# Bank transparency, market discipline and bank panics

**Maria Semenova**[1,2]

## Abstract

In this paper we make an attempt to discover the statistically significant relationship between market discipline and banking system transparency using the cross-country data (1990-2003). The dependent variables cover the quantitative and price-based disciplining. Measuring banking system transparency we use three groups of possible proxies: on the country, corporate and banking system levels. We found no statistically significant influence of banking system transparency on market discipline. This result implies that measures aimed to increase transparency, not being accompanied with requirements related to information availability and/or interpretability, may be not efficient in reaching the goal of market discipline stimulation.

In light of this empirical result we, we model the deposit market with costly information signals. The model adds to the volume of literature related to the Diamond-Dybvig model and related models of information-based bank runs. The inclusion of costly information signals indicates that depositors must decide whether to pay for information regarding changes in the riskiness of banking activities; these costs may involve, for instance, time and other resources needed to find and read financial information. We show that if these costs are too high and the deposit interest rate is low, one possible equilibrium is characterised by bank run and the withdrawal of funds before maturity. In this situation, depositors refuse to pay for information, so this bank run is not efficient, and is not based on negative information. We also describe the conditions under which this equilibrium is the only one that occurs.

[1] Maria Semenova (msemenova@hse.ru) is a Researcher at the Laboratory for Institutional Analysis of Economic Reforms (http://lia.hse.ru), State University – Higher School of Economics, Moscow, Russia.

[2] I am grateful to Maria Yudkevich for helpful advice. I am indebted to Irina Khovanskaya, Elena Podkolzina, Sergey Kovalev, Andrey Vernikov for useful discussions on this project. I warmly thank Aleksandr Krasilnikov for support.

## Introduction

Bank runs have been the subject of much research interest for several decades. Theoretical as well as empirical studies dedicated to bank runs continue to proliferate, especially during periods of financial vulnerability. By a "bank run," we refer to a situation in which most of the depositors of a bank attempt to withdraw their funds from the bank.

Economists have debated the positive and negative consequences of bank runs, and this discussion has produced distinctions between effective and ineffective bank runs. An effective bank run is one that is based on some negative information about the bank's increased riskiness. It takes place when the riskiness associated with the bank becomes unacceptable for depositors. In other words, this bank run is based on the deterioration of bank fundamentals. In this case, we observe the redistribution of funds from riskier to more reliable institutions. This is, in fact, how market mechanisms work, that is, the mechanisms Basel II relies on in its Pillar III. From the point of view of social welfare, efficient bank runs help to minimise the costs of bank bankruptcy, reducing the time needed to resolve bank creditworthiness problems.

An inefficient bank run is triggered by events and information that are not related to the deterioration of bank fundamentals. The reasons for these may be completely different, including information that is not related to the bank, the behaviour of other depositors, and so on.

The problems of bank operation riskiness monitoring by market participants and the use of market discipline mechanisms are the issues that are of particular research interest nowadays. That is obvious, however, that monitoring and market discipline analysis cannot be reasonable without taking into account banking system transparency and the ways market participants obtain and interpret the information to incorporate it into their decision-making processes.

Using the definition offered by Bellver and Kaufmann *(2005*), under transparency in the very general sense one can understand the disclosure of all the information needed to make it possible for market participants to assess correctly the bank's activities and financial results. Banking system transparency is what the New Basel Capital Accord (Basel II) heavily relies on: the third Pillar of Basel II is market discipline which implies a set of information disclosure requirements, which are aimed to help private sector agents to estimate the riskiness of bank operations and capital adequacy. However numerous studies state, that modern banking systems' transparency – whatever way is chosen to measure it – is far from being perfect (for example, look through the recent PriceWaterhouseCoopers report "Accounting for change: transparency in the midst of turmoil. A survey of banks' 2007 reports").

The aim of banking system transparency enhancement is the stimulation of market discipline. If the banks are transparent enough the depositors – the group of market participants we concentrate on in this study - base their decision-making processes on the information about bank risks, not on noisy information, other depositors' behavior or even gossip (*Hyytinen, Takalo, 2004*). This increases the efficiency of bank runs and reduces the probability of inefficient bank run that lead to bank panics, undermining the whole banking system. If the mechanisms of market discipline – disciplining either by quantity or by price – are at work, enhanced transparency prevents bank panics by making the information less noisy and available for all the depositors, so there is no need for them to take into account the behavior of their counterparts in other banks making bank runs contagious.

The theoretical conclusions about positive influence of transparency on the market discipline are, however, still not tested on the empirical data. The case is that this effect can be simply blurred by a number of reasons, which should be carefully studied and included into the policy-makers' decisions. One of the possible explanations of the absence of this positive influence is the fact that additional information disclosure requirements are not accompanied by measures aimed to make this information available to all interested groups of depositors. Another one is the different opportunities of financial information reading and interpretation. Actually, the ability of different groups of depositors to interpret these or those informational signals is not the same and a good example is the group of small individual depositors who may be not aware of all the details of bank financial statements. Thus the answers for the questions of whether the measures aimed to increase the volumes and varieties of information disclosed by banks are enough to stimulate market discipline and whether the deposit market can efficiently use it incorporating into decision-making processes are not trivial and are of particular research interest.

In this paper, we make an attempt to discover the statistically significant relationship between market discipline and banking system transparency using the cross-country data (1990-2003). After finding no statistically significant influence of banking system transparency on market discipline we model the deposit market when the riskiness of bank operations changes after depositors have invested their money. This model adds to the volume of literature related to the Diamond-Dybvig model and related models of information-based bank runs, but the distinctive feature of this model is the inclusion of costly information signals for depositors. The inclusion of costly information signals indicates that depositors must decide whether to pay for information about changes in the riskiness of banking activities. These costs may involve time and other resources needed to find and read financial information. In previous papers, information signals are costless for those who obtain them. In contrast, we aim to find out whether the need to pay for information influences the possible equilibria on the deposit market, especially the situation characterised by an inefficient bank run in which depositors withdraw their funds before maturity.

The paper is organised as follows. We start from empirical support for the idea lying in the basis of the theoretical model. Then, we overview the existing theoretical literature on the Diamond-Dybvig model and information-based bank runs. Afterwards, we develop a model of the deposit market using costly information signals. Next, we modify the model and analyse the influence of differences in the abilities of depositors to acquire information. Finally, we draw some conclusions.

## Is There Any Relationship between Market Discipline and Banking System Transparency?

### *Market Discipline*

Under market discipline we understand the set of mechanisms, through which depositors may implicitly control their banks, changing characteristics of deposit supply – changing investment strategies, in other words - in a response to changes in financial indicators of risks undertaken by banks. Numerous papers related to this phenomenon are reviewed in *Semenova (2007)*. The authors mention three possible disciplining mechanisms:

- Disciplining by price: the depositors charge higher interest rates to riskier banks because these interest rates contain risk premia.
- Disciplining by quantity: if bank fundamentals demonstrate greater risks, depositors tend to withdraw their fund from this bank, so it becomes more difficult for the bank to raise additional deposits.
- Disciplining by maturity shifts: depositors may switch from riskier long-term deposits to less risky short-term or even on-call ones if they face additional risk-taking by bank.

This phenomenon is usually studied using regression analysis methodology. The result that would suggest the existence of market discipline is the significance of the correlation between deposits or deposit growth (for quantitative mechanism), shares of deposits of various maturity in total deposits (for quantitative mechanism based on maturity structure shifts) or average deposit interest rates (for price mechanism) and a number of financial indicators of bank financial position and performance (usually the CAMEL rating model is used).

To construct the dependant variables measuring market discipline we use the results of three cross-country studies: *Demirgüç-Kunt, Huizinga (1999), Hosono (2004), Hosono, Iwaki, Tsuru (2004)*. As they cover only quantity- and price-based mechanisms we do not take into account the maturity shifts. These studies contain the results for the regression estimation for numerous countries. Table 1 demonstrates the data available there.

**Table 1. Data on market discipline.**

| Paper | Period | Price-based mechanism | Number of countries | Quantity-based mechanism | Number of countries |
|---|---|---|---|---|---|
| *Demirgüç-Kunt, Huizinga (1999)* | 1990-1997 | √ | 38 | √ | 52 |
| *Hosono (2004)* | 1992-2002 | √ | 63 | √ | 63 |
| *Hosono, Iwaki, Tsuru (2004)* | 1992-2003 | √ | 60 | X | |

Thus we have the opportunity to construct five Dummy-variables, characterizing market discipline (three - for price-based mechanism and two for - quantity-based one). They are equal to 1 if the disciplining was revealed in a country and to 0 if it was not. We consider the mechanism to be revealed is at least one bank fundamental proved to be significant in a corresponding regression.

***Banking System Transparency***

Measuring banking system transparency is a trickier task. In attempt to cover as many proxies as possible we use eight variables grouped into three groups of possible proxies, calculated on the country, corporate and banking system levels.

In *Fons (1998)*, where the relationship between banking system transparency and stability is examined, the former is measures by corruption perception index, calculated by Transparency International. This index is available for each of the years covered by the studied period (see table 1) at the organization's website. We mark this variable as *CPI*. It is worth noting that this index is used for the same purpose in *Mehrez, Kaufmann (2000)*, where the authors seek for the influence of financial liberalization on the probability of banking crisis given the degree of economy's transparency is rather low.

In *Bellver, Kaufmann (2005)* the authors suggest an aggregated transparency index for 194 countries calculated for 2004. They base in on the data from more than 20 different sources. This index characterizes the transparency of the economic system as a whole, the institutional transparency, the transparency of the rules of the game the economic agents act according to. The aggregated index includes two indices: the index of economic transparency and the index of political transparency. The first one describes the degree of usefulness and availability of the information provided by the regulators and other state authorities (namely, accessibility of the laws, transparency of the budget forming processes, openness of the regulators and state and local authorities, transparency of the governmental organizations and so on). The second one characterizes the degree of political system (and its financing) transparency, the degree of mass media freedom and so on. In our study we use the aggregate index as well as – separately - the index of economic transparency. We mark then with $I_{BK-O}$ and $I_{BK-E}$ correspondingly.

One more index of the transparency at the country level if suggested in *Allum, Agca (2001)*. The authors examine the differences in practices of information disclosures, their frequency and timeliness taking into the consideration the information about basic economic indicators. The authors present the Institute of International Finance data on 18 key indicators (such as GDP, consumer price index, money aggregates, international reserves, interest rates, currency exchange rates, external debt and so on) for 28 developed countries (for 1997 and 1999). The aggregated frequency and timeliness index is presented for both years but we use only that for 1997 as the closest to the studied period. We mark this variable as $I_{F\&T}$.

In *Bushman, Piotrosky, Smith (2004)* the authors study the corporate transparency, namely the availability of the information about the corporations. They use International Accounting and Auditing Trends report of the Center for Financial Analysis and Research as a basic source of the data. One of the characteristics for corporate transparency is the so-called financial disclosure intensity. This variable measures the number of indicators – out of 90 – being disclosed by firms in a country. The list of indicators contains the certain fundamentals from balance sheets and profit and loss accounts as well as some details about the accounting procedures and some stock exchange indicators. The index is calculated for 44 countries and is based on the data for 1995; at least three corporations per country were analyzed. We mark this index as $I_{BPS}$.

*Nier (2004)*, admitting that quantitative analysis of banking system transparency is not an easy task, stresses that not only volumes but also quality if the disclosed information is important. Basing on the Bankscope data for 1994-2000, the author constructed the banking system transparency index for 31 countries. This index aggregates 17 sub-indices, characterizing disclosure of the information related to four basic groups of bank risks (interest rate risk, credit risk, liquidity risk, market risk). The sub-indices are based on the bank fundamentals taken from balance sheet: if a corresponding group of fundamentals is presented in the database the sub-index is equal to 1 and other wise it equals to zero. The aggregated index is an average from 17 sub-indices. We mark it as $I_{Nier}$.

*Barth, Caprio, Levine (2004)* examine the influence of different regulating measures on banking system stability and efficiency, using the data from the World Bank surveys. The results of these surveys are presented at the World Bank website[3], at the moment the information about 151 countries is available. The survey results are also used in *Demirgüç-Kunt, Detragiache, Tressel (2006)*, where the authors examine the relationship between Basel principles introduction

[3]http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/0,,contentMDK:20345037~pagePK:64214825~piPK:64214943~theSitePK:469382,00.html

and banking system stability. For our purposes we construct the transparency index basing on the answers for three questions from the World Bank questionnaire:

- Are off-balance sheet items disclosed to the public?
- Must banks disclose their risk management procedures to the public?
- Are bank directors legally liable if information disclosed is erroneous or misleading?
-

Positive answer for each of this questions may witness for higher degree of banking system transparency and adds 1 to our indicator (so it may account from 0 to 3 points for each country). We mark this indicator as $I_{WB}$.

The last indicator of banking system transparency is also based on the data from Bankscope. It is the share of the banks, which are not listed at any stock exchange and are not therefore publicly quoted, in the database. As disclosure requirements for quoted banks are usually stricter than for all the other banks, this share may demonstrate how many banks disclose the information on their financial position and results without any special requirements. This indicator we mark as $I_{NL}$.

***Results***

We checked for the statistically significant relationship between each market discipline variable and each banking system transparency indicator, from country- to banking system level ones. Thus we run 40 Probit-regressions with the dependent market discipline Dummy-variables and banking transparency indices being the regressors. The results are presented in table 2.

**Table 2. The relationship between market discipline and transparency (p-value for F-stat)**

| | *Demirgüç-Kunt, Huizinga (1999)* | | *Hosono (2004)* | | *Hosono, Iwaki, Tsuru (2004)* |
|---|---|---|---|---|---|
| | Quantitative MD | Price MD | Quantitative MD | Price MD | Price MD |
| ***CPI*** | 0,9500 | 0,9500 | 0,2000 | 0,8200 | 0,5000 |
| $I_{BK-O}$ | 0,8600 | 0,6600 | 0,5800 | 0,6100 | 0,7196 |
| $I_{BK-E}$ | 0,8600 | 0,7000 | 0,3400 | 0,5000 | 0,9600 |
| $I_{F\&T}$ | 0,1100 | 0,6600 | 0,3400 | 0,9000 | 0,8700 |
| $I_{BPS}$ | 0,8500 | 0,4500 | 0,5900 | 0,2600 | 0,3900 |
| $I_{Nier}$ | 0,8200 | 0,5500 | 0,7700 | 0,9800 | 0,2900 |
| $I_{WB}$ | 0,8800 | 0,5400 | 0,8800 | 0,7000 | 0,1800 |
| $I_{NL}$ | 0,9400 | 0,2900 | 0,1800 | 0,9800 | 0,2400 |

No regression proved to be statistically significant. To provide additional confirmation for each pair of indicators we checked for statistical significance of the difference in means (t-test) and in variance (F-test) for two sub-samples: one, where market discipline Dummy equals to 1, and another, where it is equal to 0. Table 3 demonstrated the results.

**Table 3 Significance of differences in means and variances**

| | | *Demirgüç-Kunt, Huizinga (1999)* | | *Hosono (2004)* | | *Hosono, Iwaki, Tsuru (2004)* |
|---|---|---|---|---|---|---|
| | | Quantitative MD | Price MD | Quantitative MD | Price MD | Price MD |
| *CPI* | *t-stat* | 0,0655 | 0,0655 | -1,2923 | -0,2365 | 0,0516 |
| | *P-value* | *0,9482* | *0,9482* | *0,2012* | *0,8142* | *0,9590* |
| | *F* | 0,7544 | 0,7544 | 0,8396 | 1,1826 | 1,1504 |
| | *P-value* | *0,3070* | *0,3070* | *0,3192* | *0,3554* | *0,3663* |
| $I_{BK\text{-}O}$ | *t-stat* | -0,3079 | -0,4276 | -0,5520 | -0,5722 | -0,3524 |
| | *P-value* | *0,7594* | *0,6708* | *0,5830* | *0,5697* | *0,7260* |
| | *F* | 0,9300 | 1,0710 | 0,9939 | 2,0158 | 0,8954 |
| | *P-value* | *0,4329* | *0,4344* | *0,4950* | *0,0508* | *0,3882* |
| $I_{BK\text{-}E}$ | *t-stat* | 0,1766 | -0,3845 | -0,4606 | -0,7567 | -0,3849 |
| | *P-value* | *0,8606* | *0,7023* | *0,6467* | *0,4527* | *0,7019* |
| | *F* | 0,9958 | 1,4595 | 0,9167 | 1,9841 | 0,9518 |
| | *P-value* | 0,4992 | 0,1789 | 0,4083 | 0,0547 | 0,4484 |
| $I_{F\&T}$ | *t-stat* | -1,8517 | 0,1897 | 0,9555 | 0,1203 | 0,1461 |
| | *P-value* | *0,0888* | *0,8671* | *0,3535* | *0,9064* | *0,8867* |
| | *F* | 1,0918 | 0,0658 | 1,0949 | 0,8360 | 2,0674 |
| | *P-value* | *0,4589* | *0,0135** | *0,4718* | *0,3673* | *0,1684* |
| $I_{BPS}$ | *t-stat* | 0,1749 | 0,7558 | -0,5297 | -1,1450 | 1,0940 |
| | *P-value* | 0,8627 | 0,4571 | 0,6010 | 0,2714 | 0,2830 |
| | *F* | 1,4628 | 1,4569 | 1,0476 | 0,9889 | 0,5670 |
| | *P-value* | *0,2260* | *0,2694* | *0,4457* | *0,4528* | *0,1536* |
| $I_{Nier}$ | *t-stat* | 0,2217 | -0,5615 | -0,2781 | -0,0320 | 0,6482 |
| | *P-value* | *0,8268* | *0,5848* | *0,7838* | *0,9750* | *0,5246* |
| | *F* | 1,2820 | 0,8789 | 1,1969 | 2,1514 | 1,5797 |
| | *P-value* | *0,3436* | *0,4025* | *0,3612* | *0,2020* | *0,2241* |
| $I_{WB}$ | *t-stat* | -0,1419 | -0,7404 | -1,2573 | -1,0807 | -0,6481 |
| | *P-value* | *0,8879* | *0,4635* | *0,2156* | *0,2879* | *0,5203* |
| | *F* | 1,0399 | 0,8569 | 1,7234 | 0,8291 | 1,0945 |
| | *P-value* | 0,4593 | 0,3732 | 0,0852 | 0,3110 | 0,4198 |
| $I_{NL}$ | *t-stat* | -0,0749 | -1,0527 | 1,3687 | 0,8274 | 1,1663 |
| | *P-value* | *0,9408* | *0,3015* | *0,1782* | *0,4156* | *0,2521* |
| | *F* | 1,6915 | 1,0915 | 0,5945 | 0,8638 | 0,6148 |
| | *P-value* | *0,1412* | *0,4361* | *0,1136* | *0,3526* | *0,1407* |

**- differences are significant at 5% level.*

At this stage we found no statistically significant influence of banking system transparency on market discipline. This result implies that the measures aimed to increase transparency, not being accompanied with a number of requirements related to information availability and/or interpretability, may be not efficient, at least in reaching the goal of market discipline stimulation. In light of this empirical result we suggest a model of the deposit market with costly informational signals.

## Literature on Information-Based Bank Runs

The major theory on the incentives for depositors to withdraw funds simultaneously and thus create an information-based bank run originates from sunspot theory, which has been used to analyse the deposit market. This theory implies that the nature of a deposit contract means that there is a non-zero probability that a bank run equilibrium occurs on the deposit market. Notably, the reasons why different kinds of equilibria actually take place are not analyzed.

This approach originates from a classic paper by Diamond and Dybvig (1983). In this paper, they analyse a model based on the suggestion that the main function of bank deposits is to provide insurance against liquidity shocks. The Diamond-Dybvig model is a three-period model with one commodity. There are numerous agents in the model, each of whom initially owns a unit of the commodity. At t=0, an agent invests this unit as a bank deposit. The first period (t=1) revels agents' types. There are two of them: the first type of agents are included only for one period, the second type of agents are included until the end of the second period. Thus, the first type of depositors only consumes during the first period (representing a liquidity shock), while the second type of depositors consumes during both periods. Banks cannot distinguish between these two types of clients. The existence of an instrument like the bank deposit may effectively diversify the risks related to liquidity shocks. At equilibrium, each depositor chooses whether to withdraw during the first period according to agent type, so the deposit contract is constructed to ensure that agents of the second type will withdraw in the second period. However, the funds accumulated by the bank during each period are not endless. The bank may invest in a technology that earns a certain return by the end of the second period, but earns nothing in the first period. The bank allows the withdrawal of money according to a queue of depositors in each period and stops repayments when funds are depleted; this is known as sequential service constraint. If all funds are withdrawn during the first period, the bank will have nothing with which to repay deposits in the second period. If the funds preserved by the bank in the first period are not enough to ensure sufficient second-period interest rates even when second-period investment returns are taken into consideration, those depositors who wait until the end of the game will not receive their second-period interest rate. Thus, there is more than one Nash equilibrium in this model: if each and every depositor expects every other depositor to withdraw early, he/she will withdraw earlier as well. This is true for the second type of depositor as well: they retrieve their deposits due to fears that the bank may go bankrupt. So, the bank subsequently pays in full for those first in line to withdraw yet nothing to those at the end of the queue. Thus, the bank run here has a *self-fulfilling prophecy* nature.

The followers of Diamond and Dybvig have suggested some modifications to this approach to allow use of the model to demonstrate when only one equilibrium – a bank run or efficient risk diversification – is possible (*Postlewaite, Vives, 1987; Green, Lin, 2000; Cooper, Ross, 1998; Williamson, 1988*).

Subsequently, the literature has increasingly moved towards theories of information-based bank runs. Most of these modifications to the Diamond-Dybvig model are based on two assumptions absent in the basic model:

1) The return on bank investments is not determinant. Bank investments are introduced as a random variable with certain characteristics. There is information asymmetry; compared to depositors, banks know more about the actual results of the investment.

2) The depositors are not identical from the point of view of information availability. There are two groups of depositors: those who are informed and those who are uninformed. Being informed means that a depositor receives information about the results of bank investment.

One of the first papers in this set of literature is by *Jacklin and Bhattacharya (1988)*. According to their results, bank runs are not random, since they appear as a response to changes in expectations about the results of bank investments. During the first period, a certain proportion of depositors obtains an information signal indicating a new probability of the failure of the projects in which a bank has invested. The authors are able to obtain a minimal reported probability of failure, after being informed about which the informed depositors prefer to withdraw their money earlier, and this probability depends negatively on the variation of random investment results.

*Alonso (1996)* further develops the ideas of Jacklin and Bhattacharya. He shows that in the proposed set-up, the bank may offer a contract to prevent bank runs. Moreover, he demonstrates that under certain circumstances, allowing a non-zero probability for a bank run may be a part of a bank's optimal strategy. Banks are rational in taking into account the sort of information the depositors receive and including it into the contracts the bank offers. Finally, he shows that for at least some probability of project failure, the contract offered by banks will be beneficial for depositors.

The model offered in *Chen (1999)* demonstrates that informed depositors are rational and thus take into account the possible actions of uninformed depositors who know that there was an information signal they did not receive. In this model, the informed depositors withdraw their funds earlier not only exerting market discipline. As they realise that uninformed depositors are likely to withdraw earlier and that the bank will not be able to repay their deposits after uninformed depositors withdraw, informed depositors prefer not to wait until their deposits mature.

In a recent paper (*Chen and Hasan, 2008*), the authors declare that not only the information signal, but also the expectations related to this signal may influence the probability of a bank run. If the information is expected to be accurate and clear, the resulting bank run may be efficient. If the signal is blurred, the variation of the reported investment result is high, or the signal's delivery is not precise, the informed depositors may prefer to withdraw earlier. This conclusion is particularly important for the examination of bank panics, as in this model, even some healthy banks may suffer bank runs.

Another set of papers does not rely on the assumption that decisions are made simultaneously. In these papers, the uninformed depositors decide whether to withdraw earlier by observing the actions of the informed depositors. As they cannot distinguish between first-type depositors and informed ones, the probability of a bank run is dependent upon the degree of accuracy with which the uninformed depositors read the actions of informed depositors.

For instance, *Chari and Jaganathan (1988)* offer a model characterizing the decision-making process of uninformed depositors, given they are aware of the probability of project failure before the information signal and that they observe the decisions of all other depositors. In this framework, a bank run may be the only equilibrium, even if negative information signal did not appear.

## The Model

The model proposed in this paper differs from the existing models of the information-based bank runs in the assumption that information signals are no longer free of charge. In other words, to obtain information, a depositor must incur certain costs. These costs may be interpreted as the need to spent time and effort to locate necessary information and interpret it correctly. Our main assumption is that the depositor decides whether to obtain an information signal (at a cost) or not.

We assume for simplicity that there are two depositors and one bank functioning on the simulated deposit market. There are three periods in the model ($t$=0, 1, 2).

### *Depositors*

The depositors are risk-neutral and have the following utility function[4]:

$U = c_1 + c_2$,

where $c_k$ stands for the level of consumption in $t=k$, $k$=1, 2.

Each depositor has a unit of funds that he/she may either invest as a bank deposit or store without any loss.

### *Bank*

A bank accumulates the deposited funds and invests them into a risky project lasting two periods. If withdrawn early, the investments bring no return. It is commonly known at $t$=0 that if withdrawn after two periods, the investments guarantee the return $R$, where $R$>1, per invested unit with a probability $(1-\theta)$, such that $\theta$ is the probability of project failure.

[4] The depositor consumes during the second period, so we can draw a parallel between our depositor and the second type of depositors in the Diamond-Dybvig model and other related models of information-based bank runs (see, for instance, *Postlewaite, Vives, 1987*)

The bank offers a time deposit contract. The maturity of the deposit is two periods, and the return is exactly $R$, but if a depositor withdraws early, he/she is promised a lower, on-call deposit rate $r$, where $r<R$ and $1<r<2$.

***Depositor choice when there are no information signals***

As $r>1$, the depositor participates in the deposit market. The utility in the case of participation in the deposit market is higher than in the case of storage of funds outside the market.

The timing of the game can be presented as follows:

| | |
|---|---|
| t=0 | Depositors open deposits<br>A bank invests into a risky project |
| t=1 | Depositors decide whether to withdraw their funds |
| t=2 | The project is finished, profitably or not.<br>Depositors withdraw their funds if the deposits were not closed before maturity |

During the first period ($t$=1), the depositor decides whether to withdraw funds earlier or wait until the deposit matures.

If he/she decides to withdraw, he/she obtains the following utility:

$U_1 = r$.

If he/she decides to wait, he/she obtains the following expected utility:

$EU_2 = (1-\theta)R$.

Thus, the depositors prefer not to withdraw earlier if $EU > U_1$, that is, if:

$$R \geq \frac{r}{(1-\theta)} \quad . \tag{1}$$

However, these returns are available for depositors only if the bank has enough funds to finance them. As there is no equity in this model, the bank may only repay deposited funds. If there is a lack of available funds, these funds are distributed equally among all depositors who have requested withdrawal. Thus, the case of two depositors may be presented by the following matrix:

| | | Depositor 2: *Withdraw at t=1* | Depositor 2: *Withdraw at t=2* |
|---|---|---|---|
| Depositor 1 | *Withdraw at t=1* | *1;1* ♦ | *r; (1-θ)(1-(r-1))R* |
| | *Withdraw at t=2* | *(1-θ)(1-(r-1))R; r* | *(1-θ)R; (1-θ)R* * ♦ |

Let us analyse the Nash pure-strategy equilibria in this game.

If $(1-\theta)(1-(r-1))R>1$, there is only one equilibrium in this game, namely the equilibrium when both depositors wait until the deposits mature. We mark it with a star.

If $(1-\theta)(1-(r-1))R<1$, or, in other terms,

$$R < \frac{1}{(1-\theta)(2-r)}, \tag{2}$$

two equilibria are possible (marked with ♦): a bank run equilibrium and an equilibrium when both types of depositors are patient and wait for their investments to mature. This situation of two equilibria is similar to that described in *Diamond and Dybvig (1983)*. If a depositor's counterpart withdraws early, it is preferable for the depositor to withdraw in $t$=1, and if the counterpart waits until the deposit matures, it is preferable for the depositor to act in the same way.

We mark the frontier level of returns by $\underline{\underline{R}}$:

$$\underline{\underline{R}} = \frac{1}{(1-\theta)(2-r)}$$

Proposition 1. A set of $R$, satisfying the inequalities (1) and (2), is never empty.
Proof: See the Appendix.

Thus, there is always an $R$ that allows for the existence of multiple equilibria.

***Costly information signals***

Up to this moment, we analysed a game without considering the appearance of new information regarding changes in project riskiness during the first period. In this paper, we develop a model using an information-based framework, as proposed in *Alonso (1996)*. At $t$=1, the bank obtains specific information related to project prospects. With probability $p$, where $0<p<1$, the project will fail with a higher probability $\theta_L$, with probability $(1-p)$, *it will fail* with a lower probability $\theta_H$. Note that

$\theta_L > \theta > \theta_H$, and

$p\theta_L + (1-p)\theta_H = \theta$.

We label *bad news* the situation in which the bank obtains information that $\theta=\theta_L$, whereas when information indicates $\theta=\theta_H$, this is *good news*. Thus, $p$ is the probability of obtaining bad news.

We assume that in case of bad news, the expected utility of a depositor waiting until the second period to withdraw the funds is lower than the utility of withdrawing earlier. That is,

$$EU_2=(1-\theta_L)R<1=U_1. \tag{3}$$

Thus, a depositor prefers to withdraw early in the case of bad news. However, to make this decision, he/she must have information that the probability of the bank project's success has reduced to $(1-\theta_L)$.

In our model, information signals are costly. The total costs of searching for and processing information are equal to $c$. During the first period ($t$=1), depositors decide whether to bear these costs. A depositor prefers to pay for information because the loss in expected utility in the case of bad news may exceed the costs of the information signal. We assume that other things being equal the depositors prefer to be informed.

***Depositor choice in the case of costly information signals***

The timing of the game is now presented as follows:

| | |
|---|---|
| t=0 | Depositors open deposits<br>A bank invests into a risky project |
| t=1 | The risks related to the project change<br>Depositors decide whether to pay for the information signal<br>Depositors decide whether to withdraw funds or wait until maturity |
| t=2 | The project is finished, profitably or not<br>Depositors withdraw their funds if they had not already done so |

During the first period, the decision to withdraw is, therefore, influenced by two factors:

1) The possibility of obtaining information about changes in project risks,
2) The dependence of available funds in bank on the period and volumes of withdrawals by other depositors.

Now let us analyse what strategies are available to depositors. As $r>1$, the depositors always decide to invest rather than store at $t=0$. Thus, strategies differ in the first and second periods. These strategies are presented in Table 4.

**Table 4.Depositors' strategies**

| Strategy | *t=0* | *t=1* | *t=2* |
|---|---|---|---|
| *s1* | open deposit | 1) do not pay for information<br>2) withdraw funds | |
| *s2* | open deposit | 1) do not pay for information<br><br>2) do not withdraw funds | withdraw funds |
| *s3* | open deposit | 1) pay for information<br>2) withdraw funds in case of bad news | withdraw in the case of good news |

The following matrix present the pay-offs for depositors depending on the strategies chosen by a depositor and by his/her counterpart depositor:

| | | Depositor 2 s1 | s2 | s3 |
|---|---|---|---|---|
| Depositor 1 | s1 | $1;$ <br> $1$ | $r;$ <br> $(1-\theta)(1-(r-1))R$ | $p+(1-p)r;$ <br> $p+(1-p)(1-\theta_H)\,(1-(r-1))R-c$ |
| | s2 | $(1-\theta)(1-(r-1))R;$ <br> $r$ | $(1-\theta)R;$ <br> $(1-\theta)R$ | $p(1-\theta)(1-(r-1))R+(1-p)(1-\theta)R;$ <br> $pr+(1-p)(1-\theta_H)R-c$ |
| | s3 | $p+(1-p)(1-\theta_H)(1-(r-1))R-c;$ <br> $p+(1-p)r$ | $pr+(1-p)(1-\theta_H)R-c;$ <br> $p(1-\theta)(1-(r-1))R+(1-p)(1-\theta)R$ | $p+(1-p)(1-\theta_H)R-c;$ <br> $p+(1-p)(1-\theta_H)R-c$ |

Let us analyse the possible pure-strategy Nash equilibria. To find them, we must compare the expected utilities of depositors for different strategies for each of the possible counterpart choices.

Proposition 2. The utility of the first strategy is higher if the counterpart chooses the second strategy than if he/she chooses the third:

$U^i{}_1(s^j=s2)> U^i{}_1(s^j=s3)$, where $i,j=1,2$ (4)

(where $U^i$ indicates depositor *i*'s utility, and $s^j$ stands for depositor *j*'s strategy)

Proof: See the Appendix.

Proposition 3. Expected utility of the second strategy is higher if the counterpart chooses the second strategy than if he/she chooses the third:

$EU^i{}_2(s^j=s2)>EU^i{}_2(s^j=s3)$, where $i,j=1,2$

Proof: See the Appendix.

Proposition 4. The utility of the first strategy is higher if the counterpart chooses the third strategy than if he/she chooses the first:

$EU^i{}_1(s^j=s3)> U^i{}_1(s^j=s1)$, where $i,j=1,2$ (5)

Proof: See the Appendix.

Proposition 5. If $R$ is lower than a certain level the expected utility of the first strategy is higher than that of the second if the counterpart chooses the third strategy:

$EU^1{}_1(s^2=s3)>EU^1{}_2(s^2=s3)$

Proof: See the Appendix

We mark this level of returns as $\underline{R}$:[5]

[5] This is calculated in the proof of Proposition 5; see Appendix

$$\underline{R} = \frac{p+(1-p)r}{(p(1-r)+1)(1-\theta)}$$

Proposition 6. A set of $R$, satisfying the inequality $\underline{\underline{R}} \geq R \geq \underline{R}$, is never empty.

Proof: See the Appendix.

The results of the other expected utility comparisons depend on the level of total costs $c$.

Proposition 7. There exists a level of $c$ that guarantee that the expected utility of the third strategy is higher than that of the second if the counterpart chooses the third strategy:

$EU^i{}_3(s^j=s3)>EU^i{}_2(s^j=s3)$, where $i,j=1,2$ (6)

Proof: See the Appendix

We denote this level of costs[6] $\hat{c}$

$\hat{c} = p(1-R[(1-\theta_L)-(1-\theta)(r-1)])$. (7)

Notably, the expression in the brackets is always positive due to inequality (3).

Proposition 8. There exist such levels of $c$ that guarantee that the expected utility of the third strategy is higher than that of the second if the counterpart chooses the first strategy:

$EU^i{}_3(s^j=s1)>EU^i{}_2(s^j=s1)$, where $i,j=1,2$

Proof: See the Appendix.

We mark this level of costs[7] $\hat{c}_0$:

$\hat{c}_0= p(1-R(2-r)(1-\theta_L))$. (8)

Proposition 9. There exist levels of $c$ that guarantee that the expected utility of the third strategy is higher than that of the second if the counterpart chooses the second strategy:

$EU^i{}_3(s^j=s2)>EU^i{}_2(s^j=s2)$, where $i,j=1,2$

Proof: See the Appendix.

We mark this level of costs[8] $\hat{c}_1$:

$\hat{c}_1= p(1-R(2-r)(1-\theta_L))$. (9)

Proposition 10. The featured cost levels satisfy the following inequality:

[6] This is calculated in the proof of Proposition 7; see Appendix.
[7] This is calculated in the proof of Proposition 8; see Appendix.
[8] This is calculated in the proof of Proposition 9; see Appendix.

$$\hat{c} > \hat{c}_1 > \hat{c}_0.$$

Proof: See the Appendix.

If $\underline{\underline{R}} \geq R$ we should take into consideration Proposition 11 in a search of pure Nash equilibrium.

Proposition 11: There exist levels of $c$ that guarantee that the expected utility of the third strategy is higher than that of the first if the counterpart chooses the first strategy:

$EU^i_3(s^j=s1) > EU^i_1(s^j=s1)$, where $i,j=1,2$

Proof: See the Appendix.

We mark this level of costs[9] $\underline{c}$:

$$\underline{c} = (1-p)[((R(2-r)(1-\theta_H)-1)]. \tag{10}$$

If $\underline{R} \geq R$ we should take into consideration Proposition 12 in a search of pure Nash equilibrium.

Proposition 12: There exist levels of $c$ that guarantee that the expected utility of the third strategy is higher than that of the first if the counterpart chooses the third strategy:

$EU^i_3(s^j=s3) > EU^i_1(s^j=s3)$, where $i,j=1,2$

Proof: See the Appendix.

We mark this level of costs[10] $\underline{\underline{c}}$:

$$\underline{\underline{c}} = (1-p)(R(1-\theta_H)-r). \tag{11}$$

Proposition 13. The featured cost levels satisfy the following inequalities (given the above-mentioned restrictions on $R$):

$$\underline{\underline{c}} > \underline{c},$$

$$\hat{c} > \underline{\underline{c}} > \hat{c}_1,$$

$$\hat{c}_0 > \underline{c}.$$

Proof: See the Appendix.

We call *maximal acceptable* cost level the maximum costs under which a depositor pays for information, *and* the counterpart prefers to act the same way. Proposition 13 clearly states

[9] This is calculated in the proof of Proposition 11; see Appendix.
[10] This is calculated in the proof of Proposition 12; see Appendix.

this level is $\hat{c}$. We now determine the influence of the basic parameters of the model on the maximal acceptable cost level.

$$\frac{\partial \hat{c}}{\partial R} = -p\left[(1-\theta_L) - (1-\theta)(r-1)\right] < 0$$

$$\frac{\partial \hat{c}}{\partial r} = pR(1-\theta) > 0$$

$$\frac{\partial \hat{c}}{\partial \theta_L} = pR(1-p(r-1)) > 0$$

$$\frac{\partial \hat{c}}{\partial \theta_H} = -pR(1-p(r-1)) < 0$$

The maximal acceptable cost level is the higher as 1) both the project return and the probability of a zero return after good news decrease as well as 2) both the probability of bad news and the probability of a zero return after bad news increase.

Thus, if costs do not exceed $\hat{c}_0$, the pay-off under the third strategy exceeds the pay-off under the second strategy, regardless of the strategy performed by the counterpart. If costs are higher than $\hat{c}_0$ but still lower than $\hat{c}_1$, the pay-off under the third strategy exceeds the pay-off under the second strategy, assuming the counterpart does not withdraw during the first period. Finally, if costs exceed $\hat{c}_1$ but are still lower than the maximal acceptable level, the pay-off under the third strategy exceeds the pay-off under the second strategy, assuming the counterpart pays for information.

Now let us examine the pure-strategy Nash equilibria that may appear in the game, given the possible differences in costs regarding information signals.

We start from a situation in which the interest rate is adequately high, that is, $R$ does not satisfy inequality (2).

If $\hat{c}_1 \geq c$, the only equilibrium in the game is characterised by both depositors choosing to pay for information; we mark this equilibrium with a star.

If $\hat{c} \geq c > \hat{c}_1$, there are two possible equilibria, which are marked with ▼: one involves both depositors bearing the costs of information, and the other involves both depositors waiting until the end of the game without any information signals.

If $c > \hat{c}$, the only equilibrium occurs when both depositors stay uninformed and do not withdraw early; we mark this equilibrium with ▲.

All possible equilibria are presented in the following matrix:

Depositor 2

| Depositor 1 | s1 | s2 | s3 |
|---|---|---|---|
| **s1** | *1;*<br>*1* | $r$;<br>$(1\text{-}\theta)(1\text{-}(r\text{-}1))R$ | $p+(1\text{-}p)r$;<br>$p+(1\text{-}p)(1\text{-}\theta_H)\ (1\text{-}(r\text{-}1))R\text{-}c$ |
| **s2** | $(1\text{-}\theta)(1\text{-}(r\text{-}1))R$;<br>$r$ | $(1\text{-}\theta)R$;<br>$(1\text{-}\theta)R$ ▲▼ | $p(1\text{-}\theta)(1\text{-}(r\text{-}1))R+(1\text{-}p)(1\text{-}\theta)R$;<br>$pr+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c$ |
| **s3** | $p+(1\text{-}p)(1\text{-}\theta_H)(1\text{-}(r\text{-}1))R\text{-}c$;<br>$p+(1\text{-}p)r$ | $pr+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c$;<br>$p(1\text{-}\theta)(1\text{-}(r\text{-}1))R+(1\text{-}p)(1\text{-}\theta)R$ | $p+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c$;<br>$p+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c$ *▼ |

Now we turn to the situation in $R$ satisfies inequality (2) but is higher than $\underline{R}$.

If $\hat{c}_1 \geq c$, the only equilibrium in the game is characterised by both depositors choosing to obtain information signals; we mark it with a star.

If $\hat{c}_1 \geq c > \underline{c}$, there are two possible equilibria in the market, which are marked with ■: in the first equilibrium, the depositors prefer to pay for information, and in the second equilibrium, there is a bank run during which both depositors withdraw early.

If $\hat{c} \geq c > \hat{c}_1$, all three symmetrical equilibria are possible, and we mark them with ▼.

Finally, if $c > \hat{c}$, there are two possible equilibria. Both are symmetrical, with the depositors refusing to obtain any information signals; we mark them with ▲.

All possible equilibria are shown in the following matrix:

Depositor 2

| Depositor 1 | s1 | s2 | s3 |
|---|---|---|---|
| **s1** | *1;*<br>*1* ■▲▼ | $r$;<br>$(1\text{-}\theta)(1\text{-}(r\text{-}1))R$ | $p+(1\text{-}p)r$;<br>$p+(1\text{-}p)(1\text{-}\theta_H)\ (1\text{-}(r\text{-}1))R\text{-}c$ |
| **s2** | $(1\text{-}\theta)(1\text{-}(r\text{-}1))R$;<br>$r$ | $(1\text{-}\theta)R$;<br>$(1\text{-}\theta)R$ ▲▼ | $p(1\text{-}\theta)(1\text{-}(r\text{-}1))R+(1\text{-}p)(1\text{-}\theta)R$;<br>$pr+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c$ |
| **s3** | $p+(1\text{-}p)(1\text{-}\theta_H)(1\text{-}(r\text{-}1))R\text{-}c$;<br>$p+(1\text{-}p)r$ | $pr+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c$;<br>$p(1\text{-}\theta)(1\text{-}(r\text{-}1))R+(1\text{-}p)(1\text{-}\theta)R$ | $p+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c$;<br>$p+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c$ *■▼ |

The same is true for the lowest possible levels of $R$, $R<\underline{R}$, with the only exception: two symmetrical equilibriums with no information acquisition appear if $c>\underline{\underline{c}}$.

Thus, given high information costs and low deposit interest rates, an equilibrium characterised by a bank run and the withdrawal of funds before maturity is possible. The bank run in this case is not efficient, as the depositors did not receive any information signals about the deterioration of the project's prospects.

***Depositor choice with different levels of costs***

Up to this moment, we have considered the costs of information as an external parameter for a depositor. However, if these costs are the costs each particular depositor must actually bear, then each depositor is unique in his/her ability to find and, particularly, interpret the information. Thus, the variable $c$ should be internal and linked to the depositor.

Our next step is the assumption that the depositors in the model are characterised by different levels of information signal costs. We assume that the first and second depositors are characterised by costs $c_1$ and $c_2$, respectively, and the costs for the first depositor exceed the maximal acceptable level:

$c_1 > \hat{c} > c_2$.

If this is the case, the following equation is satisfied for the first depositor:

$EU^i_3(s^j=s3)<EU^i_2(s^j=s3)$, where $i,j=1,2$

We now examine possible pure-strategy Nash equilibria with respect to the possible costs for the second depositor.

We begin with the case of high return on investments, i.e., $R$ does not satisfy inequality (2).

If $\hat{c}_1 \geq c_2$, there is the only equilibrium in which the first depositor waits until the end of the game to withdraw, and the second depositor pays for information; we mark it with a star.

If $\hat{c} \geq c_2 > \hat{c}_1$, the equilibrium is still unique but symmetrical: both depositors receive no information signal and do not withdraw early. We mark this case with ▼.

The possible equilibria are presented in the following matrix:

| Depositor 1 \ Depositor 2 | **s1** | **S2** | **s3** |
|---|---|---|---|
| **s1** | $1;$<br>$1$ | $r;$<br>$(1-\theta)(1-(r-1))R$ | $p+(1-p)r;$<br>$p+(1-p)(1-\theta_H)(1-(r-1))R-c$ |
| **s2** | $(1-\theta)(1-(r-1))R;$<br>$r$ | $(1-\theta)R;$<br>$(1-\theta)R$ ▼ | $p(1-\theta)(1-(r-1))R+(1-p)(1-\theta)R;$<br>$pr+(1-p)(1-\theta_H)R-c$ * |
| **s3** | $p+(1-p)(1-\theta_H)(1-(r-1))R-c;$<br>$p+(1-p)r$ | $pr+(1-p)(1-\theta_H)R-c;$<br>$p(1-\theta)(1-(r-1))R+(1-p)(1-\theta)R$ | $p+(1-p)(1-\theta_H)R-c;$<br>$p+(1-p)(1-\theta_H)R-c$ |

Now let us turn to the case of low deposit interest rate, i.e., when $R$ satisfies inequality (2) but does not exceed $\underline{R}$.

If $\underline{c} \geq c$, the only equilibrium in the game is characterised by late withdrawal of the first depositor's funds while the second depositor pays for information; we mark it with a star.

If $\hat{c}_1 \geq c > \underline{c}$, there are two possible equilibria, which we mark with ▼: one involves a bank run, and the other occurs when the first depositor does not withdraw early and the second depositor acts according to obtained information.

Finally, if $\hat{c} \geq c_2 > \hat{c}_1$, two equilibria are possible, which we mark with ▲: both depositors refuse to pay for information and wait until the second period (in the first equilibrium) or withdraw and incite a bank run (in the second equilibrium).

The equilibria are presented in the following matrix:

Depositor 2

| Depositor 1 | s1 | s2 | s3 |
|---|---|---|---|
| **s1** | $1;$<br>$1$ ▲▼ | $r;$<br>$(1\text{-}\theta)(1\text{-}(r\text{-}1))R$ | $p+(1\text{-}p)r;$<br>$p+(1\text{-}p)(1\text{-}\theta_H)(1\text{-}(r\text{-}1))R\text{-}c$ |
| **s2** | $(1\text{-}\theta)(1\text{-}(r\text{-}1))R;$<br>$r$ | $(1\text{-}\theta)R;$<br>$(1\text{-}\theta)R$ ▲ | $p(1\text{-}\theta)(1\text{-}(r\text{-}1))R+(1\text{-}p)(1\text{-}\theta)R;$<br>$pr+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c$ ▼ * |
| **s3** | $p+(1\text{-}p)(1\text{-}\theta_H)(1\text{-}(r\text{-}1))R\text{-}c;$<br>$p+(1\text{-}p)r$ | $pr+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c;$<br>$p(1\text{-}\theta)(1\text{-}(r\text{-}1))R+(1\text{-}p)(1\text{-}\theta)R$ | $p+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c;$<br>$p+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c$ |

Finally we analyse the case of the lowest deposit interest rate, i.e., when $R$ is lower than $\underline{R}$.

If $\underline{c} \geq c$, the only equilibrium in the game is characterised by early withdrawal of the first depositor's funds while the second depositor pays for information; we mark it with a star.

If $\hat{c}_1 \geq c > \underline{c}$, the equilibrium is unique and is characterised by a bank run and simultaneous early withdrawal of funds by both depositors; we mark this case with ■.

Finally, if $\hat{c} \geq c_2 > \hat{c}_1$, two equilibria are possible, which we mark with ▲: both depositors refuse to pay for information and wait until the second period (in the first equilibrium) or withdraw and incite a bank run (in the second equilibrium).

The equilibria are presented in the following matrix:

Depositor 2

| Depositor 1 | s1 | s2 | s3 |
|---|---|---|---|
| **s1** | $1;$<br>$1$ ■▲ | $r;$<br>$(1\text{-}\theta)(1\text{-}(r\text{-}1))R$ | $p+(1\text{-}p)r;$<br>$p+(1\text{-}p)(1\text{-}\theta_H)(1\text{-}(r\text{-}1))R\text{-}c$* |
| **s2** | $(1\text{-}\theta)(1\text{-}(r\text{-}1))R;$<br>$r$ | $(1\text{-}\theta)R;$<br>$(1\text{-}\theta)R$▲ | $p(1\text{-}\theta)(1\text{-}(r\text{-}1))R+(1\text{-}p)(1\text{-}\theta)R;$<br>$pr+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c$ |
| **s3** | $p+(1\text{-}p)(1\text{-}\theta_H)(1\text{-}(r\text{-}1))R\text{-}c;$<br>$p+(1\text{-}p)r$ | $pr+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c;$<br>$p(1\text{-}\theta)(1\text{-}(r\text{-}1))R+(1\text{-}p)(1\text{-}\theta)R$ | $p+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c;$<br>$p+(1\text{-}p)(1\text{-}\theta_H)R\text{-}c$ |

Thus, if the information signal costs are too high for one depositor, a bank run is impossible only when the deposit interest rate is very high or when the costs for the second depositor are very low. Notably, if the interest rate is very low and the costs are high, the bank run equilibrium is the only possible equilibrium.

## Conclusion

In this paper, we have discussed a model of bank-depositor relationships assuming that information signals are costly and that depositors can decide whether to bear the costs of information or not.

We calculated the maximal acceptable level of costs for depositors. If the costs are too high, there are no conditions under which the depositors will agree to acquire information. This level is positively influenced by the probability of bad news as well as by the probability of project failure in the case of bad news; this level is negatively affected by the deposit interest rate and the probability of bank failure if the news is good.

We come to the conclusion that in a situation in which the costs of information are high and the deposit interest rate is low, one possible equilibrium is a bank run. This bank run is not efficient in terms of market discipline, as it is not based on information about the deterioration of a bank's profile. In fact, depositors do not obtain these, or any, negative information signals. Notably, if the deposit interest rate is adequately high, such an equilibrium does not appear. We also demonstrate the conditions under which the equilibrium characterised by a bank run is unique. We found that this equilibrium is unique when the deposit interest rate is low and the information costs are not acceptable for all depositors.

***References:***

Admati A.R., Pfleiderer P. (2000) “Forcing Firms to Talk: Financial Disclosure Regulation and Externalities”,The Review of Financial Studies, Vol.13, No 3, pp. 479-519

Allum P., Agca M. (2001) “Economic Data Dissemination: What Influences Country performance on Frequency and Timeliness”, IMF Working paper, WP/01/173

Alonso I., “On avoiding bank runs”, Journal of Monetary Economics, Volume 37, Issue 1, 1996, pp. 73-87

Barth J.R., Caprio Jr. G., Levine R. (2004) “Bank regulation and supervision: what works best?”, Journal of Financial Intermediation, №13, pp. 205-248.

Bellver A., Kaufmann D. (2005) “Transparenting Transparency: Initial Empirics and Policy Implications”, Paper presented at the IMF conference on transparency and integrity

Berger A.N., Davies S.M., Flannery M.J. (2000) “Comparing Market and Supervisory Assessments of Banking Performance: Who Knows What When”, Journal of Money, Credit and Banking, Vol. 32, No 3, Part 2: What Should Central Banks Do?, pp.641-667

Boot A. W. A., Thakor A.V. (2001) “The Many Faces of Information Disclosure”, The Review of Financial Studies, Vol. 14, No. 4, pp. 1021-1057.

Calomiris C.W., Mason J.R. (1997) Contagion and Bank Failures During the Great Depression: The June 1932 Chicago Banking Panic, The American Economic Review, 87(5), 863-883.

Chari V.V., Jagannathan R., “Banking Panics, Information, and Rational Expectations Equilibrium” The Journal of Finance, Vol. 43, No. 3, Papers and Proceedings of the Forty-Seventh Annual Meeting of the American Finance Association, Chicago, Illinois, December 28-30, 1987. (Jul., 1988), pp. 749-761

Chen Y., “Banking Panics: The Role of the First-Come, First-Served Rule and Information Externalities”, Journal of Political Economy, 1999, vol. 107, no. 5

Chen Y., Hasan I., **“**The transparency of the banking system and the efficiency of information-based bank runs”, Journal of Financial Intermediation**,** Volume 15, Issue 3, July 2006, Pages 307-331**”**

Chen Y., Hasan I., “Why Do Bank Runs Look Like Panic? A New Explanation”, Journal of Money, Credit and Banking, Volume 40, Iss. 2-3, 2008, pp. 535–546

Cooper R., Ross T., “Bank runs: Liquidity costs and investment distortions”, Journal of Monetary Economics, Volume 41, Issue 1, 1998, pp. 27-38

Demirgüç-Kunt A., Detragiache E., Tressel T. (2006) «Banking on the Principles: Compliance with Basel Core Principles and Bank Soundness», World Bank Policy Research Working Paper №3954

Demirgüc-Kunt A., Huizinga, H., (1999) “Market Discipline and Financial Safety Net Design”, CEPR Discussion Paper №2311

Diamond. D.W. “Financial Intermediation and Delegated Monitoring”, Review of Economic Studies, Vol.51, No 3, pp. 393-414

Diamond D.W., Dybvig Ph. H. “Bank Runs, Deposit Insurance, and Liquidity”, Journal of Political Economy (June 1983), pp. 401-19

Dowd K., “Models of banking instability: a partial review of literature”, Journal of Economic Surveys, Volume 6, Issue 2, 1992, pp. 107-132

Green E. J., Lin P., “Diamond and Dybvig's Classic Theory of Financial Intermediation: What's Missing?”, Federal Reserve Bank of Minneapolis Quarterly Review, 2000, Vol. 24 Issue 1, pp. 3-13

Homölle S. (2003) “Risk Reporting and Bank Runs”, Institut für Kreditwesen, Discussion paper 03-02

Hosono, K., (2004) “Market Discipline in Bank Regulation and Governance”, prepared for the Seminar on Corporate Governance of Banks in Asia (June 10-11, 2004).

Hosono, K., Iwaki, H., Tsuru, K. (2004) “Bank Regulation and Market Discipline around the World”, RIETI Discussion Paper Series 04-E-031

Hyytinen A, Takalo T. (2002) “Enhancing Bank Transparency: A Re-assessment”, European Finance Review, Vol 6, No 3, pp 429-445.

Hyytinen A., Takalo T. (2004) “Preventing Systemic Crises through Bank Transparency” Economic notes by Banca Monte dei Paschi di Siena SpA, Vol 33, No 2-2004, pp.257-273

Jacklin Ch. J., Bhattacharya S., “Distinguishing Panics and Information-based Bank Runs: Welfare and Policy Implications”, The Journal of Political Economy, Vol. 96, No. 3. (Jun., 1988), pp. 568-592.

Mehrez G, Kaufmann D. (2000) “Transparency, Liberalization, and Financial Crisis”, World Bank Policy Research Working Paper No. 2286

Park S. (1995) “Market Discipline by Depositors. Evidence from Reduced Form Equations”, Quarterly Review of Economics and Finance, Vol. №35, pp. 497-514.

Park S., Peristiani S. (1998) “Market Discipline by Thrift Depositors” Journal of Money, Credit, and Banking, Vol. 30, Part 1, pp. 347-64

Postlewaite A., Vives X., “Bank Runs as an Equilibrium Phenomenon” The Journal of Political Economy, Vol. 95, No. 3. (Jun., 1987), pp. 485-491

Saunders A., Wilson B. (1996) “Contagious Bank Runs: Evidence from the 1929–1933 Period”, Journal of Financial Intermediation, 5(4), 409-423

Semenova M. (2007) “How depositors discipline banks: the case of Russia” Economics Education and Research Consortium Working Paper Series, №07/02

Thomas W., Brown J., Bush M., Smith G. (2006) «Full disclosure: why bank transparency matters. A comparison of US and UK lending practices in disadvantaged communities», New Economic Foundation Report.

Williamson S. D. “Liquidity, Banking, and Bank Failures”, International Economic Review, Vol. 29, No. 1 (Feb., 1988), pp. 25-43

Zhu H., “Bank runs without self-fulfilling prophecies”, BIS Working Papers, No 106, December 2001

“Accounting for change: transparency in the midst of turmoil. A survey of banks’ 2007 annual reports”, PriceWaterhouseCoopers, August 2008

## Appendix

Proof of Proposition 1

The difference between the minimal and maximal meaning of $R$ is always positive:

$$\Delta R_1 = \frac{1}{(1-\theta)(2-r)} - \frac{r}{(1-\theta)} = \frac{1-r(2-r)}{(1-\theta)(2-r)} = \frac{1-2r+r^2}{(1-\theta)(2-r)} = \frac{(r-1)^2}{(1-\theta)(2-r)} > 0$$

Proof of Proposition 2.

The difference between the corresponding utilities is always positive:

$r > p+(1-p)r$, as $r>1, p<1$.

Proof of Proposition 3.

The difference between the corresponding utilities is always positive:

$(1-\theta)R > p(1-\theta)(1-(r-1))R+(1-p)(1-\theta)R$, as $r>1, p<1$.

Proof of Proposition 4.

The difference between the corresponding utilities is always positive:

$p+(1-p)r - 1 = p+r-pr-1 = p(1-r)-(1-r) = (r-1)(1-p) > 0$, as $r>1, p<1$.

Proof of Proposition 5.

We determine when the difference between the corresponding utilities is positive:

$$p+(1-p)r- p(1-\theta)(1-(r-1))R+(1-p)(1-\theta)R>0$$

$$R < \frac{p+(1-p)r}{(p(1-r)+1)(1-\theta)}.$$

Proof of Proposition 6.

The difference between the minimal and maximal meaning of $R$ is always positive:

$$\Delta R_2 = \frac{1}{(1-\theta)(2-r)} - \frac{p+(1-p)r}{(1-\theta)(1-p(r-1))} = \frac{(1-p)(r-1)^2}{(1-\theta)(2-r)(1-p(r-1))} > 0$$

Proof of Proposition 7.

We determine when the difference between the corresponding utilities is positive:

$$p+(1-p)(1-\theta_H)R - c - (p(1-\theta)(1-(r-1))R+(1-p)(1-\theta)R) >0$$

$$p+(1-p)(1-\theta_H)R - R(1-\theta)(p(2-r)+(1-p)) >c$$

$$p(1-R[(1-\theta_L)-(1-\theta)(r-1)])>c$$

Proof of Proposition 8.

We determine when the difference between the corresponding utilities is positive:

$$p+(1-p)(1-\theta_H)(1-(r-1))R-c-(1-\theta)(1-(r-1))R>0$$

$$c<p(1-R(2-r)(1-\theta_L))$$

Proof of Proposition 9.

We determine when the difference between the corresponding utilities is positive:

$$pr+(1-p)(1-\theta_H)(1-(r-1))R-c-(1-\theta)R>0$$

$$c<p(r-R(1-\theta_L))$$

Proof of Proposition 10.

We calculate the difference between $\hat{c}_1$ and $\hat{c}_0$:

$$\Delta_0= p(r-R(1-\theta_L))-p(1-R(2-r)(1-\theta_L))=p(r-1)(1-R(1-\theta_L))>0$$

We calculate the difference between $\hat{c}$ and $\hat{c}_1$:

$$\Delta_1= p(1-R[(1-\theta_L)-(1-\theta)(r-1)])- p(r-R(1-\theta_L))=p(r-1)(R(1-\theta)-1)>0$$

Proof of Proposition 11.

We determine when the difference between the corresponding utilities is positive:

$$p+(1-p)(1-\theta_H)(1-(r-1))R-c-1>0$$

$$c<(1-p)(R(1-\theta_H)(2-r)-1)$$

Proof of Proposition 12.

We determine when the difference between the corresponding utilities is positive:

$$p+(1-p)(1-\theta_H)R-c-(p+(1-p)r)>0$$

$$c<(1-p)(R(1-\theta_H)-r)$$

Proof of Proposition 13.

We calculate the difference between $\underline{\underline{c}}$ and $\underline{c}$:

$$\Delta_2=(1-p)(R(1-\theta_H)-r)- (1-p)(R(1-\theta_H)(2-r)-1)=(1-p)(r-1)( R(1-\theta_H)-1)>0$$

We calculate the difference between $\underline{\underline{c}}$ and $\hat{c}_1$:

$$\Delta_3=(1-p)(R(1-\theta_H)-r)- p(r-R(1-\theta_L))= R(1-\theta)-r>0$$

We calculate the difference between $\hat{c}$ and $\underline{\underline{c}}$:

$$\Delta_4= p(1-R[(1-\theta_L)-(1-\theta)(r-1)])- (1-p)(R(1-\theta_H)-r)=(p+(1-p)r) - R(1-\theta)(1-p(r-1))>0,$$

when $R<\underline{R}$

We calculate the difference between $\hat{c}_0$ and $\underline{c}$:

$\Delta_5 = p(1-R(2-r)(1-\theta_L)) - (1-p)(R(1-\theta_H)(2-r)-1) = 1-R(2-r)(1-\theta) > 0$, when $R < \underline{\underline{R}}$