A CONCERNING VIEW IN THE LIQUIDITY CRISIS THROUGH THE GAME THEORY

Diana Larisa Ţâmpu [1]
Carmen Costea [2]

Abstract

The aim of this paper is to provide a substantiating view on the crises started in 2007 and of which consequences transcended around the world recession. The paper is, essentially, based on a static game theory managing the limits of classic finance theory to provide satisfactory explanations *of different* financial events. *Our intention was to* analyze two cases of application of the game theory in the financial intermediation, with impact on the crisis. The proposed games correspond to deposits and loans. The end of the game *managed to the idea that* balance is reached *only* when the players (both deponent and borrower) will withdraw money from the bank together. This will have a major impact on the bank resources. *The approach path manages to the idea that new considerations may come near the current crises through the game theory.*

Key words: game theory, financial intermediation, bank liquidity, economic crises, market efficiency

The market showed up, in different situations, the lesson of the banking systems on both versatility and its fragility. Such a period was that one between 1980 and 2008, when thirty-five countries have experienced banking crises - periods and their banking system stopped functioning effectively pushing the economies into recession [1]. Such a process was noticed in Romania as well. The banking sector restructure focused on banks privatization, continued with the closure of Bancorex, the biggest foreign commerce Romanian bank. The privatization, as a process, opened the Romanian banking sector to foreign competition enlarged the capital inflows from international institutions. The credit exploded and let the last decade banking activity is touched by a high volatility, armless in front of the 2008 crisis effects.

According to statistical data, loans from the banks had an upward swing, with increases of 87% in March 1997, decreases up to 3% in March 1998 and a level of 11% in March 2000. Since the end of 2001, these fluctuations have subsided and credit expansion had a constant growth rate of 50% per year (data from Eurobank report in 2008). The Romanian economy from the last three years (until the start of the crisis) has seen an increase sustained especially by the constant expansion of lending activity. Therefore our research considers the exposure of lending and storage in the form of game theory. In the first case of lending, we studied a Principal-Agent model, with an infinitely repeated game in the context of credit market, while for the savings a game has been considered to take into account the higher order beliefs to see under what circumstances it may happen that all

1 ASE Bucharest, DSCQM, Doctoral School in Business Administration, Bucharest –Romania, diana.tampu@yahoo.com
2 ASE Bucharest, Romania, cecostea@yahoo.com

depositors withdraw their money at the same time, fact that lead to liquidity crisis and bankruptcy for the intermediary.

Finally, outstanding on the link between games and liquidity crisis from 2008 and possible solutions are presented.

The Main Aspects That Links Finances With Game Theory

When we speak about risk, we have to make a first link to Keynes (1936) and Hicks (1939) that add the risk premium to the interest rate. Later Markowitz (1952, 1959) utilized a special approach of von Neumann and Morgenstern's (1947) about the theory of asset pricing. He considered the case where investors are only concerned with the mean and variance of the payoffs of the portfolios they are choosing [2.].

The equilibrium equation was for the first time presented by Sharpe (1964) and Linter (1965) is:

$$Er_i = r_f + \beta_i \, (Er_M - r_F)$$

Where Er_i represents the return on asset i;

r_f represents the return on the risk free asset

Er_M represents the expected return on the market portfolio and

$$\beta_i = cov \frac{(r_i, r_M)}{var\ (r_M)}$$

The same relationship is valid in the situation were $\beta=0$, and don't exist asset without risks. In the case of models applied on the competitive markets with asymmetric information and without frictions, the only possible variations are due differences in risk. A lot of anomalies are found in relationship with the efficient of markets, and the equilibrium of asset – pricing based on rational behavior.

It is believed that in the financial markets the participants do not just want the "fundamentals" (the basic data on market participants, the companies portrait, the fundamental analysis), but also on what others think about fundamentals, what others think about their beliefs, etc.. It seems that this context of considering other beliefs in the analysis was overlooked in finance, maybe because the models with asymmetry information are not high enough to take into account higher order of beliefs.

The approaches based on the game theory resolve these deficiencies. To get a clearer view we will consider an example to illustrate how the higher order beliefs on fundamentals determine the outcome. The problem analyzed is a version of Diamond and Dybvig's model (1983) [4.] on brokerage and bank liquidity crisis. In the context that we will describe is a single equilibrium. For each state of nature, we can determine whether there is or not a liquidity crisis. But the state of nature is usually determined by several factors.

It is the place to notice the depositories' beliefs: what they think about fundamentals, what beliefs they think have the others, etc. The example we will present illustrates why the game theory confirms what intuition tells us, that the higher beliefs matter and determine the outcome.

The Game Theory

The standard finance theories were unable to provide explanations about liquidity crises. The asymmetric information and strategic interaction couldn't be incorporated in previous methodologies, that why the use of the game theory it's not only useful in this situation, but also has been successful applied.

The game theory isn't as new as we may think it is. The first one who made contributions in this domain was Ross (1977) who develops a model about the appropriate level of debt in de firm. Later Myers and Majluf (1984) develop the "pecking order" theory of financing. Diamond (1989) has shown how shown how reputation can improve the stimulant risk in an extended period of time. [1.]

We consider two deponents in a bank. They will be the two players. The saver / The player "i" is from the type P_i. In this situation we have two hypotheses: H_0 and H_1.

- H_0: If $P_i < 1$, than the "i" deponent need money, and he will withdraw all the money from the bank;
- H_1: If $P_i \geq 1$ than the "i" deponent doesn't need money, and he will leave his money in the bank with the main purpose to maximize his profit.

The strategies of both players are the following: they can leave the money in the bank until maturity of the deposit or they may withdraw the money from bank. The earnings are as follows:

- $E_{0:}$ If a depositor withdraws the money from the bank (before the maturity of the deposit), receives a guaranteed gain: $e > 0$;
- E_1: If a player does not withdraw the money, and neither do the other one than each player may gain E, with $e< E< 2e$;
- E_2: If player one keeps the money in the bank, and the second one withdraws, the gain is zero for the first player.

In this case we have 4 possible situations, presented in the following matrix:

$Player\ 1/Player\ 2;$	$Remain$	$Withdraw$
$Remain$	E,E	$0,e$
$Withdraw$	$e,0$	e,e

- E, E: means that the both players don't need money in a particular moment;
- 0,e: means that the first player remains with the money in the bank, and the second one does not;
- e,0: means that the first player withdraws the money, and the second one doesn't;
- e, e: means that the both players withdraw the money from the bank.

If we are in the hypothesis H1 where Pi ≥ 1, none of the players need liquidity, and the game has two equilibriums (relative earnings method): (withdrawal, withdrawal), (remain, remain), both withdraw the amount deposited or both leaves to maturity.

Possible Scenarios:
Scenario 1

Let us now assumes a different scenario, in which no player needs liquidity, and both of them believe that none of them needs liquidity, etc. We will demonstrate that for this scenario the unique equilibrium involves that both players to withdraw their amounts deposited. Clearly, in this case the higher beliefs determine the outcomes. Let assume that P_1 and P_2 are two players and their type are correlated. We also assume that each player is uniformly distributed in the interval $[\omega - \varepsilon, \omega + \varepsilon]$ where ω is a uniform distribution for a very small ε .

Being given this distribution of types, these differ not only in terms of fundamentals, but we have ensured their differentiation depending on the higher beliefs. A player that needs liquidity is on the type of P_i, with $P_i < 1$. If a player knows that his type is P_i, that for a specific ε , he will consider that ω is in the following interval $[P_i - \varepsilon, P_i + \varepsilon]$ => the type for the other player is in the interval $[P_i - 2\varepsilon, P_i + 2\varepsilon]$.

If $P_i > 1 + 2\varepsilon$, the P_i player will think about the other one that he doesn't need liquidity, and with the same judment, if $P_i > 1 + 4\varepsilon$ he will believe about the other one that he is the one with demand of liquidity. [5.]

In general, if $P_i > 1 + 2^n\varepsilon$ than the player P_i will think that the other player don't need liquidity. What involve these higher orders of beliefs? In fact, for a small enough ε, the only equilibrium of the game is when both players withdraw money, whatever type they observe. We noticed that, by definition, each depositor must withdraw if $P_i < 1$ because he needs liquidity.

Scenario 2

Let's asume that the strategy of the first player strategy is to remain in the game only if $P_i > k > 1$. Let's also asume that the second player know *k*. The second player has the probability $p_1 = \frac{1}{2}$ that the first player to have a type smaller than *k* and to wothdraw money, because he needs liquidity. In this case the second player will have the following gain
G1: if he remains;
G2: *e* if he withdraw;

Because$e > 1/2E$, than G2 is the best situation and player two would a achieve a bigger gain if he withdraw. In the mixed strategy the equilibrium is that both deponents withdraw their sums of money. This conclusion seems to be a paradox one. Sooner we obtained as equilibrium the state where both would remain in the game, so they do not withdraw money. This paradox is explained from the main feature of incomplete information environment, namely that although the four possible states that the matrix of earnings does not take into account the infinity of states to which correspond these higher order beliefs. In all these states there is a lack of information on the liquidity needs of the players. Given our assumptions on earnings (mainly that $e < E < 2e$) the equilibrium of the game in incomplete information is that both deponents withdraw.

The Game Of Lending

We will analyze an infinitely repeated game in the context of credit market, combining the game theory with financial intermediation. A second objective of this section is to understand the importance of the relationship between lending and sustainable long term, lower costs for borrowers and unsecured loans for these ones versus secured loans for borrowers. In this part of the paper we will refer to the specialty literature on the credit contracts and moral hazard. The moral hazard has been recognized as being a key problem in borrowing; We are referring here to studies of Stiglitz and Weissfrom 1981. This led to exploring how the essentially collateral influence the interest rates of loans.

We will consider a competitive credit market, where agents are risk neutral. Competition for loans between banks lead to agreements which maximizes the surplus of borrowers projects, given the restriction of participation and compatibility restrictions. The Bank has no claim on any asset of the borrower excepting the project cash flow and collateral. The debtor borrows 1€ to invest in a project. If it is successful, the project returns a profit of R€, unless the gain is zero. The probability that the project to succeed is p (ω), where ω is the action followed by the borrower. The cost of the ω action for the borrower is

$$V(\omega) > 0 \text{ where } V' > 0, V'' > 0.$$

Let's consider $p(0) = V(0) = 0$. At the begining of this period each borrower has a wealth W_0, which represents the eligible collateral that can be used to guarantee a bank loan. The project of each borrower has a positive Net Value Added (NPV > 0) there are no other investment alternatives for borrowers and a loan from the bank is the best way to fund the project. These assumptions ensure that all borrowers enter into the competitive banking system at *t = 0* moment.

We assume that the collateral asset involve a cost namely the bank evaluation made for collateral is a fraction $\beta \in (0,1)$ from the assessment that the borrower does. If the borrower evaluates the collateral to the value of C and goes bankrupt, is executed by the bank, and it recovers from collateral βC. The difference $(1-\beta)C$ represents the cost of re-possession of collateral, including the cost of transfer of ownership, legal and administrative costs. Therefore, bank offers value on the collateral for the idea of driving factor rather than for its intrinsic value.

A credit agreement consists of an interest factor (one plus interest rate), α and the collateral, C: It is assumed also if the project is not successful and the loan is not collateralized, the bank cannot recover anything from the debtor. After accepting the credit agreement, the borrower chooses action ω, the bank does not know what action will choose the borrower (the problem is in incomplete information). The model is written as follows:

$$Max\ H = M(\omega^*) - p(\omega^*)\alpha - [1 - p(\omega^*)]C \qquad (1)$$

Where $M(\omega^*) = p(\omega)R - V(\omega)$

The objective of this equation is to maximize the expected net profit of the borrower (gain minus the cost $M(\omega^*)$). With the following restrictions:

$$p(\omega^*)\alpha + [1 - p(\omega^*)]\beta C \geq r \qquad (2)$$

The second equation represents the bank's participation constraint (r -Interest rate of deposit)

$$\omega^* \epsilon \ \underset{\omega}{\mathbf{argmax}} \{M(\omega) - p(\omega)\alpha - [1 - p(\omega)]C\} \qquad (3)$$

$$\alpha \geq 1, C \geq 0 \qquad (4)$$

The gain of the borrower consists of the gain arising from the project, less the interest that have to be paid to the bank if the project is successful, so with the probability $p(\omega^*)$ and the collateral that needs to stop if the project fails, so with the probability $1 - p(\omega^*)$. Trying to transform the problem in the context of game theory we get into the following situations.

The Infinite Repeated Game In The Context Of Market.

Supposing that the debtor / the borrower entering the loan market repeatedly in an infinite number of discrete periods. In each period the borrower needs funding, 1 €, for a project with NPV 0. Although the borrower has the ability to save, he decides not to do it from the following reasons: if the project fails at any time, he had no capital investment in the coming period and will have to use a bank loan, if, instead, the project is successful, and the borrower could save to reduce the next loan. But the best credit agreement for long-term gives the borrower a contract more advantageous if the project was a success in previous periods. So, the borrower chooses not to save.

A contract from a period $\{\alpha^*, C^*\}$ is independent of time because the gains from projects in different periods of time, encouraging by the borrower during that period are identically and independently distributed and choosing of an action in a given period is not affected, if the other factors remain constant from, the past achievements of projects. In each period is assumed that the borrower is able to provide full the collateral. The earnings are discounted at discount factor, *D = 1 / r*.

Now we can see why we are interested in studying the long-term contract. If lending takes place in a single period, the borrower works to reduce the likelihood of failure, to transfer the collateral to the bank. In the case of a long term contract, the bank has an additional instrument of stimulation that is the promise of lower cost funding in the future if the borrower is working well now. Since the action of is not observable the borrower, the contract cannot be conditioned by this action. But the bank can make a further the success of the project grant of, which will likely increase in this way. This requires a additional tool of stimulation low demand of collateral, improving in this way the wealth.

The bank can recover the present value of future subsidies before setting market prices top the grants. In terms of the borrower, the payment of higher prices in the early stages of the relationship may be regarded as an investment in its creditworthiness, and the profit from this investment will be realized in the future when become available the financing costs below the market price.

Taking into account the competitive environment, the bank is forced to zero profit during the relationship with the borrower, which means that may provide subsidies to the debtor in certain periods and can charge him at other times. The infinite repeated game structure is as follows: every time t, the borrower is launching a project that can be successful or can be a failure. The game can be represented as a tree. The states are numbered from top to bottom, Where x_{t+T}^{j} is the *j* state from the moment *t+T*.

We distinguish between the states from the upper half and from the lower half. It is assumed that there is no successful project before time *t*. States are states from the upper half that follows after a success and those the failure follows from the lower half from the range$[t, t+1]$. We will analyze a long-term contract where the bank is forced to earn zero expected profits in each period. Solving the game actually requires solving each sub-game in the assumptions above, characteristics for the principal-agent model. We will not state here the theorems that give the game balance, we believe that they are not subject of our work, but the results arising from them.

We will try to empirical present the mechanism. Let us consider a game with compatibility restriction (3) and restriction of participation (2). To maximize the usefulness of the borrower the restriction of participation should be satisfied. According to the restriction of compatibility with higher α is, greater C become and can create an additional loss. So, $\{\alpha^*, C^*\}$ is an optimal contract period (according to one of the applied theorems collateralization of a loan can reduce the moral hazard. An unsecured loan has a higher interest rate in order to satisfy the restriction of the bank participation). When bank-borrower relationship is repeated, the solution depends on the restriction of participation, which must be satisfied: every time or just overall throughout the credit relationship. If the participation constraint must be satisfied in each game, then $\{\alpha^*, C^*\}$ contract remains the optimal in the entire game. But if the participation constraint must be satisfied: only in terms of present value the credit throughout horizon, then the income of a period that can be improved because can substitute the collateral subsidies and taxes to motivate the borrower.

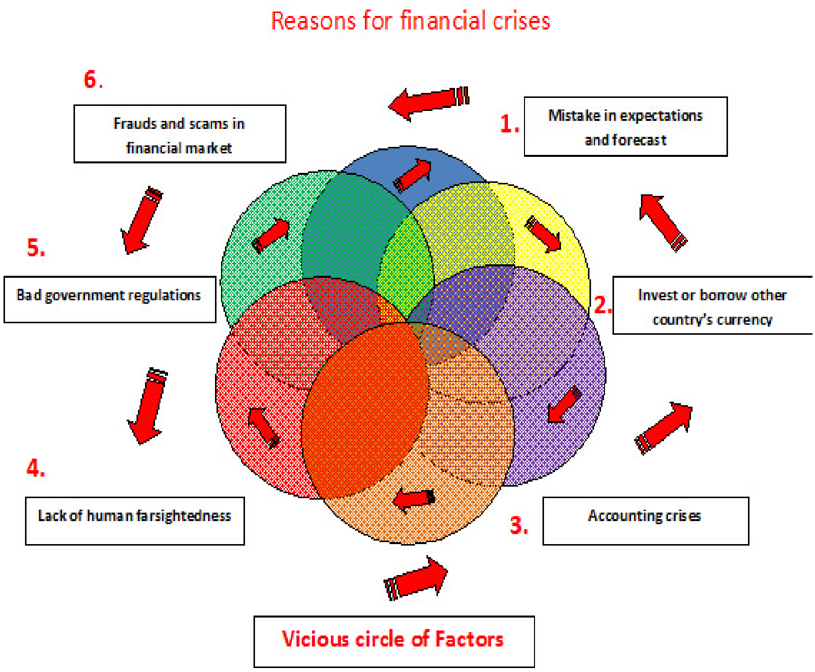
The question that arises is: how should be set these taxes and subsidies? Since the borrower can withdraw at any time from the game, the tax should be imposed in the early stages of the relationship. Indeed, one of the results obtained from solving the problem Lead - Agency said that the tax should be paid after the first successful implementation of the project, after which *C* is reduced to zero and $\alpha = rp_i^{-1}$ having regard to the saturated restriction of participation and *C=0*. The collateral less can be used to motivate actions that can improve the likelihood of success of the project. This scheme involves that the restriction of compatibility can be achieved without collateral after completion of the project and with less collateral before the success.

We have analyzed a model of infinite competitive of the credit market where borrowers can choose unobservable actions that may affect the earnings distribution (the probabilities to measures are attached), in order to study the potential gains arising from a long term relationship lender-debtor. The most interesting result is that of a single successful project the implementation is enough to guarantee the borrower an unsecured loan. To the first successful project, the borrower must accept contract with a collateralized financing cost higher after the first successful contract. It therefore explains why banks give borrowers loans grant without a history, preserving the privilege of a debt that is not collateralized, for which there is a history.

Conclusions

We have seen a liquidity crisis at the end of 2008. What we have learned from this? First we established that financial intermediaries have an important role in the money market, as Diamond sad they being the ones that monitor the relations between the lenders and the borrower. Game theory does not predict the crisis causes and solutions. Several factors are guilty for producing the crises. Lack of transparency, absence of underestimating risks and any information about how it might behave in the new financial products under stress are significantly the most recurring problems in the past and in the present crises too. This could be the main reason why the happening of the present crisis had not to be a surprise to anyone.

Figure 1. A vicious circle of factors – reasons for the current financial crises [10.]



World economies were hit by this crisis to various extents, depending on the vulnerabilities of each and their exposure to toxic assets. The response to the crisis is contingent upon the fundamental principles everyone believe in, the available resources, the institutions and the instruments everyone can make use of. What tell us the game theory about the crises? Primarily the game theory tell us that in equilibrium, when we consider higher order of beliefs of depositors in the bank (what they believe that others think, etc..), the depositors would withdraw their money from bank. Of course, this state would lead immediately to a problem of liquidity in the banking system and inevitable to collapse.

Secondly, we have seen (empirically, without going deeply into Principal Agent problem) that banks provides lower costs and unsecured loans for stable customers, while new customers, for which there is no history of relationship with the bank, have part of higher costs and only collateralized loans. Thus, we can see very well why banks have remained uncovered in the current economic environment when many established customers with long-term relationship with the bank began to have problems. Considering that in previous periods they have had successful projects (some loans have returned without problems) the Bank has granted not collateralized loans and are now they are in deadlock of not having collateral to execute in order to recover the amounts lent. This explains, with game theory, the banking liquidity crisis.

A solution to this problem is the creation of "an emergency mechanism to ensure the bank debt "[8.]. The emergency mechanism to ensure bank debt (bank debt insurance emergency mechanism - EBDIM) should not, in the vision of financial experts, replace ultimately the loan (which is granted by the

Central Bank). EBDIM must work in conjunction with the "lender of last resort" to cover the financing needs of banks and to prevent massive withdrawals and panic that is created around a bank being, even temporarily in the impossible situation to make payments to customers. The insurer should cover completely on any short term the need cash to a failing bank, preventing in this way the depositors panic, which can lead to collapse of a bank. This type of existing insurance is already inspired from the insurance practiced by the banks around the world, for deposits. It is possible that an adaptation of the practices applied by the banks for deposits and in the case of debt of crisis should exempt the credit institutions. Because EBDIM would make that the insurer, in turn, to have a very high passive in his financial balance the mechanism of insurance on bank debt should receive when needed government support is. In case of default, the secured loans should be repaid immediately through EBDIM, which if necessary, benefits and of central bank liquidity. Only then loans of last resort would be used.

This paper analyzed a model of competitive credit market, in an infinite time horizon, in which debtors have at their disposal unobservable strategies that affected the distribution of function of winning. The analysis was performed primarily to study the potential gains of the long term relationship between lender and borrower, namely between the bank and debtor. The result obtained after applying the game theory is surprising. The simple history of the borrower gives the bank the proper confidence to offer such an unsecured loan.

The very interesting correlation between a successful project and an economic boom that took place before 2008 is plausible in this case. Therefore are explained the unsecured loans that banks offered in the past, and faced with them now. Considering those presented previously, is shaped at least an interesting approach of the liquidity crisis of the banks from the perspective of the game theory.

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