replaced* with assets redeployed to their next-best use, which does not change the timing of the produced cash flow but the level to γC with $\gamma < 1$. Both alternatives result in a loss of surplus, since

$$c_1 < 1 < \gamma C < C, \tag{1}$$

However, the big difference between this two alternative is the following: The second alternative (replacement) can only be implemented by a bank who was the *only* initial financier of the project while restructuring can be done by any investor, irrespective of having been an initial financier of the project or not.

How can we interpret these alternatives? Restructuring is an activity which can be understood as changing the original content of the projects so that some immediate cash can be produced without any specific knowledge. One may think of this strategy as abandoning the uncertain technology and using instead a commonly known technology that produces goods quickly or stopping half-finished projects and salvaging the production goods. All investors can realize this cash flow, hence c_1 is the secondary market value of a project. On the other hand, replacing the entrepreneur and redeploying the assets to their next-best use, which yields γC is an activity which demands specific skills for replacing the entrepreneur but preserving the original content of the project. It may involve searching for a new entrepreneur who has similar skills to the original one, or abandoning only such aspects of the project that were particulary dependent on the old entrepreneur. Because this implies learning all about the project it takes time, effort and a constant close contact to retain this skills. Therefore, we assume that just *one* initial financier, effectively a "relationship lender" or banker who collect the savings of the investors, will undertake this costly activity. Accordingly, only the banker knows the next-best use of the project's assets. To sum up, the ban can realize $\gamma \cdot C$ from the project, if it takes the project away from the initial entrepreneur, while other investors can only realize c_1. Therefore, the initial entrepreneur will offer to repay $\gamma \cdot C$ to a bank and only c_1 to other investors.

How can we grasp the differences between financial systems in this modelling structure? One obvious difficulty lies in the fact that this framework taken at face value allows only banks to exist as intermediaries. Capital markets in the literal sense as institutions, where firms issue stocks and bonds, households buy and trade these securities and the resulting prices incorporate valuable information, are not caught in our modelling structure. Yet what makes the framework attractive is the possibility to grasp certain consequences of market-based and bank-based financial systems.

We view a bank-based system as a configuration with a relatively high γ and a low c_1 while the reverse, a relatively low γ and a high c_1 is true in a market-based system. A high γ points out that usually in a bank-based system the intermediary has a great deal of information about her borrowers and their projects because of a longlasting and close relationship. As a consequence, she can enforce higher repayments from a borrower than a typical lender in a market-based system who does not collect as much knowledge and information. So the banker in a bank-based system can "replace" the entrepreneur easier, thereby retaining much of the original strategy of the initial entrepreneur. This gives her bargaining power. In our opinion, this is an essential characteristic of a bank with typically firm-specific knowledge.

On the other hand, c_1 is the payoff of restructuring. Because this restructuring is the best alternative, publicly available use, it can be interpreted as the market value of these projects. A relatively high c_1 indicates that much information about the best alternative use is released in the market. In sum we conclude that the difference between γC and c_1 is rather small in market-based systems.[7] The assets are relatively liquid because a great deal of information gets "*externalized*" through the market activities. This reflects the notion that there are many analysts working for mutual funds, pension funds and other intermediaries who gather private information and incorporate these through their trading activities in stock prices which is the general advantage of a market-based system.

In bank-based systems assets are more illiquid. In countries with bank-based systems, relatively few companies are listed and accounting disclosure requirements are limited, so very little information is incorporated into stock prices. Also the number of analysts who follow stocks is small, so only limited *private* information is incorporated into stock prices. However, intermediaries have more information available in these systems. The greater

[7]Of course, we maintain the relation $\gamma C > 1 > c_1$ for a market-based system. Only the difference is small.

prevalence of long term relationships, i.e. the "hausbank"-relationship, in bank-based systems means that the banks are able to acquire considerable information about the firm they lend to. Typically this information will not be released to the market; instead the information will be used internally to allow a smooth functioning of the long term financial relationship and allocate resources efficiently.[8] Therefore information in a bank-based system is more or less " *internalized*", outsiders to the financial relationship have only a small chance to get valuable information.[9] Banks have strong incentives to acquire and use information because they can profit from information which doesn't leak to outsiders. However, this creates the problem that most of the assets are rather illiquid because only the banker has the relevant information. This means c_1 is small and the difference between γC, the payment a bank can extract, and c_1, the market value of a loan, is large.

We feel that this parameterization captures one of the most important underlying causes of the observable differences between bank-based and market-based systems, namely the different ways of acquiring and using information in the respective systems.

2.2 Financial structure of firms and banks

What complicates the financial relations in this economy is the presence of specific skills at two different layers. First of all, original entrepreneurs with their specific abilities can generate a higher expected return from the projects than everyone else but they cannot commit this human capital on a long term basis to the projects. Thus, projects are illiquid in the sense that they cannot be financed to the full extent of their cash flows. The second layer causes the illiquidity of the loans. Only an initial lender has specific skills to extract high repayments from the entrepreneur but she also cannot commit her human capital to the loan. For these reasons the financial contracts we consider specify only who owns the physical assets conditional on the payments made.[10] Let us turn to the resulting financial structure of

[8] See for instance von Thadden (1995) and Aoki/Dinc (1997) for theoretical analysis and Elsas/Krahnen (1998) and Berlin/Mester (1998) for empirical analysis.

[9] See Tyrell (2001) for a discussion how these two perspectives on information, i.e. externalization and internalization, can be mapped into two approaches to the role of information in financial systems, namely the rational expectations literature on the role of prices in resource allocation and the intermediation literature which is concerned with the role of banks as delegated monitors.

[10] We assume a court system, which can enforce financial contracts and transfer assets to lenders when contracted repayments are defaulted upon, but cannot compel entrepreneurs or bankers to contribute their human capital. Thus the court can help to seize the project's

a firm first.

Initially the entrepreneur owns the machinery or project to produce goods. Since he has no endowment, he needs to borrow to invest and is obliged to pay back the credit later on. Hence, the contract signed by the entrepreneur specifies a repayment and the assets the financier gets in case of default. Because of his specific abilities and the limited commitment of human capital, an entrepreneur can credibly threat to withhold his human capital at any time until the cash flows are produced. That gives him bargaining power vis-a-vis the banker. Thus notwithstanding any ex-ante agreement between entrepreneur and banker, the most the banker can get as repayment for the credit is just her best outside option "replacement", which yields γC. Only by threatening to take away the project and redeploy it to this next-best use, the banker as an initial financier can extract this amount as future repayment for the credit. In turn, this is also the maximum amount the entrepreneur can credibly pledge to an initial financier. Since the economy is short of investment capital at date 0, entrepreneurs are competing for the scarce resources and only a few of them get a loan by bidding the maximum amount they can credibly pay back. This means that in the financial contract the borrower promise to pay the banker $P_t = \gamma C$ on demand. If, however, the project turns out to be late and the entrepreneur cannot repay this amount and defaults, the bank has the property rights over the project's assets and will decide what to do with them next.

How can the banker refinance the project? Only the banker as an initial lender knows the next best use of the project's assets. During the course of lending she acquired specific skills which she can use to collect more on the loan than other lenders could do. Similar to an entrepreneur the banker possess human capital that she can threaten to hold back unless investors reduce the required payment. Thus, she cannot commit to repaying to outside investors the full amount that she can extract from an entrepreneur. This also implies that the banker may not be able to raise the full present value of the loan held. But bankers themselves have no endowment, so they have to find a way to refinance the loan through outside investors, otherwise they cannot persuade investors to entrust them with their goods in $t = 0$. As a consequence, the bank couldn't act as the only initial financier of an entrepreneur and the projects wouldn't be financed.[11]

assets resp. the bank's loans, however the value of these assets depends on the cash flow the lenders can generate out of the assets.

[11] Acquiring the specific collection skills to enforce repayment on the part of an entrepreneur is a costly activity which is not worth doing by a small investor in analogy to arguments given in Diamond (1984)

As Diamond and Rajan (2001) show the bank can use a device to commit to repayment up to the full value of the loan. The bank should refinance lending by issuing uninsured demand deposits subject to a sequential service constraint. The sequential service constraint creates a collective action problem among depositors: If the bank makes an attempt to renegotiate deposit repayments she will cause a run. Rather than making concessions which may be in their collective interest, depositors find it in their individual interest to run immediately to capture full repayment of their deposits. Because of the "first come, first served" aspect of uninsured demand deposits, they cannot be negotiated down. Individually each depositor has an incentive to withdraw his claims as fast as possible because his payoff depends on his place in line; it is a Nash equilibrium. In case of a run depositors seize the assets and restructure all the projects destroying any potential rent of the banker. It is not in the interest of a bank to renegotiate down an ex-ante agreed repayment because courts would enforce depositors' demands, and the rents of the banker would be destroyed. Therefore, the bank's ability to create liquidity is inseparable from its potential fragility.[12] Hence in a world without uncertainty, a bank refinances entirely with demand deposits to maximizes the credit it can offer to entrepreneurs. The possibility of runs exerts market discipline on banks, although bank runs are never observed in equilibrium. Since the banker can threat not to deploy her specific collection skills on behalf of the investors at any point after the deposit is made, deposits must be demandable at any time to provide commitment value, although consumption occurs only at date 1 or 2.

But a bank's capital structure typically involves (long-term) capital in addition to demand deposits. The reason is that capital represents a softer claim that demand deposits which can be renegotiated. In a world of uncertainty, financing with only demand deposits carries a cost. It impose the banks to destructive runs if they truly cannot pay because the realized project cash flows of entrepreneurs are too low. In this way, Diamond and Rajan (2000) show that with observable but not verifiable uncertainty in project returns, it may be optimal for a bank to partially finance with a softer claim called capital. Capital holders cannot commit not to renegotiate because they are not subject to a collective action problem. Thus capital acts as a buffer because its value adjusts to the underlying asset values and can prevent inefficient runs. On the other hand, this allows a banker to capture some rents in the future and therefore reduces its ability to raise funds and creates liquidity in the present. The optimal capital structure of

[12] See Diamond and Rajan (2001) for a full analysis of this mechanism.

a bank has to trade-off these costs against the benefits of capital.

In the following we assume that banks face a capital requirement k.[13] stating that a fraction k of the present value of a banks assets has to be refinanced using capital. By normalizing our financing problem and the capital structure of the bank on one investment project, we know that the bank assets are worth γC when the entrepreneur can repay at date 1: Owing to the capital shortage at date 0, the bank extracts all the rent from the entrepreneur that can be pledged, leaving the entrepreneur a rent of $(1-\gamma)C$. If D denotes the repayments on deposits , then $\gamma C - D$ is the surplus that can be split between the banker and the capital holder in the renegotiation process. Assuming equal division of the surplus, capital owners will be paid $\frac{1}{2}(\gamma C - D)$ and the same amount will be absorbed by the banker as a rent. It follows that $D + \frac{1}{2}(\gamma C - D) = \frac{1}{2}(\gamma C + D)$ will be passed on as *total* pledgable payment per loan to depositors and investors holding a capital claim. Inserting this into the definition of the capital requirement ($k = \frac{\frac{1}{2}(\gamma C - D)}{\frac{1}{2}(\gamma C + D)}$) gives the maximum amount refinanced by deposits: $D = \frac{1-k}{1+k}\gamma C$. Hence, the banker gets a rent of $\frac{k}{1+k}\gamma C$ per finished project and capital owners get the same. Thus, the total value that can be pledged to outsiders amounts to $\frac{\gamma C}{1+k}$.

2.3 Local lending markets and the time structure of the model

We argued in the last section that a banker acquires specific collection skills vis-a-vis entrepreneurs through her lending activity. But typically this experience or knowledge, which is costly to develop, can only be acquired for a subset of the date 0 project opportunities. For instance, a bank may only have experience in specific industries or possess knowledge about specific locations. From this it follows that each bank has a local monopoly in lending.

To simplify our analysis we assume that the economy is divided into *two* regions of the same size. The two regions are ex ante at date 0 identical in every respect but can become heterogenous at date 1 in the sense that the fraction of early projects in the two regions differ. More specifically, ex ante the regions are populated by many identical banks, each of them being a monopolist in their local market and facing an identical pool of (many) entrepreneurs. With probability p_1 no macroeconomic shock occurs which

[13] This requirement is either exogenously imposed by regulators or endogenously determined as a result of unmodelled uncertainty.

means that all projects in both regions generate cash flows in $t = 1$. With probability $1-p_1$ a negative macroeconomic shock occurs which delays some projects. In one region only a fraction $\underline{\alpha}$ of the bank loans generates cash flows at date 1 while in the other region a fraction $\overline{\alpha}$ of projects financed by banks produce early cash flows with $\overline{\alpha} > \underline{\alpha}$. Ex ante nobody knows which region will be hit by the more severe macroeconomic shock. Thus, while banks are identical ex-ante, in t_1 half of them turn out to be *weak*, i.e. having a higher fraction of delayed projects, while the other half turns out to be *strong*, which means having a high fraction of projects that generate an early return.

Closing this section, let us describe the time structure of the model. At date 0 the ex ante identical banks compete for the investors' endowments. They issue a mix of deposits and capital to investors and promise them the maximum pledgable amount since consumption goods are short relative to projects at that date. Investors will invest as long as their opportunity rate of return, i.e. storage, is met. After raising cash, banks lend to entrepreneurs in their local lending market. We normalize without loss of generality the amount each bank can raise at date 0 to be 1. In lending to entrepreneurs the banks will charge the maximum repayment γC on demand.

Shortly before date 1 entrepreneurs learn if their projects are early or late. In case the project is late, an entrepreneur informs his bank about the delay. Thus, banks know before date 1 the fraction of their bank loans that turns out to be early projects. As soon as a bank discovers that even with restructuring late projects it cannot generate enough liquidity to payoff depositors, the banker tries to renegotiate the deposit repayments. This will trigger right away a run and all the late projects will be restructured to yield c_1 immediately.

If their bank survives, entrepreneurs with early projects will repay γC at date 1. These entrepreneurs have $(1-\gamma)C$ at their disposal which they can either invest or consume. Entrepreneurs with late projects will default. Then the bank decides how to deal with late projects. It can restructure the projects if liquidity is needed at date 1 or it can reschedule the loan payment until date 2 and keep the project as a going concern. Of course, what decision gives the bank a greater value depends on the prevailing interest rate and its need for funds. The bank itself uses repayments from the early entrepreneurs, from the restructured late projects, and the cash invested by early entrepreneurs in the bank (as deposits and capital) to repay investors at date 1.

At date 2, the bank gets repayments from the unrestructured late projects. Entrepreneurs will consume.

3 Stability of an individual bank

In this section we want to analyze the stability of an individual bank. It is important to understand how decisions in the bank will be taken because of their influence on the stability and the payoffs of three stakeholder groups of the bank: bankers, capital owners, and depositors. The optimal decision concerning restructuring or continuing late projects depends on the particular interest rate r that occurs in date $t = 1$.[14] Although the banker would always prefer to continue late projects, since only when continuing he earns a rent but gets nothing in case of restructuring, the capital owners will force the banker to maximize the net present value of the projects. The capital owners of the bank want to consume at date 1 and therefore they try to maximize the t_1-consumption goods available to the bank. This means they will force the manager to restructure a project if $c_1 > \frac{\gamma C}{(1+k)r}$ and let him continue it otherwise, i.e. if $c_1 \leq \frac{\gamma C}{(1+k)r}$. The higher the interest rate for getting liquidity, the more valuable is restructuring because it generates liquidity immediately. But this restructuring decision is biased, because only part of late projects' return is pledgable to outside financiers of the bank. As long as $c_1 < \frac{\gamma C}{r}$, it is socially inefficient to restructure late projects.

Turning to the decision of depositors, we already mentioned that it is individually rational for them to withdraw their funds whenever the net present value of the bank at date 1 is not enough to fulfill their claims. Consequently, a run on the particular bank is triggered whenever the sum of deposits exceeds the net present value of the bank at date 1: $D \geq V_1$.[15]

Therefore, given that capital owners force bankers to restructure late projects because $r > \frac{\gamma C}{(1+k)c_1}$, depositors will run if

$$V_1 = \alpha\gamma C + (1-\alpha)\, c_1 < D = \frac{1-k}{1+k}\gamma C. \tag{2}$$

[14] In the following analysis we have taken the banks' date 0 portfolio decision concerning investment in storage and lending as given and analyze the case where the bank will not store but invest any funds in lending activity. We are sure this is the optimal decision when the probability p_1 for the state where all the projects in both regions are early, is sufficiently high.

[15] Clearly, as in Diamond/Dybvig there exist two equilibria in those cases where $D < V_1$ but $D > c_1$. Under these circumstances the individually rational decision of every depositor depend on his belief about the decision of all other depositors. As long as he expects the others to withdraw he also has an incentive to do so. But if he thinks the others will wait until $t = 1$ he is also inclined to withdraw not before $t = 1$. Here we assume that depositors will always wait until $t = 1$ as long as $D \leq V_1$.

Solving for $(1-\alpha)$ gives the critical level of late projects that triggers a run:

$$1-\alpha > \frac{2k}{1+k}\frac{\gamma C}{\gamma C - c_1}.$$

However, if late projects are continue because $r \leq \frac{\gamma C_1}{(1+k)c_1}$ depositors will run if

$$V_1 = \alpha\gamma C + (1-\alpha)\frac{\gamma C}{(1+k)\,r} < D = \frac{1-k}{1+k}\gamma C. \tag{3}$$

Thus, given that capital owner want to continue late projects a run will occur if the interest rate increases beyond:

$$\hat{r} = \frac{1}{1-k\frac{1+\alpha}{1-\alpha}}. \tag{4}$$

It is easy to see that this interest rate level increases with α and k. A higher fraction of early projects just like a higher capital ratio increases the stability of a bank. In the following analysis we assume that the fraction of early projects in the strong region is so high enough so that the liquidity inflow from early projects is sufficient to repay deposits. Thus, strong banks (those with the higher fraction of early projects) never depend on the liquidity raised at the t_1-financial market to prevent a run. Therefore a run on these banks can never be triggered by interest rate increases. However, weak banks we assume to be dependent on the liquidity inflow from financial market transactions to repay depositors. Following equation (3) this means that we restrict our parameter space to

$$\overline{\alpha} > \frac{1-k}{1+k} > \underline{\alpha}. \tag{5}$$

4 Equilibrium in the liquidity market

The gross liquidity produced in the economy is the return on early projects. But part of the liquidity goes to banks, which split it into rents to the bank manager, return to capital owners and repayment to depositors. Since we assume that bank managers, capital owners as well as depositors have a discount rate of t_2- consumption that exceeds any upper bound of the equilibrium interest rate, they will immediately consume this fraction of the liquidity. The other part of the liquidity produced by early projects are the rents of the entrepreneurs. Since they do not discount future consumption, they will supply their liquidity at the t_1-financial market, as long as they get

at least a return of 1. Given the overall fraction $(\overline{\alpha} + \underline{\alpha})$ of early projects in both regions, the aggregate liquidity supply amounts to:

$$L^S = (\overline{\alpha} + \underline{\alpha})(1 - \gamma) C \tag{6}$$

Because all the stake holders in the bank - bank manager, capital owner and depositors - have a strong preference for immediate consumption in t_1, the bank manager will try to raise liquidity against the pledgable income of late projects, in order to repay deposits, pay the return on capital and consume his own rents.

Proposition 1 *In the secondary financial market banks try to borrow liquidity from early entrepreneurs against the pledgable return of late projects.*

In competing for the fixed liquidity supply of early entrepreneurs banks bid up the interest rate. An increase in the interest rate reduces the present value of the future pledgable income and the liquidity that each bank can raise.

For an interest rate that only sightly exceeds 1 this simply reduces the rents of the bank managers and the return of bank capital owners. As long as the interest rate does not increase beyond the threshold level $\hat{r} = \frac{1}{1-k\frac{1+\underline{\alpha}}{1-\underline{\alpha}}}$ banks in both regions are stable and will raise new funds against the pledgable return of their late projects from early entrepreneurs in the given mixture of capital and deposits. The demand for liquidity is given by the pledgable return of both type of banks' late projects discounted with the respective interest rate: $(2 - \overline{\alpha} - \underline{\alpha}) \frac{\gamma \cdot C}{(1+k) \cdot r}$.

But for interest rates above $\hat{r}$ the liquidity available to weaker banks falls short of the liquidity needed to repay all depositors. Banks with the higher fraction of late projects will be subject to a run of its depositors. The depositors will seize the banks' late projects and restructure them. Therefore, beyond an interest rate of $\hat{r}$ weak banks will not demand any liquidity at the financial market. In contrast, the stronger banks can still raise enough liquidity to repay their depositors. Since the fraction of late projects is smaller at these bank, the fraction of liquidity provided by inflows from selling assets in the t_1 financial market is smaller and the liquidity available to these bank is less dependant on the interest rate. Therefore, at interest rates above the threshold level $\hat{r}$ only the strong banks demand liquidity against the future pledgable return of their late projects.

However, at an interest rate exceeding $\tilde{r} = \frac{\gamma \cdot C}{(1+k) \cdot c_1}$ even strong banks get into trouble. But not due to a run of their depositors. The liquidity

available to these banks is even at this threshold level enough to repay the deposits.[16] At an interest rate above $\tilde{r}$ the returns to capital owners are higher if projects are restructured in order to generate early returns. Thus, bankers will be forced by capital owners not to continue late projects but to restructure them. But if there is no late project continued in the economy at an interest rate above $\hat{r}$ there is not demand for liquidity at all.

If the interest rate meets exactly the threshold level $\tilde{r}$ capital owners are indifferent between restructuring and continuing late projects, so the demand for liquidity - the fraction of continued late projects is undetermined in that case.

Altogether, the aggregate liquidity demand in the economy can be summarized by:

$$L^D = \begin{cases} 0 & r > \tilde{r} \\ \left[0; (1-\overline{\alpha}) \frac{\gamma \cdot C}{(1+k)\cdot \hat{r}}\right] & r = \tilde{r} \\ (1-\overline{\alpha}) \frac{\gamma \cdot C}{(1+k)\cdot r} & \hat{r} < r < \tilde{r} \\ (2-\overline{\alpha}-\underline{\alpha}) \frac{\gamma \cdot C}{(1+k)\cdot r} & r \leq \hat{r} \end{cases} \tag{7}$$

Obviously, given this aggregate liquidity demand three qualitatively very different equilibria occur depending on the aggregate liquidity supply, which is given by the overall fraction of early projects in the economy.

Proposition 2 *Depending on the aggregate fraction of late projects three types of financial crises may emerge. 1) Slight liquidity crises, in which no bank collapses, 2) moderate liquidity crises, in which only weak banks are subject to a run and 3) severe liquidity squeezes, which also destabilize stronger banks.*

Given that the overall fraction of late projects is rather limited, a slight liquidity crises occurs. This case is depicted in figure 1. Trying to attract new funds from the early entrepreneurs against the required mixture of deposits and capital banks bid up the interest rate only slightly to

$$r^* = \frac{2-\overline{\alpha}-\underline{\alpha}}{\overline{\alpha}+\underline{\alpha}} \cdot \frac{\gamma}{1-\gamma} \cdot \frac{1}{1+k} \tag{8}$$

But this only reduces the rents of the bank manager and the return of capital owners. It does not destabilize any bank in the economy.

[16] Note that we assumed $\tilde{r}$ always being below the interest rate level at which the strong bank cannot raise enough liquidity to repay deposits: $\hat{r} < \tilde{r} < \hat{\hat{r}}$.

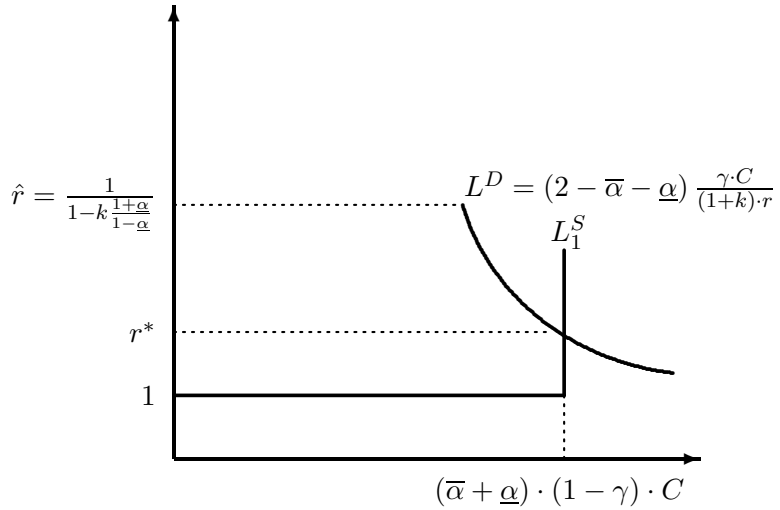

Figure 1: Equilibrium in a slight liquidity crisis

Obviously, the interest rate in slight liquidity crises is the higher the larger the aggregate fraction of late projects relative the fraction early projects and the higher the relation of pledgable to non-pledgable income of finished projects, since both describes the relative scarcity of liquidity in t_1. Moreover, the interest rate is higher if the capital requirements are smaller, since capital requirements increase the rents of the banker and thereby reduce the returns of late project, that can be promised to new depositors and capital owners.

However, if the cash in the market constraint is more restrictive, i.e. the aggregate fraction of early projects smaller, the economy ends up in a moderate liquidity crises, in which part of the banking sector collapses. In that case, which is shown in figure 2, the lack of liquidity causes the equilibrium interest rate to climb up to

$$r^{**} = \frac{1 - \overline{\alpha}}{\overline{\alpha} + \underline{\alpha}} \cdot \frac{\gamma}{1 - \gamma} \cdot \frac{1}{1 + k} \tag{9}$$

At this level the liquidity inflow at weak banks is insufficient to meet the repayment to depositors. Therefore, the bank with the stronger liquidity needs will fail, whereas the stronger banks, which are less dependant on the liquidity inflow from transaction in the t_1-financial market will not be destabilized by the liquidity squeeze and will continue all late projects. As

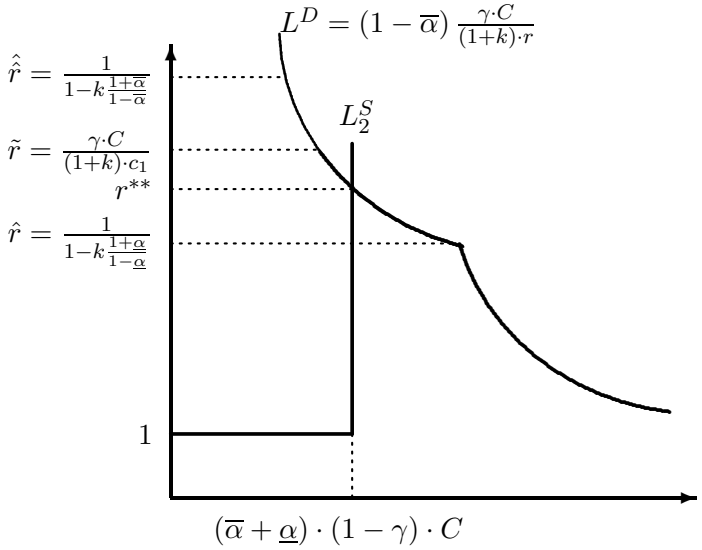

Figure 2: Equilibrium in a moderate liquidity crisis

the weak banks fail their depositors seize the late projects and restructure them. Since weak banks do not demand liquidity in the financial market at this interest rate levels, the equilibrium interest rate in a moderate liquidity crises only depends on the relation 1) of late projects at strong banks to the overall fraction on early projects, 2) of pledgable to non-pledgable income of finished projects and 3) of returns bank can credibly promised to new depositors and capital owners to the total return of the bank.

So roughly spoken, in a moderate liquidity crises only part of the banking sector that is subject to a more or less idiosyncratic adverse liquidity shock will collapse. The other part of the banking sector that does not face a severe idiosyncratic liquidity shock, because only a limited fraction of its projects turns out to be late, can finish all projects.

In contrast, if the aggregate fraction of late projets is even higher the economy ends up in a severe liquidity crisis. In this case equilibrium interest rate will reach its upper bound

$$r^{***} = \tilde{r} \tag{10}$$

Obviously, at this interest rate level weak banks collapse. But what dif-

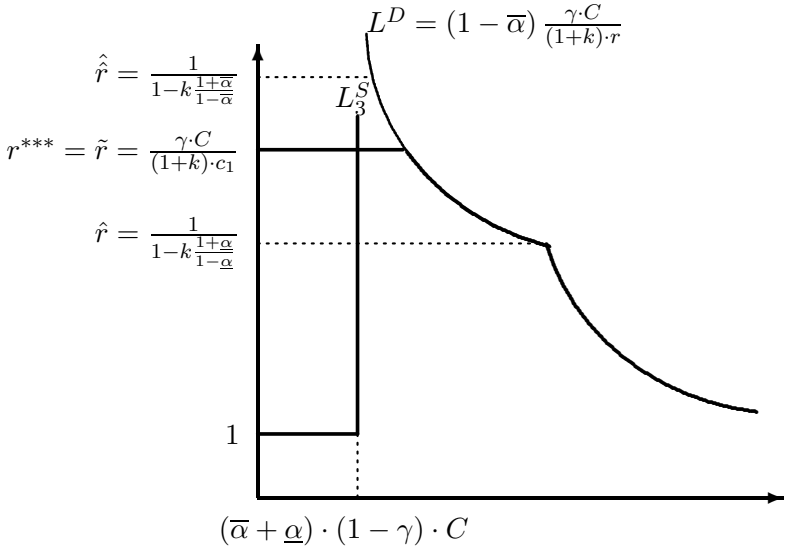

Figure 3: Equilibrium in a severe liquidity crisis

ferentiates a moderate from a severe liquidity crisis is that in the latter even strong banks have to restructure part of their late projects. At the equilibrium interest rate $\tilde{r}$ capital owners are indifferent between restructuring and continuing late projects. However, the available liquidity is insufficient to repay all depositors. Therefore, the bank manager, who only receives a rent if projects are finished, will restructure just enough late projects to produce sufficient liquidity to prevent a run. The fraction of late projects that can be continued in a severe liquidity crises is given in equilibrium by

$$\mu^{***} = \frac{\overline{\alpha}+\underline{\alpha}}{1-\overline{\alpha}} \cdot \frac{(1-\gamma)}{\gamma} \cdot \frac{(1-k)\cdot\tilde{r}}{1} = \frac{\overline{\alpha}+\underline{\alpha}}{1-\overline{\alpha}} \cdot \frac{(1-\gamma)}{\gamma} \cdot \frac{\gamma\cdot C}{c_1} \qquad (11)$$

Apparently, the this fraction will be higher 1) the larger the aggregate fraction of early projects relative to the fraction of late projects at strong banks, 2) the higher the non-pledgable returns of entrepreneurs in relation to the pledgable returns going to the banks and 3) the smaller the present value of the fraction of the banks' returns that can credibly be promised to new capital owners and depositors at the given interest rate $\tilde{r}$. Inserting the equilibrium value for $\tilde{r}$ into the last expression shows that this is just

the relation between the pledgable return of late projects if continued to the return of these projects if restructured (see equation (11)). Consequently, if continuing late projects gives a higher return to banks relative to restructuring, a higher fraction of late projects will be finished even in a severe liquidity shortage.

To sum up, in a severe liquidity shortage it is not enough that weak banks fail and therefore stop demanding liquidity. If the aggregate fraction of late projects is too high, even those banks that have financed a comparatively small fraction of projects that turn out to be late will not be able to raise sufficiently liquidity at the financial market. However, the stronger liquidity rationed banks do not collapse, but they will have to restructure late projects to raise sufficient liquidity to repay deposits.

Having described the equilibrium in the financial market it is straightforward to see which impact the particular type of the financial system has on the equilibrium. Obviously, the higher fraction of pledgable income (γ) in bank-dominated financial systems shifts the entire liquidity demand to the upper right. Because the higher the pledgable income the higher the present value of late projects and the more aggressive banks can bid for fund in t_1 in slight and moderate liquidity crises. In severe liquidity crises the higher return on late projects makes capital owners more willing to accept a continuation of late projects even for higher interest rates. On the supply side a higher fraction of pledgable income reduces the return of early entrepreneurs reducing the liquidity supply in the economy. All these effects of a higher fraction of pledgable returns point in same direction: Fluctuations of the interest rate in case of a financial crisis are higher in bank-dominated financial systems than in market-oriented financial systems. This is also reflected in the respective equations of the equilibrium interest rate (see equations (8), (9) and (10))

A lower return on restructured projects (c_1), which we also characterized as being typical for a bank-dominated financial system only influences the equilibrium interest rate in severe liquidity crises. The lower the returns form restructuring late projects the higher the interest rate up to which capital owners will accept a continuation of late projects of the bank manager. Thus, as can also be seen in equation (10), the interest rate fluctuations in severe liquidity crises also increase with a lower c_1 and are therefore higher in bank-dominated financial systems.

It is interesting to note, that also the threshold level for the different financial crises with respect to a given liquidity supply depends on the type of the financial system. Inserting $\tilde{r}$ into the liquidity demand one can derive the threshold level for aggregate liquidity supply between moderate and

severe liquidity crises. This shows that if the aggregate liquidity supply falls short of $(1-\overline{\alpha})\cdot c_1$ the economy ends up in a severe crisis. While this threshold level obviously is not influenced by the fraction of pledgable returns, it increases the higher the returns on restructured projects. Thus, in market-oriented financial systems, in which c_1 is higher, even for a higher aggregate liquidity the economy ends up in a severe liquidity crisis, while in bank-dominated financial systems given a certain level of aggregate liquidity supply moderate liquidity crises are more likely. Similarly, the threshold level between slight and moderate liquidity crises can be derived by inserting $\hat{r}$ into the liquidity demand function showing that for a given liquidity supply in bank-dominated financial systems characterized by a high γ it is more likely to be in a moderate than in a slight liquidity crisis.

Proposition 3 *In bank-dominated financial systems interest rate fluctuations are higher in financial crises than in market-oriented financial systems. With a given liquidity supply moderate liquidity crises are more likely in bank-dominated financial systems, while in market-oriented financial systems severe but also slight liquidity crises are more likely to occur.*

5 Optimal LOLR-policy

Restructuring late projects is always welfare reducing in this economy. If the interest rate is below $\tilde{r}$ this is most obvious, since in that case even net the present value of the pledgable income from late projects that can credibly be promise to capital owners and depositors of the bank is higher than the returns generated if the projects are restructured.

$$c_1 < \frac{\gamma \cdot C}{(1+k)\cdot r} \qquad \text{for} \qquad r < \frac{\gamma \cdot C}{(1+k)\cdot c_1}$$

However, even in a severe liquidity crises were the equilibrium interest rate reaches $\tilde{r}$ and the present value of the pledgable returns of continued late projects that can be credibly promised to outside financiers of the bank is therefore equal to the return of restructured late projects it would still be strictly welfare improving to finish all projects. If late projects are continued entrepreneurs as well as bankers will earn a rent, while they both get nothing if projects are restructured. Since both rents are not pledgable they are never taken into account by capital owners of banks, when they decide to force the bankers to restructure late projects.

But besides the fact that parts of the returns a finished investment project generates can not be passed on by entrepreneurs and bank manager, which distorts the decision of bank owners to continue late projects,

what contributes to the inefficient termination of late project is the bank's refinancing through deposits. What is in general the advantage of demand deposits - the threat of a coordination failure among depositors that allows bankers to credibly commit to repay - turns out to be a serious drawback in a liquidity crises particularly for weak banks. Banks are not able to bargain on the repayment of deposits in a crises situation to finish late projects.

A LOLR can provide banks with additional liquidity. To keep the analysis as simple as possible, we assume that the LOLR can raise the liquidity by taxing t_1-consumption. This can be interpreted as a shortcut for an inflation tax: The central bank as the LOLR increases the currency in circulation by providing additional means of payments to the banks to enable them to settle their *nominal* obligations. Since this increases the money supply without changing the contemporaneous provision of goods, this simply reduces the real value of money in terms of t_1-consumption goods. It therefore resembles a taxation of any t_1-consumption in the economy.[17]

However, the provision of liquidity by the LOLR is associated with a cost. An inflation tax just like any other tax (apart from per capita taxes) brings about inefficiencies in the economy that cause welfare losses. For simplicity we take these welfare losses as an exogenous cost, that increases proportional with the volume of the liquidity assistance (LA): $WL = \beta \cdot LA$.

There are two distinct policies the LOLR can follow in providing the liquidity to the banking sector in a crisis. The first option, which captures the basic features of Bagehot's suggestions, is to supply liquidity to the market by buying financial assets, i.e. bank equity or deposits. In doing so the LOLR can stabilize the interest rate and prevent the banks from restructuring late projects. The second option, which reflects a more discrete policy, is to provide liquidity assistance to individual banks. Applying this policy the LOLR can supply liquidity at different terms to different banks.

In a slight liquidity crisis there is no need for a LOLR-intervention. All late projects are continued in spite of the liquidity shortage. The interest rate increase due to the slight liquidity squeeze only increases the consumption of early entrepreneurs at the expense of bank managers and bank capital owners. Therefore, a slight liquidity crisis only causes a reallocation of resources, that does not bring about any inefficiencies.

Proposition 4 *In a slight liquidity crisis there is no need for a lender of last resort, since all late projects are continued anyway.*

In a moderate liquidity crisis weak banks are threatened by a run in

[17] For a more detailed discussion of this argument see Allen and Gale (1998).

which depositors would seize the assets and restructure the late projects. Therefore, a liquidity assistance to prevent this could be beneficial.

If the LOLR decided to supply the weak banks with the funds to repay the deposits through an individual assistance (IA), the amount of liquidity the LOLR has to provide is given by deposits less the liquidity available to the bank from the returns on early projects:

$$LA_m^{IA} = D - \underline{\alpha} \cdot \gamma \cdot C \tag{12}$$

The LOLR offers the liquidity assistance at the interest rate $\hat{r}$ against the future income of late projects that can be promised to outside financiers of the bank. So in t_1 there is just enough liquidity available to the bank to repay depositors. Therefore, the LOLR-assistance enables depositors to collect the full value of their deposits (D) from late projects not just the return generated by restructuring (c_1). Using the LOLR assistance even bank managers and bank capital owners gain since they can at least realize their rents from late projects ($\frac{2 \cdot k \cdot \gamma \cdot C}{1+k}$). However, since these rents are realized in t_2 they have to be discounted with the rather high discount factor ρ of bank managers and capital owners.[18] In addition, the LOLR-assistance enabling the continuation of late projects also preserves the rents of late entrepreneurs. In sum, an individual liquidity assistance in a moderate liquidity crisis can generate welfare gains that amount to:

$$WG_m^{IA} = (1 - \underline{\alpha}) \left[D - c_1 + (1 - \gamma)C + \frac{2k}{1+k} \cdot \frac{\gamma C}{\rho} \right] - \beta \left[D - \underline{\alpha} \gamma C \right] \tag{13}$$

If the LOLR uses market interventions to prevent inefficient restructuring of late projects in a moderate liquidity crisis he has to provide additional liquidity to the market up to the point where the interest rate is reduced to $\hat{r}$. At this level weak banks get just enough liquidity against the future pledgable returns of late projects to repay deposits. However, the additional liquidity the LOLR has to provide in that case is larger than if he uses an individual liquidity assistance. In addition to the liquidity needed at weak banks to repay depositors, the LOLR also has to meet the increase in liquidity demand of strong banks due to the interest rate reduction. Therefore, the overall liquidity supply by the LOLR using market intervention (MI) amounts to:

[18] Remember that we assumed a discount rate for these agents that always exceeds the equilibrium interest rate. Therefore: $\rho > \tilde{r}$.

$$LA_m^{MI} = LA_m^{IA} + (1-\overline{\alpha}) \cdot \left[\frac{\gamma \cdot C}{(1+k) \cdot \hat{r}} - \frac{\gamma \cdot C}{(1+k) \cdot r^{**}} \right] \tag{14}$$

However, there are no welfare gains associated with the increased liquidity provision. The additional funds available to strong banks in t_1 only increase the consumption of bank managers and capital owners at the expense of the the consumption of early entrepreneurs. This reallocation is neutral in terms of the overall welfare.

Therefore, the larger volume of liquidity provided in a market intervention does not bring about any benefits but causes additional costs. Thus a market intervention is always inferior in a moderate liquidity crises. The inefficiency of a market intervention is the higher the bigger the costs of the waste of liquidity. Inserting $\hat{r}$ and r^{**} into (14) the welfare losses from using market interventions in moderate liquidity crises are given by:

$$WG_m^{IA} - WG_m^{MI} = \beta(1-\overline{\alpha}) \left[\frac{(1-\underline{\alpha}) - k(1+\underline{\alpha})}{(1-\underline{\alpha})} \cdot \frac{\gamma C}{(1+k)} - \frac{(\overline{\alpha}+\underline{\alpha})(1-\gamma)C}{(1-\overline{\alpha})} \right] \tag{15}$$

Obviously, the inefficiency of a market intervention are more severe:

1. the larger the fraction of late projects at strong banks because
   a) on the one hand this increases the additional liquidity demand of strong banks and
   b) on the other hand this reduces the supplied liquidity by early entrepreneurs in the economy increasing the liquidity that has to be supplied additionally to strong banks,

2. the larger the fraction of late projects at weak banks, because an increase in the fraction of late projects at weak banks
   a) on the one hand this reduces the liquidity supplied by early entrepreneurs, too, and
   b) on the other hand this reduces the threshold level to which the LOLR has to bring down the interest rate to prevent a run on these banks,

3. the smaller the capital requirements, which is also mainly due to the reduction of liquidity demand by increasing capital requirements and

4. the lower the fraction of non-pledgable income (the higher the pledgable return on late projects), also because this a higher pledgable return increases additional liquidity demand of strong banks.

Consequently, in bank-dominated financial systems, which are particularly characterized by comparatively high levels of pledgable income, the inefficiencies of market interventions are more severe, whereas they are relatively limited in market-oriented systems.

Proposition 5 *If a LOLR-intervention is beneficial at all in a moderate liquidity shortages an individual liquidity assistance is always preferable over a market-intervention. However, the efficiency loss of a market intervention is higher in bank-dominated financial systems.*

In a severe liquidity crisis not only late projects at weak banks but also some of the delayed projects at strong banks would be restructured without an additional liquidity supply by a LOLR.

Applying individual liquidity assistance in a severe liquidity squeeze the LOLR would have to supply to weak banks the same amount of liquidity as in moderate crises. In order to prevent the inefficient restructuring of late projects at weak banks the LOLR has to provide the additional liquidity that weak banks need to repay depositors at he threshold level $\hat{r}$. But in addition to prevent the inefficient restructuring at strong banks the LOLR has to supply them with the funds needed to finish their late projects, too. However, at strong banks it is not a potential run that could bring about the restructuring of late projects. At these banks it is the capital owners that do not allow the manager to pay higher interest rates than $\tilde{r}$ on funds allowing to continue late projects. Bank managers can use only the liquidity they get at $\tilde{r}$, to finish late projects, while they have to restructure the remaining delayed projects. Therefore, the LOLR simply has to supply the additional liquidity strong banks need to continue all late projects at $\tilde{r}$. Thus, given the fraction of restructured late projects at strong banks without a LOLR-intervention $(1-\mu^{***})$ the overall liquidity the LOLR has to provide to the banking system amounts to:

$$LA_s^{IA} = D - \underline{\alpha}\gamma C + (1-\overline{\alpha})(1-\mu^{***})\frac{\gamma C}{(1+k)\tilde{r}} \tag{16}$$

Besides the welfare gains due to preventing the restructuring at weak banks in a severe crisis the LOLR-policy increases welfare by enabling strong banks to continue their late projects, too. However, since at strong banks depositors are repayed anyway, only bank managers, capital owners and late entrepreneurs benefit from the LOLR intervention, since their rents are preserved. Thus inserting the quilibrium values of μ^{***} and $\tilde{r}$ in a severe crisis overall welfare gains from an individual liquidity assistance are given by:

$$
\begin{aligned}
WG_s^{IA} &= WG_m^{IA} + (1-\mu)\left[(1-\gamma)C + \frac{2k}{1+k}\frac{\gamma C}{\rho}\right] \\
&- \beta\left((1-\overline{\alpha})\,c_1 + (\overline{\alpha}+\underline{\alpha})\,(1-\gamma)C\right) \qquad (17)
\end{aligned}
$$

In contrast, if the LOLR pursues a market intervention he has to provide enough liquidity to bring down the interest rate to $\hat{r}$, just like in a moderate liquidity squeeze. But again in order to do so, it is not sufficient to supply the same amount of liquidity to the market. At $\hat{r}$ strong banks do not just demand the liquidity needed to finish all late projects. Since the present value of their late projects is higher at $\hat{r}$ than at $\tilde{r}$ the additional liquidity they demand is given by:

$$
LA_s^{MI} - LA_s^{IA} = (1-\overline{\alpha})\left[\frac{\gamma C}{(1+k)\hat{r}} - \frac{\gamma C}{((1+k)r^{***}}\right] \qquad (18)
$$

But this additional liquidity provision again only brings about a reallocation of consumption between the bank managers and capital owners on the one hand and early entrepreneurs on the other. Thus, there are no overall welfare gains associated with this additional liquidity supply, only extra costs to raise these additional fund. Consequently, compared to an individual liquidity assistance market interventions are also inefficient in severe liquidity crises. Inserting $\hat{r}$ and $\tilde{r}$ into (19) the welfare gains from using an individual liquidity assistance instead of a market intervention as the LOLR-policy in a severe liquidity crises are given by:

$$
WG_s^{IA} - WG_s^{MI} = \beta(1-\overline{\alpha})\left[\frac{\gamma C}{(1+k)}\frac{(1-\underline{\alpha}) - k(1+\underline{\alpha})}{(1-\underline{\alpha})} - c_1\right] \qquad (19)
$$

Obviously, applying individual liquidity assistance as the LOLR-policy is the more preferable in severe liquidity crises:

1. the smaller the fraction of late projects at strong banks, because this reduces the inefficient additional liquidity demand of strong banks,

2. the smaller the fraction of late projects at weak banks, because an increase in the fraction of late projects at weak banks reduces the threshold level to which the LOLR has to bring down the interest rate to prevent a run on these banks,

3. the smaller the capital requirements, which is also mainly due to the reduction of liquidity demand by increasing capital requirements,

4. the higher the pledgable return on late projects, also because this increases additional liquidity demand of strong banks and and

5. the lower the return on restructured projects, since the lower c_1 the higher the difference between the interest rate in a market intervention $\hat{r}$ and the highest sustainable interest rate for strong banks $\tilde{r}$ and therefore the higher the additional (wasted) liquidity provision to strong banks in a market intervention.

Proposition 6 *In a severe liquidity crisis an individual liquidity assistance is always preferable over a market-intervention, too. The efficiency loss of a market intervention is also higher in bank-dominated financial systems in the case of a severe liquidity squeeze.*

To sum up, in all kinds of liquidity crises in which a LOLR-intervention is beneficial an individual liquidity assistance is strictly preferable. However, the welfare gains of an individual liquidity assistance compared to a market intervention vary with the particular parameter setting of the respective economy. Most interestingly, an individual liquidity assistance is in general more preferable the more the parametrization of the economy resembles a bank-dominated financial system. For instance, in both moderate as well as severe liquidity crises a high relation of pledgable to non pledgable income in financial relations between firms and banks (a higher γ), which is due to the relationship lending most characteristic for bank-dominated financial systems, makes an individual liquidity assistance more preferable. Moreover, relatively low returns from restructured projects (c_1), which is also typical for bank-dominated financial system compared to market oriented financial systems, make an individual assistance more beneficial, too.

So far we did not take into account the different informational requirements of the LOLR-policies. However, it is obvious that an individual liquidity assistance requires much more information to be effective than a market intervention.

To pursue an individual liquidity assistance the LOLR has to collect precise information about the liquidity needs of every single bank. Besides the administrative costs, this takes time and may cause an inefficient delay of the LOLR-intervention. This is particularly true, since banks do not have an incentive to honestly report their liquidity needs to the LOLR. By overstating the fraction of late projects bank managers could increase the individual liquidity assistance and at the same time reduce the interest rate the LOLR demands on the provided liquidity. Both increases his rents.

In contrast, if the LOLR applies market interventions, the LOLR only has to keep the interest rate in the money market at the threshold level $\hat{r}$. Given that the lower bound $(1-\underline{\alpha})$ of the distribution of the fraction of late project is public information, there is no information on individual banks required by the LOLR.

In order to take these considerations into account but keep the analysis tractable we assume that there are some fixed informational costs associated with a policy of individual liquidity assistance.

So obviously, given these additional costs a policy of individual liquidity assistance is only preferable if the welfare gains of this LOLR-policy outweighs these costs. But as we have already argued the gains of an individual liquidity assistance differ with respect to the financial system under consideration. Thus, in a bank-dominated financial system in which the efficiency gains of an individual liquidity assistance are relatively large in moderate as well as in severe liquidity crises it is rather likely that a LOLR prefers to bear the additional information costs in order to be able to pursue this LOLR-policy. In contrast, in market-oriented financial systems, where the drawback of market interventions is in both types of financial crises less severe, the LOLR may decide to save the costs of acquiring the required information for an individual liquidity assistance and use market interventions to provide the banking system with additional liquidity.

Proposition 7 *Taking into account, that there are more cost intense information requirements associated with an individual liquidity assistance, a LOLR-policy based on individual liquidity assistance may be preferable in bank-based financial system but not in market-oriented financial systems.*

6 Conclusions

In this paper on liquidity crises and lender of last resort policies we can distinguish between three different types of crisis situations. In a slight liquidity crisis there is no need for a lender of last resort. No banks are subject to a run, the only thing we observe is a slight increase of interest rates. In contrast, a moderate liquidity crisis is characterized by runs on weak banks. Depositors seize assets and late projects will be restructured. Finally, in a severe liquidity crisis not only runs on weak banks can be observed but also strong banks will be liquidity rationed and have to partially restructure their late projects. Accordingly, in a moderate and in a severe liquidity crisis the intervention of a lender of last resort may be preferable to prevent runs from occurring.

However, from our main results we can draw a connection between financial system configurations and the optimal lender of last resort policy, i.e. a market intervention following Bagehots' rules and lending liquidity freely at penalty rates, or a individual liquidity assistance provided discretionary by the lender of last resort.

In a moderate as well as in a severe liquidity crisis individual liquidity assistance guarantees a more efficient allocation of the provided liquidity. However, in both crisis situations the welfare losses due to the inefficient waste of liquidity are higher in bank-dominated financial systems than in market-oriented financial systems. Thus, taking into account the more costly informational requirements of a lender of last resort that follows a policy of an individual liquidity assistance it may follow that the information costs outweigh the efficiency gain from a individual liquidity assistance in a market-oriented but not in a bank-oriented financial system.

Presumably, this argument in favor of a market intervention in market-oriented financial systems can further be strengthened: By incorporating into the analysis that a market intervention proportionally wastes more liquidity in the moderate than in the severe liquidity crises, we get lower efficiency loss from market intervention in a severe liquidity crisis if the informational costs of the LOLR increase with the amount of liquidity provided on an individual basis. Having in mind that under reasonable assumption a market-oriented system is more often in a severe than in a moderate liquidity crisis, this implies that the efficiency losses of a market intervention are lower still in a market-oriented system.

References

Allen, F., and D. Gale, 1998, "Optimal Financial Crises," *Journal of Finance*, 53, 1245–1283.

Allen, F., and D. Gale, 2000, *Comparing Financial Systems*, MIT Press, Cambridge MA.

Allen, F., and D. Gale, 2001, "Comparpative Financial Systems: A Survey," Working Paper 01-15,Wharton Financial Institution Center.

Bagehot, W., 1873, *Lombard Street*, H.S. King, London.

Diamond, D., and R. Rajan, 2000, "A Theory of Bank Capital," *Journal of Finance*, 55, 2431–2465.

Diamond, D., and R. Rajan, 2001, "Liquidity Risk, Liquidity Creation, and Financial Fragility: A Theory of Banking," *Journal of Political Economy*, 109, 287–327.

Diamond, D., and R. Rajan, 2002, "Liquidity Shortages and Banking Crises," Working Paper, University of Chicago.

Diamond, D. W., 1984, "Financial Intermediation and Delegated Monitoring," *Review of Economic Studies*, 51, 393–414.

Fischer, S., 1999, "On the Need for an International Lender of Last Resort," *Journal of Economic Perspectives*, 13, 85–104.

Franks, J., and C. Mayer, 1995, "Ownership and Control," in H. Siebert (ed.), *Trends in Business Organization: Do Participation and Cooperation Increase Competitiveness?* . pp. 171–195, Mohr, Tbingen.

Freixas, X. et al., November 1999, "Lender of Last Resort: A Review of Literature," *Financial Stability Review*, pp. 151–167.

Giannini, C., 1999, "Enemy of None but a Common Friend of All? An International Perspectives on the Lender of Last Resort Function," *Princeton Essays in International Finance*.

Goodhart, C., 1995, *The Central Bank and the Financial System*, MIT Press, Cambridge, MA.

Goodhart, C., 1999, "Myths about the Lender of Last Resort," *International Finance*, 2, 339–360.

Hackethal, A., R. H. Schmidt, and M. Tyrell, 2002, "Convergence of Financial Systems in Europe," *Schmalenbach Business Review*, pp. 7–54.

Lindgren, C., G. G., and M. Saal, 1996, *Bank Soundness and Macroeconomic Policy,*, International Monetary Fund, Washington, D.C.

Rochet, J.-C., and X. Vives, 2002, "Coordination Failures and the Lender of Last Resort Was Bagehot Right After All?," Working Paper, Universit de Toulouse and Universitat Autnoma de Barcelona.

Thornton, H., 1802, *An Enquiry into the Nature and Effects of Paper Credit of Great Britain*, Hatchard, London.