Doctoral School of
Economics

RÉSUMÉ

for

Márton MICHALETZKY

LIQUIDITY OF FINANCIAL MARKETS

Ph.D. dissertation

Supervisor:

Imre CSEKŐ, Ph.D.
associate professor

Budapest, 2010.

Department of Finance

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Contents

1 Preliminaires

According to Acerbi and Scandolo [2007] "people in the ... the market use the term "liquidity risk" for at least three distinguished phenomena: 1. Facet 1: the risk that our portfolio may run short euros 2. Facet 2: the risk we run trading in a illiquid market 3. Facet 3: the risk of a drainage of the liquidity circulating in our economy. The first can be associated with *csah–flow risk*, i.e. the risk we cannot meet our debt obligations, the second is usually termed (*price impact, market impact*) and the third is the risk of the financial intermediary system *drying-out*.

On the other hand according to Basel Committee on the Global Financial System [1999]: „A liquid market is a market where participants can rapidly execute large-volume transactions with a small impact on prices." But as Kyle [1985] cites Fisher Black: "a liquid market is a continuous market, in the sense that almost any amount of stock can be bought or sold immediately, and an efficient market, in the sense that small amounts of stock can be bought or sold very near the current market price, and in the sense that large amounts can be bought or sold over long periods of time at prices that are, on average, very near the current market price."

We might grasp from the excerpts above that it is not an easy task to define the notion of liquidity. Due to this the first two sections of the dissertation are totally devoted to a short summary of the relevant scientific literature.

The notion of liquidity In the first chapter the colorful but ambiguous notion of liquidity is discussed starting from the *liquidity of the companies*, through the *portfolio liquidity*, and the *liquidity of the banks* to the *liquidity of the market*. At the end of the section I specially focus on the Hungarian and international literature of network theoretic methods of financial markets.

Market microstructure theory The second chapter gives a short summary of the basic results in the literature of market microstructure theory especially focusing on the liquidity of the market.

The central notion of market microstructure theory is the process by which the price for an asset is determined, so that equilibrium is reached. This aspect was somewhat neglected by neoclassical economics. The theory analyzes how information asymmetry, heterogeneous market participants and market structure have on price formation, trading bahavior and trading costs. The orderflow and the bid-ask spread are of central importance in these models. The results might be connected

to the theory of effective markets and can be used for designing market structures.

The chapter starts with presenting the model in Kyle [1985], where based on the order given by the informed trader and the liquidity traders together the market maker determines the market clearing price in such a way that his expected profit will be zero. The paper analyzes how quickly the insider information of the informed traders is incorporated into the price, how large the profit obtained by the informed traders is, and the liquidity characteristics of the market.

Next the model presented in Glosten and Milgrom [1985] is discussed. In this model the market maker sets the bid and ask prices in such a way that his loss on the contracts with the informed traders are compensated by the profits obtained on the transactions with liquidity traders. The paper gives a bound on the average of the bid-ask spread and proves that the process of the price remains martingale under the condition that the information asymmetry is the source of the spread.

The last part of this chapter presents the results of Back and Baruch [2004] giving a model providing a unified framework for the two models discussed above and Das [2005] developing further the Glosten–Milgrom's model.

The closing part of the chapter gives a short summary of the bid-ask spread models.

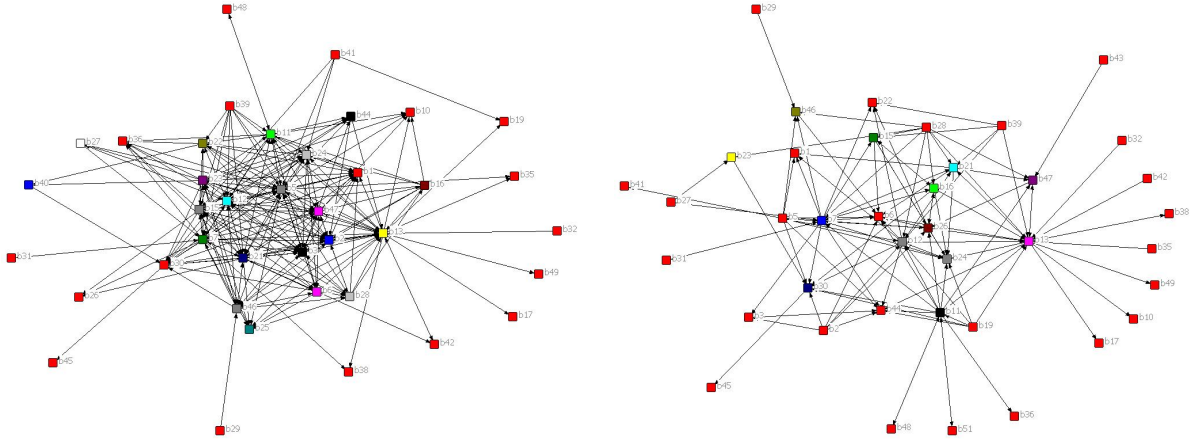
Liquidity of stock markets In the third chapter I examine the liquidity of hte four largest companies listed on the Budapest Stock Exchange. The research has double purpose. First, I carry out the time series and cross-sectional analysis of various liquidity measures. Second, the value of the Hurst–exponent can contain important information when one develops the forecasting strategy of the various measures, therefore I deal with this issue.

Forecasting turnover, one of the simplest liquidity measures can be important to the brokerage firms on the stock market executing customer orders for a fee that is proportional to the turnover and to the ones carrying out VWAP (volume weighted average price) orders. They need to possess conditional turnover forecasts, which makes it clear why it is important to know when turnover, and hence liquidity can be forecasted.

Estimating the bid-ask spread is crucial for every trader on the market, since it represents a kind of transaction cost. The forecast also reveals the factors influencing the bid-ask spread, and the extent to which these factors are responsible. This is also relevant to the financial authorities designing market structures, since these results can be used to assess the cots market participants incur due to adverse selection or

the lack of competition. In my research I will not estimate to bid-ask spread but will deal with its forecastability.

Figure 1: Representation of the interbank uncovered deposit market based on monthly networks in August 2008 and December 2008



Analysis of the Hungarian interbank uncovered deposit market Figure 1 shows the Hungarian interbank uncovered deposit market in August 2008 and in December 2008. The nodes of the graph represent the financial institutions in the market and two nodes are connected by a link if there was a transaction in the given month between the two market participants. If the link is directed then it shows the direction of financing; the nodes are colored base on their turnover in that month

If we compare the network in August prior to the Lehman bankruptcy on the 15th of September, 2008 the following observations are eye-striking: i) the earlier network is more dense, there are more links between the banks; ii) banks in the center are closer to each other in August than in December; iii) the number of banks with a single connection has increased. Moreover, we can speculate whether the links showing the direction of financing have changed their direction or not.

In this empirical research my objective was to characterize the market prior to and after the Lehman bankruptcy using graph theoretical tools. It is well known that markets, hence this one, had been essentially liquid before the bankruptcy, and that the character of the markets has fundamentally changed thereafter and they have become illiquid. My goal is to identify such measures that show this change observed in the market, since this way these measures might characterize the liquidity of this market. Moreover, if these measures show significant change earlier than the Lehman bankruptcy then these might be used to forecast liquidity.

Network (or graph) theoretical researches can be divided into two groups, *static* and *dynamic*. The former deal with a snapshot of the market. Researches focusing on the dynamics can also be grouped: there are the ones that create a static graph based on the market snapshot and analyze the impact of an exogenous factor on the behavior of the graph; and there are the others which assess the dynamics of the graph representing the market. The *novelty of my research* is that the analysis of financial markets with these tools is relatively new even in the international scholarly literature, while no Hungarian market has been analyzed this way by this time.

2 Methodology

The analysis of the colorful notion of liquidity cannot be carried out by a single method. In the following section I will summarize the methods applied in my dissertation and the methodology used in the scholarly literature covered by the dissertation.

Market microstructure theory The area of market microstructure theory dealing with liquidity uses a very much diversified methodology. Efficient markets and the area of how information is incorporated into prices cannot be studied without Bayesian statistics and stochastic analysis. Equilibrium games (game theory) is the useful tool when the behavior of optimizing market participants in the presence of information asymmetry (adverse selection) is in the focus.

Bid-ask models are usually estimated using linear regression, while the interdependence of the variables is discovered by covariance analysis, but even option pricing is handy at certain inventory models.

Descriptive statistics During the research of stock market liquidity the time series and the cross-sectional analysis if the liquidity measures was carried out by standard statistical tools.

The Herfindahl–Hirschman index, its normalized version and the effective number was used the capture the change in the concentration of the interbank uncovered deposit market.

Transaction durations During my research on the stock market liquidity I mainly focused on the predictability of the transaction durations. The starting point was the notion of *volume weighted transaction duration* and *capital weighted transaction duration* based on Gouriéroux, Jasiak and Le Fol [1999] and Barra [2008]. Weighted duration shows the time needed to trade a given volume or given value of stocks on the market.

The Hurst–exponent I used the Hurst–exponent in my research on the stock market liquidity to assess the predictability of transaction durations and that of bid-ask spreads.

The variance of the increments of the fractional Brownian motion (fBm) is given by

$$Var(fBm(t) - fBm(s)) = v|t - s|^{2H},$$

where $fBm(t)$ and $fBm(s)$ are values of a fractional Brownian motion in time t and s, v is the variance of the Wiener–process and H is the Hurst–exponent.

Network theory – graph theory My research on the interbank uncovered deposit market mostly took advantage of the methods in graph theory concentrating on the links between the financial institutions. Unfortunately, due to the small number of banks on the market (small network size) more complex network theoretical tools could not be utilized. The conventional graph theoretical measures such as centrality measures (degree, betweenness, closeness) were naturally taken advantage of.

3 The Results of the Dissertation

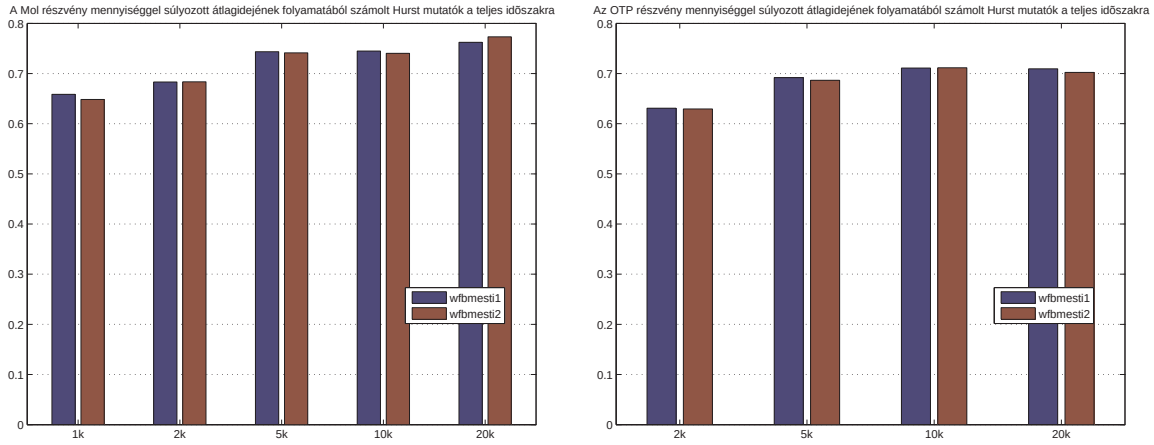
3.1 Liquidity of stock markets

I have analyzed the liquidity of the four largest stocks listed on the Budapest Stock Exchange from September 1, 2006 to June 30, 2009 based on transaction lists. In the first part of the research I have carried out the time series and cross-sectional analysis of several liquidity measures. In the second part of the research I have studied the long memory transaction durations. The following hypotheses have been justified:

H1 The different dimensions of liquidity do not show the same phenomena. *Tightness*, well captured by the bid-ask spread and *depth*, strongly connected to turnover showed opposite behavior during the market turmoil of fall 2008, as the widening of the spread was accompanied by the drastic increase in turnover.

H2 The Hurst–exponent of the transaction durations of the four largest stocks listed in the BSE calculated for the entire time period was typically between 0.6 and 0.75, which confirms that the transaction durations can be forecasted (see Figure 2).

Figure 2: Hurst–exponent of two stocks' volume weighted transaction durations based on data from September 1, 2006 to June 30, 2009 (MOL, OTP)



The Hurst estimations were done by two built-in functions of MATLAB, wfbmesti 1 and wfbmesti 2, 1k, 2k, 5k, 10k and 20k are the volume thresholds for the volume weighted transaction durations.

H3 The estimated Hurst–exponents are increasing functions of the threshold (volume or capital) to a point, and then they start to decrease. Certainly, one reason for the decrease of the Hurst–exponent is that the length of the time series on which the exponent is estimated shortens with the rise of the threshold. The reason for the initial increase of the exponent is not clear, but it rather seems to be a statistical phenomenon than a market characteristic, considering that i) Hurst–exponents calculated from one day's data are extremely volatile ii) the time series of transaction durations calculated with different thresholds are strongly correlated.

H4 Based on the preliminary research it seemed that the long memory of transaction durations during market turmoil is shorter. This would mean that transaction duration, which is a kind of liquidity measure, would be more difficult to predict in these times. Calculations for longer periods and more stocks unfortunately could not confirm this statement (see Figure 3).

Figure 3: Daily Hurst–exponents of transaction durations of OTP, threshold=5000, September 1, 2006 – June 30, 2009

H5 During the preliminary research the question rose: does the long memory of transaction durations have a characteristic level, independent of time periods and instruments? If it has such a stable level independent of time period, does it change from instrument to instrument? The detailed research revealed that the characteristic level of the Hurst–exponent is between $0,6$ and $0,75$, but – even if we set aside the decreasing Hurst–exponents for larger thresholds – no typical level could be identified for the different instruments.

H6 Correlation of the daily Hurst–exponents with other time series (price, volatility, turnover) was meaningless, as the daily Hurst–exponent showed excessive

versatility.

H7 According to my calculations the change of the average size of transaction durations did not influence the long memory of the process.

3.2 Graph-theoretic analysis of the interbank uncovered deposit market

What makes the interbank uncovered market interesting is that the debts provided on this market are uncovered consequently it plays an important role in the behavior of the market players what they think about the credit risk of their partners. This assumption might appear in the turnover, the interest rate of the transactions and even in that whether they at all give credits to each other (credit rationing). The graph-theoretic analysis, based on the connections between the various banks might expose some patterns of this process.

The change in the market behavior after the bankruptcy of Lehman Brothers might have various interconnected reasons. For example, the decrease in risk appetite, increase of the credit risk premiums, the drop of the limits between the various banks, the change in the policy between the banks and its subsidiaries. Although we are not going to focus on these specific issues sometimes we make some remarks regarding these.

Hypotheses

I have started the analysis of the Hungarian interbank uncovered deposit market with setting forth the following hypotheses:

H1 The topology of the network of the Hungarian interbank uncovered deposit market prior to the bankruptcy of the Lehmann Brothers is radically different from that of after the bankruptcy.

H2 There exist some network indicators showing the decrease in liquidity before September 15, 2008.

Data

Our investigation was based on the databank provided to us by the National Bank of Hungary containing transactions from the beginning of 2003 until the first quarter

of 2009 of the interbank uncovered deposit market. This time interval contained relatively peaceful periods, crisis, and some recovery phase after the crisis. The market players experienced abundance in liquidity and shortage, as well.

The databank is based on the mandatory reports of the financial institutions on the market complied by the central bank. Every record contains the date of the report, the number of the reporting bank[1], the number of the partner bank, the first day of the transaction, the maturity day of the transaction, its size, the interest rate of the credit and whether it was a deposit or credit from the point of view of the reporting bank. Majority of the transactions were overnight credits, thus its tenor is one day consequently we did not distinguished the credits with various tenor. They were taken into consideration using the day of the report.

Matrix representation

Computing the daily, weekly and monthly aggregates of the data we get a matrix showing the mutual positions of the banks. The entry in the i^{th} row, j^{th} column shows the amount of the credit given by the i^{th} bank to the j^{th} bank during the given period. The sum of the entries in the i^{th} row shows the total amount of credits given by the i^{th} bank to all the other financial institutions. The i^{th} column-sum shows the amount of credit obtained by the i^{th} bank. The difference of these two quantity shows the net position of the i^{th} bank during the investigated period, i.e. whether it was net borrower or net lender.

These matrices can be represented by a graph where the nodes represent the financial institutions, and the nodes are connected by an edge if one of corresponding banks gave credit to the other one. In case when this edge is a directed one then it shows which bank was the lender and which one was the borrower. Note that in this representation the amount of the transaction does not play any role. To take into consideration this information evaluated (directed) graphs should be considered. The present research is based on these matrices and graphs focusing on their time behavior.

Results

We summarize the results of the research highlighting the change experienced in the uncovered deposit market after the Lehman bankruptcy.

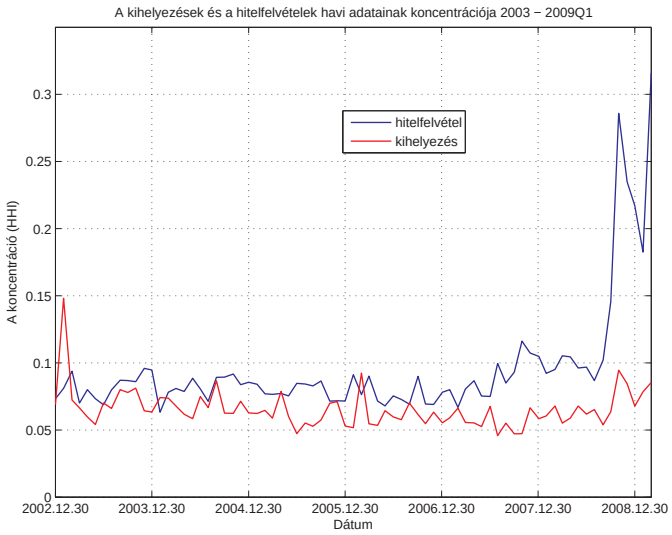
[1]Due to the confidential nature of the data the financial institutions are represented not by their names but by a number.

E1 The *turnover* drastically decreases due to the credit crisis at the end of year 2008. The average level drops from 600 to 300, i.e. it is becomes *half* of the previous value.

E2 The market *interest rate* after the Lehman bankruptcy increases from the previous 8% to 11,5%, i.e. by 350 basispoint.

E3 The *deposit concentration* perceptibly increased (the HHI from 4,6% increased to 6,1%), while the *credit taking concentration* drastically increased after the Lehman bankruptcy. This is shown by the increase of the corresponding HHI from 6,6% to 18,4%. The effective number of credit taking dropped from 15,2 to 5,4. Figure 4 shows that the increase of the concentration of credit has already started *before the Lehman bankruptcy* in the second half of 2007.

Figure 4: The concentration of the monthly turnover of the deposits and credits – 2003-2009Q1



E3a The index of concentration of the deposits increased during the crisis but its amount cannot be considered significant[2].

E3b The concentration index of credit taking started to increase already at the end of 2007, its growing turned to dramatic due to the crisis.

E3c The effective number based on the credits was fluctuating around 12 until the middle of 2007, while by the end of 2007 it dropped to 10, during the crisis to 4. We might interpret this result as if the number of bank on the market taking credit during the crisis practically dropped to 4.

[2]There are other examples for increments of similar size during the investigated period.

E3d During the crisis approximately the same number of depositors finance less number of creditors.

E4 The *concentration of transactions at extreme interest rate* is higher then that of at the normal interest rate. This holds before the Lehman crisis and after it, as well. Due to the crisis the concentration of the transactions at extreme interest rate increased, as well.

E5 The roles of the banks fundamentally changed due to the crisis; many of the former *sources*, *sinks* and *market makers* have changed their positions or lost their primary roles and new players of the market took primary roles.

On Figure 5 red circle denotes the bank No. 13 which could be considered as a market maker before the crisis. Blue broken ellipse denotes the banks with larger turnover which are significant net lendors, thus they can be considered as *sources* (6, 1, 2 and 3). Black ellipse indicates the significant net borrowers. These are the *sinks* (21, 5, 7, 12, 15, 23, 24, 11 and 28). The rectangle with red broken line denotes the financial institutions with small turnover. They can be sources, sinks or market makers but due to their small turnover this is not essential on the market.

Figure 5: The average weekly deposit and credit of the banks – before Lehman bankruptcy

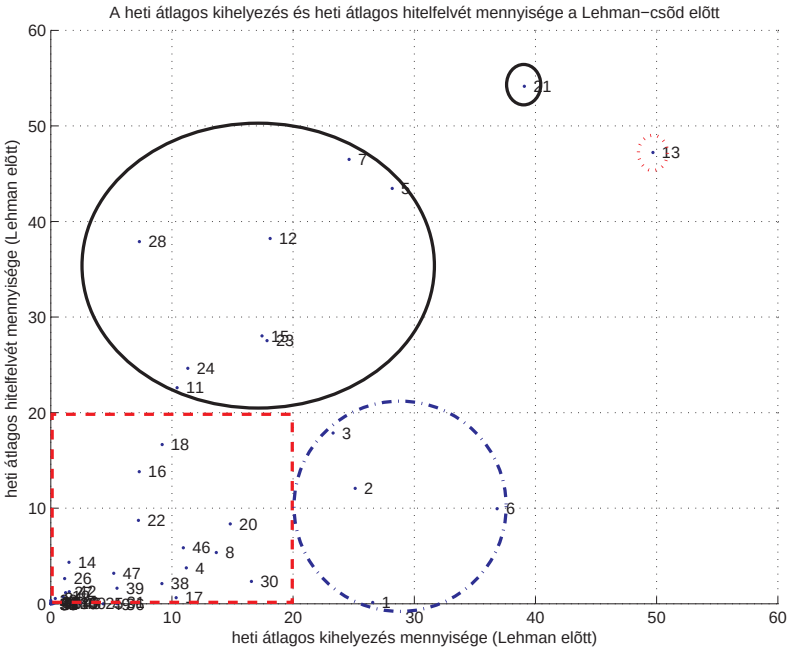
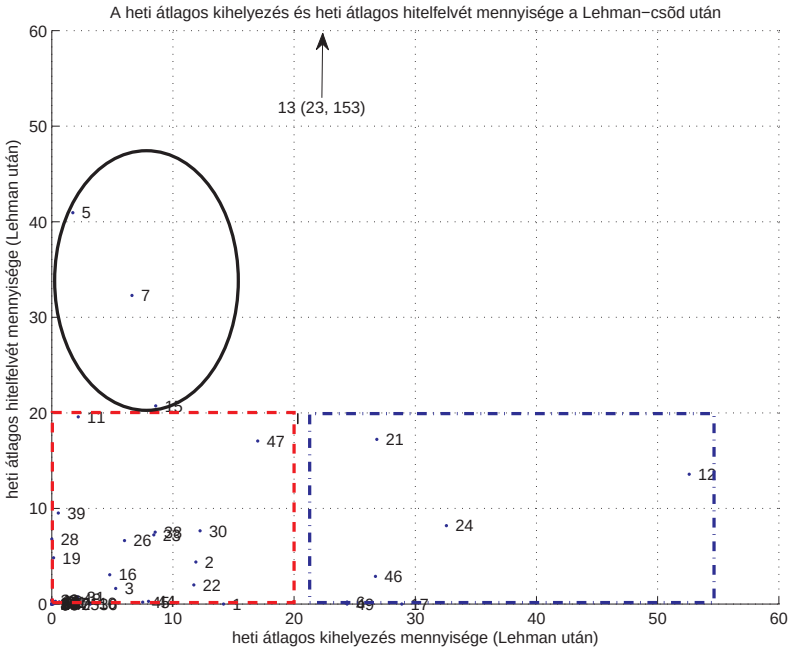


Figure 6: The average weekly deposit and credits of the banks – after Lehman bankruptcy



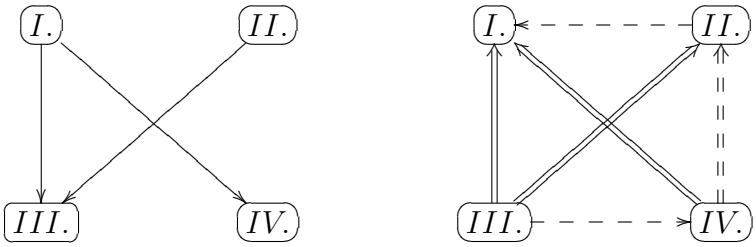
The difference is obvious. For example, after the Lehman bankruptcy the formerly well-balanced bank No. 13 took seven times larger amount of credit than it deposited. From among the banks No. 1, No. 2, No. 3 and No. 6 behaving as sources prior to the crisis only the bank No. 6 remained source, the others have lost their significant role. Bank No. 21 was a sink, but during the crisis it turned to be a source.

E6 Financing between the *group of bank* constructed on the amounts of *deposits* was relatively balanced before the Lehman bankruptcy. Group No. I financed the groups No. III and No. IV, while the group No. II financed the group No. III. *During the crisis the former direction of financing turned around*, moreover the crediting between the groups strengthens, and new credit connections are born.(See Figure 7).

In the figures below the single arrow denotes weaker connection, smaller flow, while the double arrow indicates stronger connection, larger flow. The continuous line denotes the connection existing before Lehman bankruptcy, while the broken line corresponds to the new connection, after the bankruptcy.

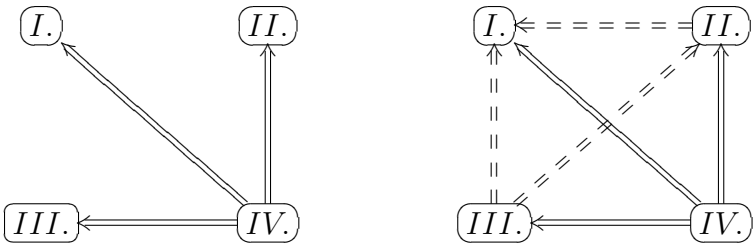
E7 The financing between the *groups of banks* based on the *total turnover* was approximately balanced before the Lehman bankruptcy, the only severe unbalance

Figure 7: Credits between the groups of banks before and after the Lehman bankruptcy – groups are based on deposits



was caused by the group No. IV. The banks belonging to this group are relatively small from the point of view of the turnover but they notably finance the other three groups. During the crisis strong connections are formed between the other groups, but again the group containing banks of smaller turnover provide credits for the bank with larger turnover. The group No. IV continues to finance the groups No. III, No. II and No. I, but now the group No. III finances the groups No. II and No. I, finally group No. II finances group No. I. Thus during the crisis every group of banks finance the groups consisting of banks with larger turnover. (See Figure 8).

Figure 8: Credits between the groups of banks before and after the Lehman bankruptcy – groups are based on total turnover



E8 the analysis of the *net positions* of the *groups of banks* showed that these groups were in an approximately neutral position before the crisis (the only exception was the group No. IV as a strong net lender when the grouping was based on the total turnover), while during the crisis strong intergroup connections were formed. When the grouping was based on *deposits* the groups No. III and No. IV financed the groups No. I and No. II. (See Table 1); in case of the groups based on the *total turnover* during the crisis the group No. I was financed by all the other groups. (See Table 2).

Table 1: Net position of the four groups of banks before and after September 15, 2008 – grouping is based on deposits

Group of banks	relative net position	
	before Lehman	after Lehman
No. I $\Longrightarrow$ others	12,1%	-78,5%
No. II $\Longrightarrow$ others	6,3%	-66,5%
No. III $\Longrightarrow$ others	-13,3%	66,4%
No. IV $\Longrightarrow$ others	-3,9%	63,9%

Table 2: Net position of the four groups of banks before and after September 15, 2008 – grouping is based on total turnovers

Group of banks	relative net position	
	before Lehman	after Lehman
No. I $\Longrightarrow$ others	-21,3%	-121,4%
No. II $\Longrightarrow$ others	-26,7%	30,5%
No. III $\Longrightarrow$ others	-10,2%	47,8%
No. IV $\Longrightarrow$ others	61,2%	90,6%

E9 The *size of the weekly network* during the crisis has dropped from 36 to 30 then further to 28.

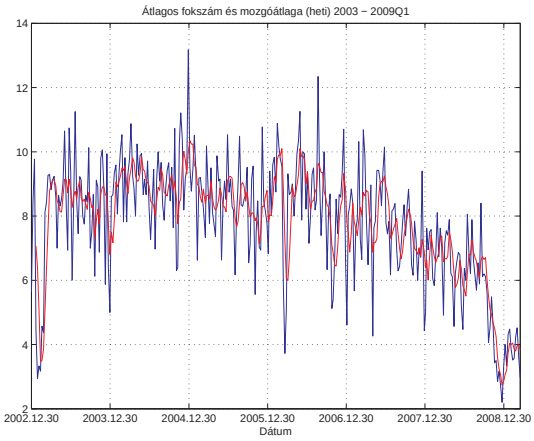
E10 The *diameter of the weekly network* has dropped from the 5-7 before the Lehman crisis to 4-5.

E11 The *average degree of the weekly network* has dropped after the Lehman bankruptcy from the former 7 to 4. It is worth pointing out, that the average degree of the the weekly network during the previous years was around 9, and this dropped to 7 *by 2007* (see Figure 9). Equally important, that, during the first three quarters of 2008 the market turnover did not decrease, while the average degree already did. During the Lehman bankruptcy the turnover and the average degree decreases simultaneously leading to the fact that after a certain amount a retrogression *some of the banks quit the market.*

E12 The *average betweenness* of the weekly network reaches its peak at the end of 2007 at around 30, it decreases continuously during 2008, and falls to 5 from the former 20 during the during the crisis.

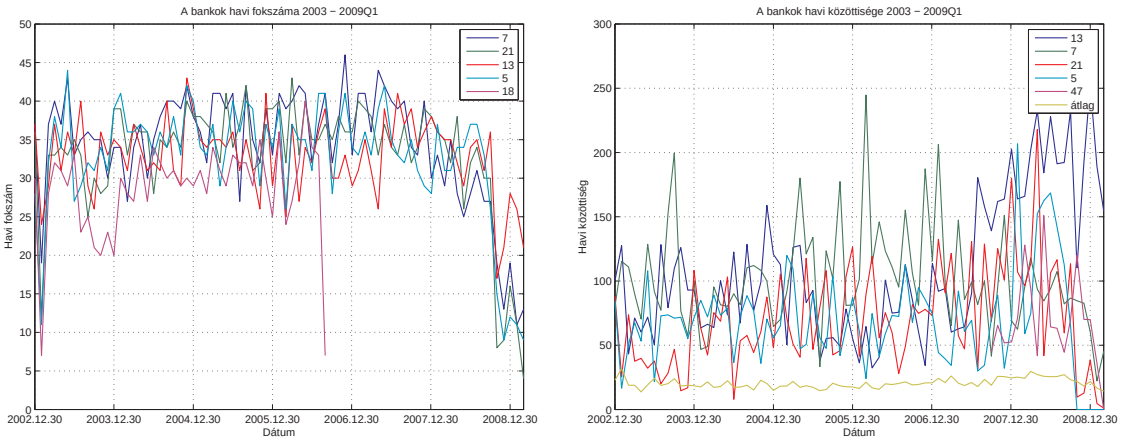
E13 The *average closeness of the weekly network* started its decrease in the middle of 2006.

Figure 9: The weekly network's average degree and its moving average



E14 The *behavior of the first five financial institutions* regarding monthly *betweenness, closeness and degree* during the crisis is similar to the behavior in average, i.e. falling back, except for bank No. 13. Bank No. 13 followed an other path: the number of its connections (degree) decreased only slightly; its betweenness increased significantly from the middle of 2006 and it dropped sharply only for a single month due to the Lehman bankruptcy; its closeness drops only for a month and then quickly returns to its previous level.

Figure 10: The degree of the first five bank 2003–2009Q1



E15 The increase of the *concentration of the connections* between banks exceeds the increase of the concentration of the credit taking banks. The effective number of the connections before Lehman bankruptcy was 250, while after the bankruptcy it dropped to 49.

E16 The *core of the monthly network* consisted of 10-11 banks until the middle of 2007, this drops to 8 by the middle of 2008, while during the crisis it drops

further to 6. It is important to observe that the decrease in the size of the core started *already in 2007*.

E17 The banks being in the core of the monthly network most frequently can be considered relatively stable. This *hard core* consists of four banks. There were only 6 months out of the 75 when some of them were missing from the core.

E18 It is interesting that this *hard core* splits apart right during the turbulence of October 2008; the financial institution No. 13 and No. 7 remain in the hard core, but No. 21 is missing during October and November returning afterwards, while No. 5 is still in the hard core in October but disappears from November.

The hypotheses listed earlier can be evaluated as follows based on these results.

H1 The topology of the Hungarian interbank uncovered deposit market prior to the Lehman bankruptcy differs significantly from that of after the bankruptcy.

Based on E1–E18 it is *valid*.

H2 There exist some network indicators showing the decrease in liquidity before September 15, 2008.

Based on E3, E11–E13 and E16 it is *valid*.

H3 We have obtained two additional phenomena, which are connected to liquidity. The *change of the role* of players in the market (see E5), and the change of the *financing between the group of banks* (see E6–E8).

H4 We might conclude based on these investigations, that from the indicators above a lot can be used for the analysis of liquidity. Beside the total turnover the following quantities might serve as indicators: the size of the network, its diameter, degree, betweenness, closeness, the size of the core of the network, the stability of the hard core, the concentration of the credits and deposits, their difference, the concentration of the interbank connections and finally the change in the financing between the group of banks.

The most promising from these *new liquidity indicators* are those, which indicated they change already before the Lehman bankruptcy: the *degree of the network*, the *betweenness*, the *closeness*, the *size of the core* and the *concentration of credit taking*.

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