



**PhD Program  
in Economics**

**PhD dissertation**

**Vilmos Fliszár**

**Budapest interbank offered rate  
in the shadow of London interbank offered rate**

**Abstract**

**Supervisor:**

**Tamás Solymosi PhD**

Budapest, 2015

**Operations Research and Actuarial Sciences Department**

**PhD dissertation**

**Vilmos Fliszár**

**Budapest interbank offered rate  
in the shadow of London interbank offered rate**

**Abstract**

**Supervisor:**

**Tamás Solymosi PhD**

© Fliszár Vilmos

# Contents

Contents.....	3
<b>1. Introduction</b> .....	4
<b>2. Methodology background</b> .....	6
<b>2.1. Game Theory</b> .....	6
<b>2.2. Statistics</b> .....	7
<b>3. London interbank offered rate</b> .....	10
3.1. Early signs in the press.....	10
3.2. Definition of London interbank offered rate.....	10
3.2.1. Incentives arise from the LIBOR definition in connection of game theory.....	12
3.3. Results of the investigation of regulators.....	16
3.4. The effect of the scandal to other benchmarks.....	18
<b>4. Budapest interbank offered rate</b> .....	19
4.1. History of Budapest interbank offered rate.....	19
4.2. The definition of BUBOR.....	20
4.3. Main differences between the LIBOR and BUBOR.....	22
4.4. BUBOR in the Hungarian law process.....	23
<b>5. Statistical analysis of BUBOR-based transactions and fixed values</b> .....	23
5.1. BUBOR related studies before the LIBOR scandal.....	24
5.2. BUBOR based transactions.....	25
5.2.1. BUBOR based deposit and loan portfolio.....	25
5.3. Calculation method of BUBOR and individual fixing.....	26
5.3.1. Calculation method of BUBOR.....	26
5.3.2. Standard deviation of the daily BUBOR fixing.....	26
5.3.3. Individual fixings.....	27
5.4. Tenors and possible benchmarks.....	28
5.4.1. Tenors.....	28
5.4.2. Benchmarks (base rate, DKJ, swap and FRA).....	31
5.4.3. The single active tenor.....	32
5.4.4. Counterparty risk in BUBOR values.....	34
5.5. Statistical modeling of possibility anomalies in the fixings of contributor banks.....	35
5.5.1. Actual data and behavior.....	37
5.5.2. Individual data – fact versus estimation.....	37
5.5.3. Comparison of the estimated results.....	38
5.6. Summary of the statistical analysis.....	38
5.7. Connection between BUBOR and the internal banking process.....	39
5.8. Possible ways in the further research.....	39
<b>6. Conclusion</b> .....	41
<b>7. Main references</b> .....	43
<b>8. Own publications</b> .....	45
8.1. In the topic of the dissertation.....	45
8.2. In the topic of the used methodologies.....	45

# 1. Introduction<sup>1</sup>

The interbank reference rates play a crucial role in the everyday financial processes. The reference values defined by the main players of the interbank market appear in the most banking products. Beyond the interbank deals the retail and corporate loan and deposit products also reprice according to a given reference rate. Only in case of the US dollar LIBOR more than 300 trillion US dollar transactions belong to the fixed interbank reference rate in the whole world. The Budapest interbank offered rate is the basis of more than 3000 billion Hungarian forint retail and corporate transactions.

These huge numbers also show the importance of the interbank reference rates and the fact that these would be an integral part of the economic processes. Their analyses are very important because based on such studies give much information about the market and the behavior of the contributor banks. Therefore the results can be useful for the financial institutions, the consumers and the regulators. With an accurate knowledge about the reference rate's market can result more operating profit for a financial institution or the supervisory authority is able to identify the distortion of the market. However a study about the reference rate is able to strengthen the social acceptance. These reasons confirm that the interbank reference rates are key players in the economic world and the relevant studies can send very important messages for the market players.

Coming into the view of interbank reference rates was the inspiration of my thesis. In summer 2012 it turned out the biggest contributor institutions manipulated the fixing process in London. The result of the manipulation was the level of LIBOR didn't show the real market whereas it showed better the interest of some contributor institution. Therefore the English regulator took into counter with tight control against the referred contributor institutions (Barclays, UBS, Royal Bank of Scotland), set up huge punishments and in some cases it waited the replacement of the referred chief officers.

In the study I describe the background of the chosen methodology, the fixing process of the LIBOR, the incentives for manipulation, the history of the scandal and the main regulatory responses. I also use the elements of the game theory to show the weak points and the manipulative incentives of the definition and the fixing process. The regulatory responses is

---

<sup>1</sup> The views in this study are those of the author and do not necessarily reflect those of Hungarian Financial Supervisory Authority or the Central Bank Hungary.

an important part of the topic because under short time many guidelines, analysis were published by regulators. These documents showed the former studies about reference rates missed a very important aspect which is the accurate data. Thus a new area came into focus where there weren't benchmark studies for the researchers.

The focus point of my thesis is the fixing of Budapest interbank offered rate (BUBOR). Beyond the description of history of BUBOR I show the connected rules and point out the differences from the LIBOR. Near that I analyze the fixed values of forint reference rate and the behavior of the market and the contributor institutions. In the study I would like to find the answer to the following questions:

- Can be founded manipulation incentives in the LIBOR definition?
- Are the founded weaknesses in the LIBOR fixing relevant for the BUBOR? How much the level of similarity between the BUBOR and LIBOR?
- Is the BUBOR replaceable with any other benchmark?
- What kind of attribute does the fixing process of BUBOR show? Can we found any information about the market of the unsecured lending market?
- Can define any behavior structure in the whole fixing process or in the individual fixing of a contributor bank?

First I show with the help of the game theory there are manipulation incentives in the LIBOR definition. After this to answer the further questions I use descriptive statistic and cluster analysis. In the study I show that an old definition from a new aspect has got in the centre of interest and the former used time series methods are hardly applicable. My goal is to show how can an analyst handle this situation and find the most information which can be an important source for future research.

## 2. Methodology background

In this study before the statistical analysis I detailed show the definition of the London interbank offered rate and it's fixing process between the description of the LIBOR scandal and the regulatory reactions. In the LIBOR definition chapter in a simple fixing market with the tool of game theory I emphasize the weaknesses of the definition and the fixing process. In a simple example I show the fact even if one injured condition the truthfulness can be a dominated strategy. Therefore in a non-cooperative simultaneous game for the gamer (contributor institution) in the equilibrium it is better if he deviates from the truthfulness strategy. It is easily foreseeable if every contributor institutions hurt the same condition the result of their simultaneous decision will be such a dominant Nash-equilibria in that everybody is lying. It is very important to emphasize there is differences between the LIBOR and the BUBOR definition. In case of BUBOR there is much less incentives for lying. In the statistical analysis I also will examine these incentives and the weaknesses/strengths of the fixing process and definition.

### 2.1. Game Theory

I use only non-cooperative models in this study therefore I give the definition based on the normal form of non-cooperative games. This models has got three main elements:

- list of players
- strategies' list of each players
- the payments' list of each players for each joint strategy which contains only one strategy from each player.

The  $G = \{S_1, \dots, S_n; f_1, \dots, f_n\}$  structure is (n-players) game, where the  $S_i$  is the  $i^{\text{th}}$  player's non-empty strategy set, the  $f_i : S \rightarrow R$  is its payment function where  $S = S_1 \times \dots \times S_n$ .

I use only simultaneous games in my models which mean that the players make the decisions at the same time and they are not able to choose mixed strategies. The dominance is an important definition in these analyses. Let  $G$  is an n-players game in normal form and  $s_i; t_i$  are the  $i^{\text{th}}$  player clear strategies:

- $s_i$  is strictly dominated  $t_i$  if  $f_i(s_i; s_{-i}) > f_i(t_i; s_{-i})$  for each  $s_{-i} \in S_{-i}$ ;
- $s_i$  is weakly dominated  $t_i$  if  $f_i(s_i; s_{-i}) \geq f_i(t_i; s_{-i})$  for each  $s_{-i} \in S_{-i}$  and there is a  $(t_i; s_{-i})$  that the inequality is strict,

where  $S_{-i}$  is the set of those strategy profiles which do not contain the strategies of the  $i^{\text{th}}$  player.

The best response function gives those strategies of the  $i^{\text{th}}$  player which result the highest payment for the player assume the others do it according to a given strategy profile. It is formally the following  $B_i : S \rightarrow S_i$  function:

$$B_i(s) = \{t_i \in S_i \mid f_i(t_i; s_{-i}) \geq f_i(r_i; s_{-i}) \text{ for each } r_i \in S_i\}.$$

Through Nash the conception of the selection of a game's equilibrium would be the stability (Nash [1950]). A solution of a game is stable if any player is not able to raise its payment if the others do not change their strategy. It means that the player gives its best response for the expected strategy of the other players. The definition of the Nash-equilibrium gives back this attribution:

Let  $G$  is an  $n$ -players game in normal form. The  $s^*$  strategy profile (which only contains clear strategies) is a Nash-equilibrium if the following inequality is true

$$f_i(s_i^*; s_{-i}^*) \geq f_i(s_i; s_{-i}^*)$$

for each  $s_i \in S_i$  and  $i = 1, \dots, n$ . Expressed: each players give their best response for the action of the others. If each players choose a dominant strategy in the equilibrium it results a dominant Nash-equilibrium.

## 2.2. Statistics

In the statistical analysis I focus on the identified manipulation incentives and the attribution of the fixing process. My goal is to show the useful of description statistic in such a problems. The distributional parameters of the fixed rates of contributor institutions contain much information for the analysts. The examination of central values, outliers, percentiles or standard deviation results important statements. Beyond these I also examine the difference time series of an individual bank. It is very important to emphasize that these methods are easily applicable.

In the possible benchmarks chapter I examine the difference between BUBOR and base rate. Next to this I mention the behavior of correlation between Budapest forint reference rate and the possible benchmark rates under disjunct periods. Erhart, Ligeti and Molnár pointed to the fact the 3 months BUBOR time series is very strong autocorrelated and it can be describe as an AR(1) process (Erhart-Ligeti-Molnár [2013]). Their – above 0.99 – coefficient urged me to avoid the OLS estimation methods or the other time series methodology and show the applicable of descriptive statistic.

In the analysis I also will examine the fixing behavior of contributor institution. With help of descriptive statistic I point to that it is difficult question because we need to find behavior

structure not only a break event. I support it could not define any manipulation event in Hungarian data. Because the fixing time series is highly autocorrelated my target is to show is there any variables with them we can conclude from the individual fixed values to the fixing of the other contributors. For this reason I rescaled to ordinal scale my target variable and I will use the clustering methods. To validate the choosed methodology I cluster the fact data next to the estimated variables and compare the results.

### *Cluster analysis*

My analysis is based on a “two-steps” clustering. First I clustered with K-means algorithm the trading days in case of every contributor institution into three categories taking into consideration both the external (other benchmarks) and the internal (the derivative position of the institution) effects. Because the units of the used variables were different I standardized them. This estimation is result an alternative variable which will be challengeable with the from the real fixing rates rescaled ordinal target variable.

The K-means cluster algorithm is based on an iteration process which contains three main steps:

- *Choosing the initial cluster centers*
- *Updating the cluster centers*
- *Classifying the observations into the nearest cluster*

This iteration process stops if the number of iteration reaches the given maximum value or the change of the cluster centers remains under a predetermined  $\varepsilon$  between two steps.

After that I will cluster separately by institutions the estimated (with K-means algorithm) and the rescaled fact variables with hierarchical method. The hierarchical clustering is such a classifying methodology which is based on similarity or dissimilarity measure. Denote  $S$  the initial similarity matrix and  $S_{ij}$  the similarity measure between the  $i$ -th and  $j$ -th cluster. Because the variables measure are ordinal I will use the chi-square method for define the distances.



The massing process of hierarchical clustering is based on the following general steps assuming N clusters:

- For starting to assume each variable is a separate cluster.
- Define the S similarity matrix (N×N dimension) of variables.
- To find the most similar clusters (p and q) where p is greater than q. Denote  $S_{pq}$  their similarity measure. Note if we use dissimilarity measure the higher value shows less similarity (as in the case of chi-square).
- To reduce the number of clusters by merging p and q cluster. Denote t the merged cluster.
- Updating the similarity matrix between the new cluster groups. Iterate this process while only one cluster remains.

From the possible agglomeration methods I use the further neighbor algorithm where

$$S_t = \begin{cases} \max(S_{pr}, S_{qr}) & \text{if } S \text{ dissimilarity measure} \\ \min(S_{pr}, S_{qr}) & \text{if } S \text{ similarity measure} \end{cases}$$

In this algorithm the agglomeration is based on the distance of the furthest clusters therefore this method is particularly sensitive for the outliers.

### **3. London interbank offered rate**

#### **3.1. Early signs in the press**

In the press there were articles in connection the sign of problems in LIBOR fixing before in the 2012 started scandal. In Wall Street Journal (WSJ) many articles were published by Carrick Mollenkamp about the credibility of the LIBOR fixing (Mollenkamp [2008] and Mollenkamp – Enrich [2011]).

In 2008 he called the attention to the risk which arises from the LIBOR definition. This comes from that the contributor institutions were able to modify their own pictures on the market with fixing false reference rates. Thus they can even hide they bad liquidity situation with these false signals. Mollenkamp's article also contained a detailed description about the definition of LIBOR, its role in the market (from the interbank deals to the mortgage loans) and the list of potential benchmarks.

In 2011 Mollenkamp and Enrich wrote the world manipulation. In the article they stated that there is very low probability that the regulators would refer the founded failures in the LIBOR fixing process only simple incorrect mistakes. To confirm this statement they referred the study of Snider and Youle (Snider – Youle [2010]). Snider and Youle examined how the LIBOR is able to meet its own definition. Did the contributor banks fix that interest rate level on which they can get unsecured liabilities from the market?

In professional journals the reader could meet the word manipulation even in 2008 but at that time Mollenkamp was not so brave to declare it in the much more popular WSJ. Abrantes-Metz and his colleagues has already questioned it in the title: LIBOR manipulation? (Abrantes-Metz et al. [2008]). The authors identified many signs (for example the move of CDS spreads and LIBOR) which could imply anti-competitive manipulative behavior but they had not got any concrete evidence to proof the manipulation. In the conclusion further examinations were urged.

#### **3.2. Definition of London interbank offered rate**

The London interbank offered rate is the most used reference rate in the world which is the base of more than 300 trillion US dollar valued transactions. The LIBOR fixing process was taken place in 10 different currencies for 15 tenors (till one year) in 2012 by the contributor banks which are defined annually by the British Bankers' Association (for example in GBP

LIBOR fixing the number of contributors is 16, in US dollar panel it is 18)<sup>2</sup>. Before the reforms which came after the scandal the British regulator, the Bank of England did not play a role in the fixing process. The individual fixed rates were asked, merged and published by Thomson Reuters.

In the fixing process every contributor institution has to answer to the next question:

*„The rate at which an individual contributor panel bank could borrow funds, were it to do so by asking for and then accepting interbank offers in reasonable market size, just prior to 11.00 am London time?“* (BBA [2014])

The main indicators of the definition are the followings:

- unsecured interbank funds – it highly depends on the market opinion of the institution;
- an individual contributor panel bank – key player in the market;
- reasonable market size – significant amount in the operational process of the contributor.

From the main indicators it is easy to see that a contributor bank under the LIBOR fixing process states an opinion about own market situation and with its own fixed rate the bank has to publish it. Thus in the fixing process not only the profitability is the incentive because the contributor can use it for signals to repair its reputation and hide the problems. The creators of the LIBOR fixing process did not take into consideration with significant weight. There is only one sentence in the LIBOR manual about the truthfulness.

From mathematical view the LIBOR value is a simple trimmed mean. In the calculation process the lowest and the highest 25% of the individual fixed rates are trimmed in each tenor. The trimming is able to limit the measure of incentive arise from profitability because if only one contributor lies the probability of a big move in level of LIBOR is very low on account of the elimination of its own fixed rate. Therefore for a significant move in LIBOR level it needs cooperation between many contributor institutions.

But in case of the reputational question the limitation effect of trimming is very low because the elimination is not decrease the strength of the signal about the bank's condition. If both incentives present at the same time this situation holds significant pressure to the contributors for giving false reference rate. Unfortunately in the past more banks could not resist to this temptation.

---

<sup>2</sup> Due to the LIBOR scandal the ICE Benchmark Administration (IBA) has coordinated the fixing from 1<sup>st</sup> February 2014. The fixing has been taken place in 5 different currencies for 7 tenors from 2014.

The manipulation facilitates the fact that in the majority of tenors the market is not active thus the fixed rate is considered to the opinion of the contributors and not closely linked to real deals. The contributor institutions know exactly the calculation process thus they can define only with very low uncertainty the result of a given cooperation.

### **3.2.1. Incentives arise from the LIBOR definition in connection of game theory**

Based on the fixing process from the point of view of a contributor bank the incentives of the manipulation can be describe as the following under the assumption that every contributor fixes a hundred percent fully definition compatible value. For the simplification in the fixing process there are only six contributors (A, B, C, D, E, F). In the fixing process the lowest and the highest fixed values are trimmed and the average of remained fixings gives the reference rate, the LIBOR. Under the fixing process the contributors decide simultaneously their individual values.

#### ***Profitability incentive***

Look contributor F. The contributor F beyond the general market information knows its own interbank positions. (About the other contributor's position it has only partly informed.) Assume that F has big deal which value date is today and the higher reference rate results more profit for F. F knows that the other contributors will fix a not distorted value and they will not change their behavior for the next trading day whatever will be fix today by F if it is under or over a limit.

For simplicity I assume that F has two options. It will fix the real value (V) or a manipulated value (M). Let it  $M > V$  and the difference between M and W is under that limit above which the fixed values gets attention from the other contributors or regulators. If F chooses V then its profit is x in other case (chooses M) it is  $x + y$ . Easy to see that  $y \geq 0$  because - ceteris paribus - the fixed reference rate cannot be lower. Equality is only in that case if both V and M will be a trimmed value. Because the M is under the limit it does not arouses suspicion and there is no danger of the behavior change of the other contributors. Thus chosen M strategy for F contributors is a dominant strategy. Because the role of the contributors in this game is homogeneous (the difference can be only that for some contributors the lower value is more profitable) and every contributors' manipulated value is between the limits the truthfulness is a dominated strategy for every player. Thus in the Nash equilibrium of this game every player

lie. The goal of the regulators is to control the whole process that the mentioned limit would be the closest to value  $V$ .

### ***Signaling of better condition***

But in the fixing process of LIBOR there is another manipulative incentive which arises from the definition. According to the definition the contributor bank has to answer that question at what price it can borrow funds from the interbank market at a given time in reasonable size. Thus the higher value indicates that the contributor's conditions are not the best. With fixing a lower value the contributor can send a false signal to the market that its position is good and it can get funds from the market on lower price. In that case the contributor uses the situation of asymmetric information because about its real condition it has the most information and with this false signal it wants to avoid the exclusion from the market. This situation is similar to Akerlof's very famous Lemons' market. (Akerlof [1970]). But here the bad institutions would be excluded from the market. To abolish the asymmetric information Spence suggested the signal (Spence [1973]). In Spence's job market model the better employee would like to signal their quality but there is an inverse situation here. Under the fixing the contributor lies about their bad condition and believed with the market it is in good situation.

Look again contributor F and assume it knows the other five contributors will not be lie. Due to turbulent market circumstances the pricing of interbank funds is very sensitive for the situation of an institution. For the more seamless operation it is important for F to get interbank funds cheaper. In this case assume F has two strategies in the reference rate fixing. It fixes a true value  $V$  or lies (send a signal) and fixes  $S$  where  $S < V$ . Because if it chooses  $S$  its operation will be cheaper and its operational cost is  $x-y$  even with choosing  $V$  its operational cost is  $x$  ( $y \geq 0$ ). Easy to see that  $V$  strategy is dominated by  $S$  strategy thus in the equilibrium F lies. Because the situation of the contributors in this simultaneous non-cooperative game is homogeneous in the Nash-equilibrium of this game every player lies and they reach an unauthorized competitive advantage across the false signal. Obviously in this point assume that the difference between  $S$  and  $V$  is under regulatory reaction limit.

So we can with help of the tool of the game theory that the fixing process and the definition of LIBOR contain incentives for manipulation. Unfortunately the contributors used also in the past these weak points.

### ***Repeated simultaneous game in case of manipulation incentive***

I assume that F institution realize  $\alpha \geq 0$  profit with choose M strategy, and F is able to manipulate the reference rate continuously. The probability of caught is zero at the first time and it is growth by  $\lambda \geq 0$  on each manipulated day. If F is caught then the supervisory authority starts an examination and F will get a punishment in value of  $B \geq 0$ . I assume if F institution finishes the manipulation and fix the real value it is not able to start again the manipulation. For simplification I assume that the payment has not got time value and the discount rate is zero.

In such a case it is obvious that the manipulation is remunerative for F till the expected payment of manipulation is positive (n is the number of the continuous manipulated trading days):

$$0 \leq \alpha[1 - (n - 1)\lambda] - (n - 1)\lambda B \quad (3.1)$$

and the total income from manipulation is higher than the punishment

$$B \leq \sum_{i=1}^n \alpha[1 - (i - 1)\lambda] - (i - 1)\lambda B \quad (3.2)$$

If the discount rate is different from zero the (3.2) formula:

$$B \leq \sum_{i=1}^n \frac{\alpha[1 - (i - 1)\lambda] - (i - 1)\lambda B}{(1 + r)^{i-1}} \quad (3.3)$$

To expose the (3.2) inequality – use the formula of finite arithmetic series – we got the following:

$$0 \leq -\lambda(\alpha + B)n^2 + [2\alpha + \lambda(\alpha + B)]n - 2B \quad (3.4)$$

With using the solving formula of quadratic equation for the number of continuous trading days we got the following nexus:

$$n_{1,2} = \frac{-[2\alpha + \lambda(\alpha + B)] \pm \sqrt{[2\alpha + \lambda(\alpha + B)]^2 - 8\lambda(\alpha + B)B}}{-2\lambda(\alpha + B)} \quad (3.5)$$

Because  $\alpha$ ,  $\lambda$  and  $B$  are non-negative the (3.4) quadratic equations describes a reverse parabola. From that if there is a solution then the possible n values are in the  $[n_1, n_2]$  interval. It can be seen if the section of  $[n_1, n_2]$  and  $[2, \infty)$  intervals is not empty then it worth for F the manipulation. In this case the F chooses such n when its profit is maximized:

$$\max_n \sum_{i=0}^n \alpha[1 - (i - 1)\lambda] - (i - 1)\lambda B \quad (3.6)$$

In any other case F manipulates only on the first day because the (3.2) is not met and the probability of caught is zero at the first time.

In this content the  $\alpha$  is an institution specific parameter and its value can be different for each contributor banks and the supervisors cannot influence it. To give the value of B punishment is a supervisory right. In the LIBOR scandal the supervisors gave huge fines for the concerned institutions but we have no exact information about the real value of the reached profit. I can be simply seen that with a huge B value the supervisors are able to avoid the continuous manipulation.

For the further examination I assume that  $B = k\alpha$  and  $k, \alpha > 0$ . Then (3.1) is the following:

$$n \leq 1 + \frac{1}{\lambda(k+1)} \quad (3.7)$$

From (3.7) we can see if  $\lambda(1+k)$  is above 1 then the continuous manipulation can be avoid. It means that the supervisors must increase the probability of the caught. After that let see the formula (3.5). The quadratic equation has got a solution if its discriminant is negative that is

$$0 \leq [2\alpha + \lambda(\alpha + B)]^2 - 8\lambda(\alpha + B)B \quad (3.8)$$

After simplification with  $\alpha^2$  and assume that  $B = k\alpha$

$$0 \leq [2 + \lambda(1 + k)]^2 - 8k\lambda(1 + k) \quad (3.9)$$

Let  $x = \lambda(1+k)$  then (3.9)

$$0 \leq [2 + x]^2 - 8kx \quad (3.10)$$

that is

$$0 \leq x^2 + (4 - 8k)x + 4 \quad (3.11)$$

Easy to see because k is positive the (3.11) inequality has not got solution if the k is above 1.

With using the public data of Barclays case I try to estimate this model for a contributor bank. The Barclays got 333 million EUR total punishments for manipulation. According the EBA stress test 2014 the Barclays' trading profit was 7 836 million EUR in 2013. I assume half of the trading profit came from the manipulation. Then

$$k_{Barclays} = 333 / \left( \frac{0,5 * 7836}{250} \right) = 21,25$$

To substitute this k value in the (3.9) and to use the solving formula of quadratic equation I get 0,00108 for  $\lambda$  which means the probability of caught is 0,11% on the second day. In case of optimal manipulation (3.7)

$$n \leq 1 + \frac{1}{0,00108 * (21,25 + 1)} = 42,6$$

that means the manipulation is optimal for 42 trading days. But it is worth to think about the fact that in case of Barclays the real manipulation was much longer. How low could be the probability of caught? Or how high could be the manipulation's profit?

### **3.3. Results of the investigation of regulators**

The signs in the press called the attention of the regulators that there can be some problems with the LIBOR fixing. In 2008 Mervyn King the governor of Bank of England said about LIBOR disapprovingly in the Parliament of United Kingdom. On the Treasury meeting of House of Commons King said for example the following:

*„I think it is convenient, very often, for people to justify what they do for other reasons, in terms of Libor, but it is not a rate at which anyone is actually borrowing.”* (House of Commons [2008])

Based on this according to the governor of Bank of England the LIBOR could not have fully filled its role already in 2008 because it show such a rate on which none of the main market players wanted to lend funds.

However at that time there was not happen any supervisory reaction which is totally surprising because the chief executives of Bank of England and US FED knew the problem about the LIBOR. Jill Teanor and Dominic Rusche also raised this omission in the Guardian in 2012 (Treanor-Rusche [2012]).

But after a time it would be obvious for the regulators that it was not a simple methodological or definitional problem it was a more serious failure and a simple reform would not be solve the problematic question. Therefore the fixing process had to investigated in detail, find the weak points of it and identify the unfair market players. For this reason many investigation started to revise the fixing process of LIBOR in 2011. In 2012 when the first results of regulatory investigations came out it would be obvious this serious problem was manipulation and the scandal was not avoided.

In 28<sup>th</sup> February 2012 Mollenkamp wrote in Reuters about the investigation and in connection with a suspicion of a crime (Mollenkamp [2012]). According to the investigation the traders of contributor institutions violated the internal independence in the reference rate fixing because there were many proof that there was communication about the required level of



LIBOR between the different departments in some contributor banks and the results of this communications appeared in the final fixed value.

First the Barclays was catch up by its destiny in summer of 2012. In 27<sup>th</sup> June 2012 the US Commodity Futures Trading Commission (CFTC [2012a]) and the Department of Justice (USDJ [2012a]) fined the Barclays 360 million US dollar beyond this the English supervisors (FSA [2012a]) also fined it 59,5 million pound for the found serious deficiencies in the LIBOR and EURIBOR fixing process.

From the announcement of the USDJ have come true that in case of Barclays the manipulation had started at least in 2005 and it had two reasons:

- at the fixing the traders took into consideration their own business position and with the diversion of reference rate they increased their profitability;
- under the global financial crises the bank fixed intentionally lower reference rate than the real value because it would like to show better picture about itself to the other market players.

The reports of supervisors/regulators showed there were serious deficiencies in the general fixing process. The used internal and external control mechanisms were not enough to ensure the full transparency of the reference rate and stop the distortions arise from individual interest in the contributor's fixed values.

The Barclays' case of London reference rate manipulation caused a huge storm it wobbled the faith in the LIBOR even in the City. The scandal has result the abandonments of many chief executive officers of Barclays in July 2012. Beyond this the scandal had serious effect on the business operation of Barclays also the two big credit rating agencies (Moody's and S&P) downgraded the bank. On the stock exchange the price of the Barclays' shares fell by more than 26% in period of May – July 2012. It would be obvious that the fines were not enough and new regulations were necessary.

The British Financial Services Authority (FSA [2012c]) and the US Commodity Futures Trading Commission (CFTC [2012]) published its own reports at the same time about the Barclays' LIBOR manipulation investigations. Joint statement of both reports was that general problem the fixing process was not appropriate and the fixed reference values would have to reflect the price of borrowing unsecured funds from the market. In both investigations ascertained the manipulation. Unfortunately in the most cases the Barclays did it with cooperation of other contributors.

Between September 2007 and May 2009 on account of the increasing reputational risk the Barclays defined its fixed reference value so that it took into consideration the concerns from the negative effect from that press news which emphasized the Barclays fixings were higher than the other contributors fixings and according to the market experts it meant the bank were in band condition and its financing were more expensive.

The reports of British FSA said that the Barclays did not have appropriate risk management systems and effective control functions to ensure a fully transparent reference rate fixing. Beyond these there were compliance failures when the bank did the LIBOR fixing without an appropriate caution.

Final the FSA took a principle based decision. The investigation ascertained the Barclays hurt the following principles of the FSA's guideline (FSA [2014]) in connection with the business:

- the institution should do they business activities with appropriate competence, caution and care (Principle 2);
- the institution should do the business activities with appropriate responsibility and efficiency and use appropriate risk management system for monitoring (Principle 3);
- the institution should keep the expected norm of market behavior (Principle 5).

The report of CFTC coincided mainly with the FSA's report. The CFTC emphasized the Barclays did not fix the London reference rate according to the definition of the British Bankers' Association and gave false values. The daily control system of a contributor and the periodical revision of communication ought to identify such an incorrect fixing behavior.

In the dissertation I show in details the related guidelines of FSA, EBA, ESMA, IOSCO and GFMA.

### **3.4. The effect of the scandal to other benchmarks**

Under the LIBOR manipulation's investigations identified problems have got effect on the other benchmarks in the whole financial world and also in the other markets. The IOSCO investigated the spot price of oil and the European supervisors focused on the EURIBOR. The results of EURIBOR investigation incorporated in the report of British supervisors also.

From the point of interbank reference rates there were investigation in many European countries. The competent authorities examined the local reference rate's fixing process (for example the CIBOR in Denmark, the WIBOR in Poland or the BUBOR in Hungary).

## **4. Budapest interbank offered rate**

### **4.1. History of Budapest interbank offered rate**

The Hungarian commercial banks decided initiative to Magyar Forex Társaság (MFT) in 1995 that they created the Budapest interbank offered rate (BUBOR) model to the LIBOR. An expert group based on the delegated members of MFT and the Central Bank Hungary (MNB) formed to elaborate the calculation of BUBOR used the international experiences.

The Expert Committee of MFT negotiated and accepted the draft BUBOR regulation in 1<sup>st</sup> July 1996. The fixing started in August 1996. In the first regulation the founders suggested to use BUBOR for basis Hungarian forint interest based derivatives and assets or liabilities with floating rates. At this time there were fix parallel bid and offer reference rates with maximum 100 basis points spread in connection with 1 and 3 months tenors. The size of the maximum spread was fixed in the BUBOR regulation. In 1996 there were 8 contributor institutions and the calculation was based on the trimming of the two highest and lowest fixing. The Central Bank sent the fixed values to the Eurowien and the FX Plc. The fixed values with 100 million forint limit involved contractual obligation.

The first modification of the regulation was in May 1997 and it based on the experiences of the first ten months. The 6 months tenor and a minimum bid-offer spread (25 basis points) were introduced. It is very important that one of the biggest problems of BUBOR market - too low limits between the contributors - was mentioned at that time.

In June 1999 the overnight (O/N) tenor was introduced. The contractual obligation was increased up to 200 million forint but in case of that the overnight tenor was an exception. In 2002 increased the number of fixed tenors the 1, 2 weeks, 9 and 12 months tenors were introduced. But the contractual obligation was cancelled. The number of contributor banks was extended to 16 and their list was reviewed quarterly by the Central Bank and the MFT. The selection of the contributors based on their past interbank activities. At this time the calculation method also changed the four highest and four lowest fixed values were trimmed from the average.

**1. Table – Main parameters of BUBOR fixings 1996 - 2014**

	<b>Tenors</b>	<b>Contributors</b>	<b>Trimming</b>	<b>Bid&amp;Offer fixing</b>	<b>Contractual obligation</b>
1996	2	8	2-2	yes	yes (100 M HUF)
1997	3	8	2-2	yes	yes (100 M HUF)
1999	4	8	2-2	yes	yes (200 M HUF)
2002	8	16	4-4	yes	no
2003	15	16	4-4	only bid	no
2013	15	12	3-3	only bid	no
Febr. 2014	9	10	2-2	only bid	no
Aug. 2014	9	9	2-2	only bid	no

*source: MFT, own edition*

In 15<sup>th</sup> September 2003 there was also tenor extension. From that time the BUBOR was fixed in 15 tenors from overnight till 12 months. But there was sign for problem because the offer fixing was cancelled and after that only bid values were fixed. From November 2003 the technical background of BUBOR fixing changed because the Central Bank had to process 240 fixed values (16 contributors' 15 fixings) in each trading day and the size of the data had increased from the start. From this time the fixing has taken place in a Reuters' contribution page which has been available only for the Central Bank and the contributors.

But the global financial crisis from 2008 has further narrowed the BUBOR market which was also rather narrow before the crisis and the LIBOR's scandal unfortunately strengthened this process. To stop this negative process and to pass the new regulatory expectations the Magyar Forex Társaság published a new BUBOR regulation in May 2013. The number of contributor institutions decreased to 12 thus only the three highest and lowest fixings were trimmed. But the negative trend did not stop. In 2014 the regulation was changed in two times. The number of contributors was decreased to 9 and the calculation method was again changed. Parallel with this many tenors were cancelled and from 1<sup>st</sup> February 2014 the fixing has taken place only in 9 tenors (O/N, 1-,2-weeks, 1-2-3-6-9-12 months).

## **4.2. The definition of BUBOR**

The BUBOR regulation of MFT (Magyar Forex Társaság [2013]) defined the Budapest interbank offered rate rather succinctly in 1<sup>st</sup> January 2013:

- It is an interest rate for lending forint interbank funds.
- In the fixing process the contributor banks send the fixing rates at a given time - 10:30 a.m. - in each trading days. (...) The contributor banks obligate that their given fixings are real interbank lending interest rates in the fixing time.

According to the guideline of the Hungarian Financial Supervisory Authority this simple definition has been clarified (Magyar Forex Társaság [2014]):

- The BUBOR fixing means that interest rate of the contributor bank which represents according to the contributor's best knowledge and judgment the rate of an unsecured interbank loan between two contributors at given time (10:15-10:30 a.m.) on a given Hungarian trading day.

From this change one of the deficiencies of the fixing process before the LIBOR scandal can be seen. It is the lack of transparent regulation. The economic meaning of BUBOR (rate of unsecured interbank loan) was obvious for the contributors' traders who were responsible for the fixing before 2013 but the regulation did not contain it in detail. Thus there was not any clear reference for the unsecured interbank lending market. Another important change the assumption of that the rate represents a deal between contributor banks. There it would be obvious that the BUBOR has to be reflecting only on the risks of the contributor banks which are among the biggest active players on the Hungarian markets. It is favorable also for the consumers because the BUBOR does not contain the additive risks of small institutions.

The BUBOR like the LIBOR is given by a trimmed mean. In case of the changes of the calculation method has appeared the decreasing of the number of contributors. In 2013 the number of trimmed values was fix (the four lowest and highest) according to the BUBOR regulation. From 2013 the size of the trimming depends on the number of contributor institutions (Magyar Forex Társaság [2014]).

According to the new regulation the MFT calculated also with the further decreasing of contributors which has unfortunately happened. In February 2014 the number of contributors was 10 which were far away from the height with 16. In August the number decreased to nine. The primary reason were the decreasing the LIBOR scandal and consequently the more intensified consideration to the reference rates. Those active institutions which have less significant shares in Hungarian market left the BUBOR fixing results of increased reputational risk because they has judged this risk much higher than the benefit from the participation in the fixing.

### **4.3. Main differences between the LIBOR and BUBOR**

Based on the former chapters presented LIBOR and BUBOR definition a high level of similarity can be seen but the BUBOR is not perfect equivalent to the London reference rate. In these paragraphs the most important differences will be summarized.

Under the LIBOR fixing the contributor bank grades its own credit risk with its own fixing (the fixing is that price on which it can borrow unsecured funds from the interbank market). But the BUBOR – similar to the EURIBOR – is in fact a bid rate, a lending rate of unsecured funds in the interbank market. Thus according to the BUBOR definition the fixing has no indirect effect on the reputation of the contributor's own reputation because it is an opinion about the reputation of the other contributors. Therefore in case of BUBOR the definition does not hold such a manipulation incentives than the LIBOR because there is no possibility for indirect signaling. The reputational risk as manipulation incentives of BUBOR can be emerged directly in case of BUBOR.

Before the scandal there was an important difference that in case of LIBOR the Reuters summarized and published the data but in Hungary the Central Bank participated in the fixing process which is given more stability for the reference rate because the competent regulatory authority indirectly monitored the fixed values.

The size of trimming depends on a given ratio of number of contributors in case of LIBOR and EURIBOR (25% and 15%). In the BUBOR calculation the four lowest and highest were trimmed from the average till the end of 2013. (For example in 2013 there were 13 contributors and thus only five fixings gave the reference rate.)

The money market desks of the contributors are responsible for the BUBOR fixing which are the less influenced by the BUBOR connected derivative positions. Here is the smallest the size of trading position which revaluation is based on BUBOR contrary to the fixed income desks or asset-liability management departments thus the profitability incentive is much smaller.

Last but not least the connected interest positions are much smaller in case of BUBOR than in London or in Frankfurt. Therefore the risk of manipulation is significantly lower because with the manipulation reachable profit is much less which decreases the strength of incentives.

#### **4.4. BUBOR in the Hungarian law process**

The strength of a reference rate is based on its participation of legislative process. The legislative presence gives stability to the reference rate, legitimates it and sends a message to the society that the competent regulatory authority acknowledges this reference value.

From this perspective the BUBOR is able to fulfill fully its expected role because the BUBOR is part of much Hungarian legislation from its birth. And it has not changed after the scandal because actually there is much legislation which refers to BUBOR.

In the study I cover the new Hungarian fair bank law. Based on the history and usage the BUBOR passes the new regulatory requirements. But from the point of view of the BUBOR's future the fair bank law raises some questions because the law regulates strictly the modification of the interest rate spread, the difference between the interest of the loan and the reference rate. I show in the later part of my dissertation it can be problematic for the banks because the BUBOR shows only partly the change of the liabilities cost thus it can be effect on the BUBOR fixing process in the long term.

### **5. Statistical analysis of BUBOR-based transactions and fixed values<sup>3</sup>**

For the statistical analysis used data covers the BUBOR market till June 2012. The individual BUBOR fixings of the contributors has been available for this study for the former mentioned period but the data of trading deals has been available only from 2009. Therefore some parts of the analysis was made to the period 2009-2012. In some case from economic aspect I used the data only from 2006.

My final data is refer to 30<sup>th</sup> June 2012 which almost overlaps the publishing date of Barclays report which has had a rapid effect on every reference rates' market of the world. Both the strengthening of the internal controls and the intensifying supervisory participation has effect on the behavior of the contributor institutions. Even the BUBOR regulation changed many times after June 2012 thus for the new behavioral schemes it is worth to separately analyze

---

<sup>3</sup> Thanks for the permission of Hungarian Financial Supervisory Authority to use anonymous data in this study. Some parts of the analysis have been published in the first version in 2013. (Pénzügyi Szervezetek Állami Felügyelete [2013]).

the fixings from July 2012. This is not the part of this study, however I think the here presented scope would be appropriate for it and this study gives a good base for further analysis.

### **5.1. BUBOR related studies before the LIBOR scandal**

Before the LIBOR scandal the BUBOR related analysis did not focused on the reliability of the fixings but they wanted to identify the market role of the reference rate, what kind of direct or indirect effects were belong to BUBOR.

Horváth, Kerkó and Naszódi examined the effect of BUBOR's changes on the interest rate level of retail and corporate loans in 2004 because they looked at BUBOR as an emphasized reference rate (Horváth-Kerkó-Naszódi [2004]). Other studies found the movement of 3 months BUBOR is one of the main elements of the monetary transmission (Vonnák [2006] and Ábel-Kóbor [2008]).

In 2007 the BUBOR values had a special role between the drivers of the swap spread. Csávás, Varga and Balogh presented in their study the presage of BUBOR-spread<sup>4</sup> is positive in case of three years spread. It was backed to the BUBOR definition and not to the fact that the credit risk of the contributor bank was higher than the risk of the Hungarian state. Beyond this the authors prognosticated the decreasing of role of BUBOR against the bigger reference rates (Csávás-Varga-Balogh [2007]). But in 2009 Pintér and Pulai stated the BUBOR values did not presented the expectations of market players from the deepening of the global financing crisis. The BUBOR lost one part of its information content and other benchmarks were useful for yield curve estimation (Pintér-Pulai [2009]).

The LIBOR scandal highlighted to a new problem because from that time the propriety of fixings and the behavior of the contributor institutions should be examined. In case of Hungarian data the analysis was made more difficult by the fact that the BUBOR market had narrowed from its start thus the contributors fixed a theoretical value as reference rate which related very strong to the base rate and the expected level of it. Even the trading positions of the contributors did not depend on the BUBOR primarily. Therefore in many times it happened that a contributor bank did not change its fixing between two following trading days. Thus using time series analysis methods is limited by the special attributions.

---

<sup>4</sup> The difference of 6 months BUBOR and 6 months zero-coupon interest



In my study I would like to show that in such a special cases the descriptive statistics and some cross-sectional methods can be very useful.

## 5.2. BUBOR based transactions

### 5.2.1. BUBOR based deposit and loan portfolio

Based on contributor institutions' transactional data the BUBOR based deposit portfolio was 601 billion forint the BUBOR related loan portfolio was 2479 billion forint in June 2012. It meant the 6% and the 19% of the total deposit and loan portfolio. It is important that the BUBOR related mortgage portfolio increased from 376 billion to 631 billion forint between 2007 and 2012 which was more than 68% change.

2. Table – BUBOR based deposit and loan portfolio of the contributor institutions 2007-2012

			2007/12	2008/12	2009/12	2010/12	2011/12	2012/06
Deposit	Retail	bn HUF	52	53	65	47	78	110
		% y/y		1,3%	24,3%	-28,4%	67,5%	40,9%
	SME	bn HUF	70	80	85	130	132	136
		% y/y		12,9%	6,5%	53,2%	1,6%	3,2%
	Corporate	bn HUF	398	379	511	424	437	356
		% y/y		-4,6%	34,7%	-17,0%	3,1%	-18,7%
	<b>Total</b>	bn HUF	<b>520</b>	<b>511</b>	<b>661</b>	<b>601</b>	<b>647</b>	<b>602</b>
		% y/y		-1,7%	29,3%	-9,2%	7,8%	-7,0%
Loan	Retail	bn HUF	25	9	13	108	214	345
		% y/y		-62,6%	36,1%	763,9%	97,7%	61,1%
	SME	bn HUF	727	660	597	629	628	638
		% y/y		-9,3%	-9,5%	5,4%	-0,1%	1,6%
	Corporate	bn HUF	1 859	1 906	1 793	1 626	1 468	1 495
		% y/y		2,5%	-5,9%	-9,3%	-9,7%	1,9%
	<b>Total</b>	bn HUF	<b>2 611</b>	<b>2 575</b>	<b>2 403</b>	<b>2 363</b>	<b>2 310</b>	<b>2 479</b>
		% y/y		-1,4%	-6,7%	-1,6%	-2,2%	7,3%

source: HFSA, own edition

Based on the deposit and loan portfolio data it can state but the global financial crisis weakened the position of BUBOR (less contributors, empty market) the solution for the Hungarian FX loans problem strengthened much more the role of BUBOR because between the consumers loans increased the weight of BUBOR related products. The use of BUBOR in the revaluation process was legitimated by the regulators because the BUBOR was added into the legislative process and deemed as a stable reference value. The stronger connection with

the consumers gives more pressure on the contributor banks because any confusion in BUBOR fixing can become easily a huge social problem. Therefore the set up and maintenance of a transparent, well regulated and controlled fixing process is very important. But it may not forget the fact it is also the interest of the customers that the Budapest reference rate fixing survives and will not go to London or Frankfurt. In this case also such institutions define the forint reference rate which has not got any BUBOR related consumer portfolio and it has only BUBOR related deals in its trading book. For this institutions there will not get any social pressure because the solvency of the people will not have effect on their profitability thus the incentives for manipulation are stronger in their case.

### **5.3. Calculation method of BUBOR and individual fixing**

#### **5.3.1. Calculation method of BUBOR**

Between 2004 and 2012 there were 21 contributors in the BUBOR fixing. The participation is voluntary than in case of LIBOR. In the examined periods the contributors were the most active institutions on the forint interbank market and 16 institutions gave a fixing each trading days. From this 16 fixed reference rate the four highest and lowest were trimmed thus the final BUBOR gave the average of the eight mid fixed values. Unfortunately the number of the voluntary contributors has slightly decreased. At present there are only nine contributors and the two highest and lowest values are trimmed.

This trimming based method is able to limit the possibility of manipulation but the limitation effect is getting smaller parallel with the decreasing number of contributors. Only in 2012 four contributor banks left the BUBOR fixing. According to the former BUBOR regulation in case of 12 contributors the final reference rate was given by the six mid values thus more than 50% were trimmed. Therefore the participation of relevant institutions is a key question in the fixing process. With the participation the BUBOR would not be an external facility for the market players and thus they can strengthen also its transparency. Under a certain limit the calculation method has to be changed. It happened in 2014 and the trimming method was adjusted to the actual number of contributors in the new BUBOR regulation.

#### **5.3.2. Standard deviation of the daily BUBOR fixing**

I examined the standard deviation of the daily individual fixings for 1, 3 and 6 months tenor in period of 2004 – 2012 without taking into consideration of the trimming process. Outlying

values are observed only in the turbulent periods when generally 1-3 contributors deviated from the average fixing value. Without these turbulent trading days the daily standard deviation of the fixed values did not reach the 20 basis points therefore the trimmed data presented hardly differences.

The observed outliers were consequences of one contributor's extreme fixing. Except for this the period of January 2012 when three contributors deviated from the average during some trading days. In the following chapters it can be seen at that time the considered benchmarks moved also significantly and the fixing of these three contributors held this effect strongly. It has to emphasize such situations can happen in the future result of the emptied market of unsecured interbank loans. Therefore there is no formula what is the exact weight of the benchmark rates in the fixing process.

It can be state the daily fixings' standard deviations without trimming were very low. Bigger values observed only in the turbulent market circumstances. There was not identifiable permanently extreme behavior between the individual fixings under period of 2006 - 2012.

### **5.3.3. Individual fixings**

Before the further analysis it is worth to examine the values of individual fixings. In the previous chapter it can be seen the daily standard deviations of the contributors' fixings were very low on the majority of the observed trading days till June 2012. It means there were not big differences between the opinions of the contributor banks. But it does not mean that there is no manipulation suspicion in case of a contributor because to this it is enough such a behavior when a contributor fixes permanently (but not extremely) under or above the trimmed mean (the BUBOR) because it results a pressure for down or up to the reference rate. For this analysis I examined the connection between the individual fixings and daily BUBOR values.

It is important to underline the former presented fact that the BUBOR – against the LIBOR – is not appropriate for indirect signaling because according to the definition the contributors say their opinion about a lending rate and about their borrowing rate which would be the cost of their unsecured interbank funding. I also showed that the BUBOR values did not hold the effect of their own derivative positions. Beyond these taking into consideration the fact that in the total BUBOR rated balance sheet positions the loan portfolio of contributors were approximately by 2000 billion forint higher than the deposit portfolio (and there is no

underlined repayment day) only the permanent over fixing via the profitability incentives would have suggested to manipulative behavior.

It is foreseeable such a behavior was not observed in case of any contributor institutions. Even the majority of individual fixing remained in the BUBOR  $\pm$  25 basis points zone in the 1, 3 and 6 months tenor and these behaviors result the former mentioned very low daily standard deviation. Thus permanent one-way distortion has not been identifiable which happened in the LIBOR with permanent under fixings (signaling).

Before the further analysis I examined two contributors' 3 and 6 months fixings' difference time series. Let it V and W. In case of both institutions there were more frequent those trading days before 2008 when the contributor changed its fixing compared to the previous day's fixing. The fact that the differences most frequent values are 0, 5, 10 or 15 makes difficult the use of many modelling methodology. In case of V and W institutions the 3 months BUBOR fixing passed this criterion on 95% and 76% of the examined trading days (2006-2012). If I split the analyzed period on October 2008 the change is very conspicuous in case of W contributor bank this rate increased from 50% to 90%. Even I look only at those trading days when the fixing did not changed from the previous day the rates were the following: from 63% to 87% for V and 48% to 80% for W institution.

Such a behavior is not characteristic of a reference value which has got an active, well-functioning market. These attributions come from the narrowing of the unsecured market and it encourages caution for the analysts.

## **5.4. Tenors and possible benchmarks**

### **5.4.1. Tenors**

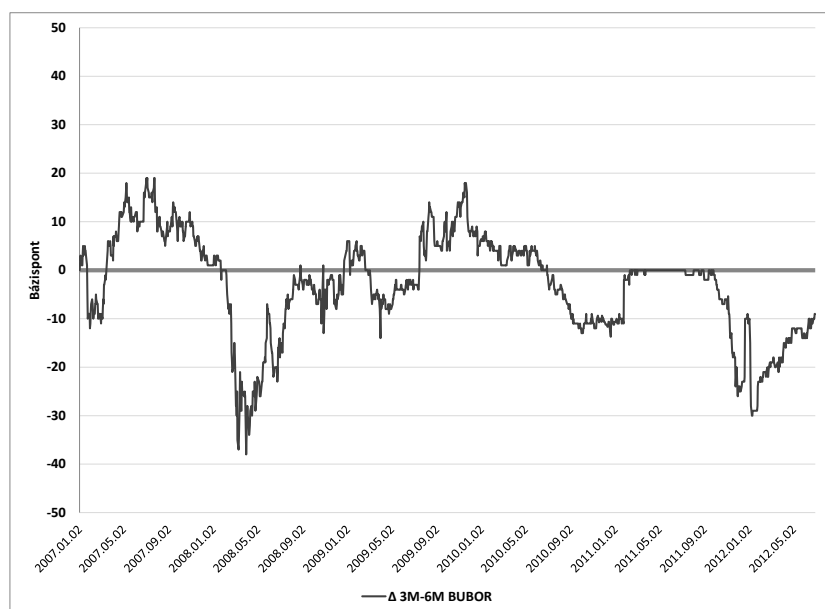
The BUBOR was calculated in 15 tenors in June 2012. According to practical experiences the institutions have used primarily the 1, 3 and 6 months tenor both in their internal and the external (for customers) pricing process therefore in the further chapters I used these former detailed examined tenors.

The BUBOR values have followed primarily the base rate. There are notable differences only on very low level but it is useful to analyze these differences. For this look at the correlation matrixes of the three main BUBOR tenors and base rate.

If we look the fully available period (2004 – 2012) the BUBOR tenors have shown a very high correlation with each other and the base rate. The lowest correlation coefficient is almost 0,98 (between 6 months BUBOR and base rate). It means that the BUBOR values sent only on minimal level expectations about the future market and the BUBOR has followed the path of base rate.

Due to the stress effects of the past periods I examined the correlation coefficients in discrete yearly periods from 2007 to 2012. The lowest coefficient between the main BUBOR tenors is 0,88 which means there were no additive expectations between the tenors neither in the most turbulent market circumstances. Moreover the values of these main tenors were very close in every trading day to each other. The following figure shows the differences between the 3 and 6 months BUBOR values<sup>5</sup> which moved mainly in the +/- 20 basis points zone between 2007 and 2012. Higher differences were only at the beginning of 2008 and 2012. At that time the 6 months BUBOR were 30 – 40 basis points higher than the 3 months BUBOR which meant the contributors expected a further increase in base rate and not only the maintenance cost were represented in the differences.

**1. Figure - The differences between 3 and 6 months BUBOR values (basis points) between January 2007 – and June 2012**



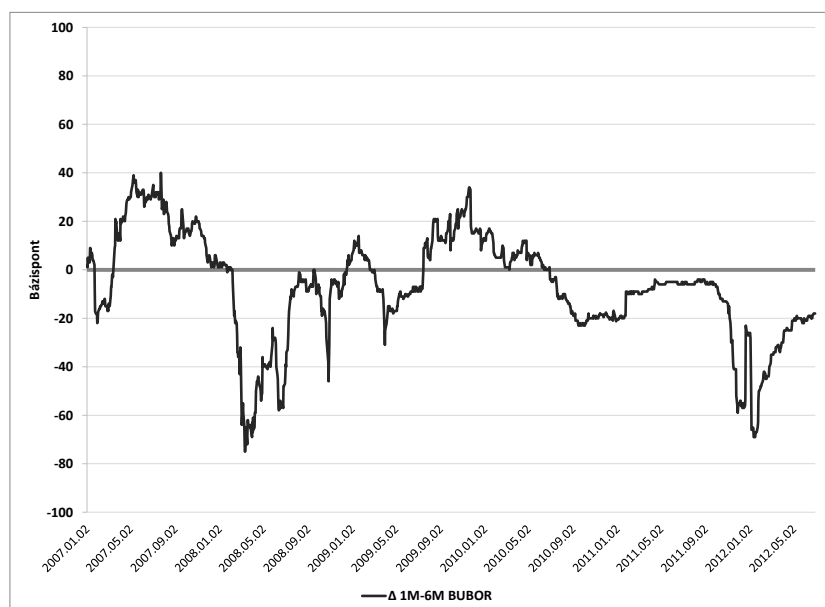
source: CBH, own edition

During the examination of the differences between the 1 and 6 months BUBOR (2. figure) it can be seen the differences were materially higher than between 3 and 6 months tenors and in

<sup>5</sup>  $3M\ BUBOR_t - 6M\ BUBOR_t$

many times there were out of the +/- 20 basis points zone. It means that in some times the differences of 1 and 6 months tenors contained not only the time value arise the maturity of a loan and a base rate's change also was taken into consideration in the level of 6 months BUBOR.

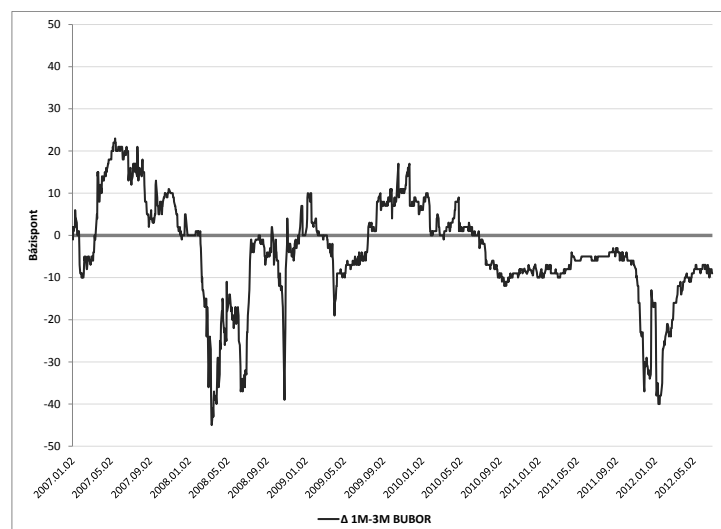
**2. Figure - The differences between 1 and 6 months BUBOR values (basis points) between January 2007 – and June 2012**



*source: CBH, own edition*

From pricing aspect the statements of previous section are very important because there is not identifiable such a main tenor which fixings were on every trading days over at least one of the other main tenors thus it could be preferable for the institutions. In a contrary case the use of this tenor (for pricing of the consumer loans) would be resulted higher profit.

**3. Figure - The differences between 1 and 3 months BUBOR values (basis points) between January 2007 – and June 2012**



*source: CBH, own edition*

The three figures of this chapter state also that there was not such a distortion on the BUBOR market and in case of the main tenors the used expectations about the future market had changed consequently in the tenors. A preferable tenor is not identifiable. This means also the BUBOR fixings took place according to the definition in the examined period. But it cannot be ignore that the in the business less used tenors were calculated according to a given interpolation formula in many contributors' daily fixing. The background of this was it there were not enough relevant interbank data which could be an option against the interpolation mechanisms. From this view the decreasing of the fixed tenors would not be effect on the relevance of BUBOR because with a given interpolation formula the left tenors would be replaceable.

This happened also in 2014 when the MFT decreased the number of fixable tenors and there have been fixing only in nine tenors (O/N, 1, 2 weeks, 1, 2, 3, 6, 9, 12 months) from February 2014.

#### **5.4.2. Benchmarks (base rate, DKJ, swap and FRA)**

During the BUBOR fixing the contributor institutions took into consideration many benchmarks: 2 weeks CBH bill (its interest rate is the base rate), forward rate agreement (FRA) deals, swap deals, implied interest rates of FX swaps, interest rate of T-bills (DKJ). But it is important not to forget in case of BUBOR above the 1 months tenor the activity of interbank market have been very limited and the fixings were almost theoretical.

From October 2008 the BUBOR values followed the path of the base rate. But there was a disengagement from December 2011 to February 2012 when the swap rates had got a very strong influence to the level of BUBOR and it moved temporary apart from the base rate. From October 2008 to November 2011 the BUBOR values followed very close the path of base rate. Before October 2008 this effect was milder.

Summarize notable disengagements were only in the turbulent trading days when due to a stress effect the contributors incorporated more severely their market expectations into their fixings. Beyond these the role of benchmarks can be observed in those periods when the path of base rate remained stable during a relative longer period. From the swap and FRA values primarily the swap values appeared in the level of BUBOR. In case of FRA rates more extreme values could be observed (for example in January 2009 and January 2012) while the swap rates were less susceptible to present huge differences from the BUBOR.

The explanation of conformation to swap rates can be that the contributor institutions hedged their banking books position rather with swap deals than FRAs thus the swap rates had got bigger influence on their risk profile. This fact also states the appropriate use of the BUBOR definition because during the fixing the contributor says its opinion about what is the actual price on which it can lend unsecured forint loan. These values are notable influence by the hedge positions of the other market players in which the role of swap deals are determinative.

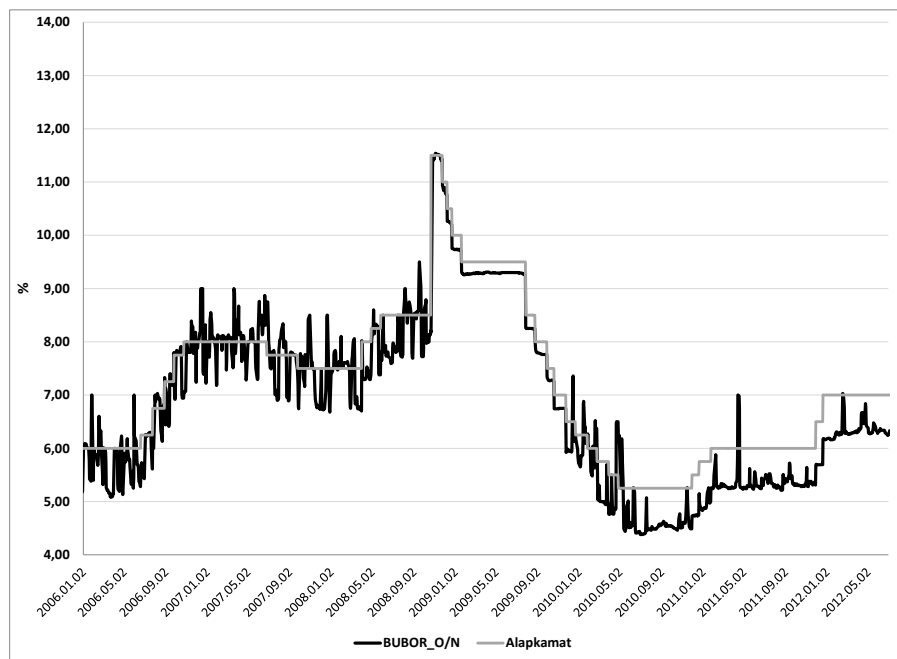
At present there has been no active market of the unsecured interbank forint loans (except the shortest tenors) therefore the examination of benchmarks and proxies is indispensable. The fixing has followed primarily the level of base rate. Based on the analysis of the past fixings it can be stated the BUBOR had not replaceable with the base rate because the benchmarks had got systematic effect on the fixings. The adaptability of BUBOR has been weakened parallel with the drying up of the market. Therefore it would be important to increase of the activity in the BUBOR market.

#### **5.4.3. The single active tenor**

Erhart, Ligeti and Molnár stated in their study in 2013 that the overnight tenor is the single medium active tenor (Erhart – Ligeti – Molnár [2013]). The activity is very low in the other tenors. They highlighted the situation in case of LIBOR is different. For example in case of USD LIBOR the activity is very high in the overnight and one week tenor and medium from 2 weeks to 3 months thus the 40% of the tenors can be considered active.



**4. Figure – The O/N BUBOR and the base rate (Alapkamat) January 2006 – June 2012**



*source: CBH, own edition*

In case of the overnight BUBOR the value of the fixing are fluctuated about the base rate. The size of this fluctuation decreased after the crises which mean that the narrowing of the unsecured interbank market reached also the single active tenor.

The standard deviation of the O/N tenor refers to it that the contributor banks' opinions are more heterogeneous than for the above examined 1, 3 and 6 months tenors. The reason of this is that much more information is available for the contributors in case of an active market. This additional information results a healthy diversification which is reflected by the standard deviation. For this reason the standard deviation of the fixings of O/N tenor was above 20 basis points in many examined trading days.

To examine the descriptive statistics the spread of O/N BUBOR and base rate I experienced also the sign of narrowing the unsecured interbank loan market. The standard deviation of the values of the spread would be lower by 30% (from 45.1 to 33 basis points – the two examined periods are 2<sup>nd</sup> January 2006 – 21<sup>st</sup> October 2008 and 27<sup>th</sup> October 2008 – 30<sup>th</sup> June 2012) thus the size of the spread stabilized after October 2008.

From my opinion the O/N and the 3 or 6 months tenor is not fully comparable because these connected to different banking products thus we have to handle the findings with huge discretion. The overnight tenor belongs primary to the corporate deposits but in case of these deposits many institutions use a single pricing formula and they do not want to reach a

homogenous pricing structure (for example fix spread) between the large corporate clients. But in case of those product which connect to the 3 and 6 months BUBOR for the retail products the standardized pricing is the expectation and if these are not active tenors the unification mechanism spreads into the fixing process of the connected tenors. Because the 3 and 6 months BUBOR based portfolio is much bigger in the Hungarian market primary an analyst has to concentrate to these tenors.

#### 5.4.4. Counterparty risk in BUBOR values

In the former sections I showed that there is only a minimal difference between the BUBOR and the base rate. From autumn 2008 when the crisis came into the Hungarian market this difference has decreased. From that time there were bigger differences only on the more turbulent trading days. To the further analysis I cut the time series on 22<sup>nd</sup> October 2008 and I examined the descriptive statistics of the difference between BUBOR and base rate for two periods: 2<sup>nd</sup> January 2006 – 21<sup>st</sup> October 2008 and 27<sup>th</sup> October 2008 – 30<sup>th</sup> June 2012.

**3. Table - The descriptive statistics of the difference of the 3 or 6 months BUBOR and the base rate in basis points**

		<b>3 m BUBOR – base rate</b>	<b>6 m BUBOR – base rate</b>
02.01.2006 – 21.10.2008	min	-24	-41
	max	79	140
	mean	15,3	24,7
	st. dev.	23,3	38,4
	median	14	22
27.10.2008 – 30.06.2012	min	-24	-40
	max	96	103
	mean	10,3	14,0
	st. dev.	15,8	23,9
	median	10	10

*source: CBH, own edition*

From the descriptive statistics it can be seen the difference of BUBOR and base would be lower after October 2008 generally. The extreme values did not change; the maximum is 2.5-3 times higher than the absolute value of minimum. Both the median and the average decreased after 2008. In case of 6 months BUBOR the decrease was more than 40%. The decrease of the standard deviations shows that the difference from the base rate would be lower and the weight of displayed further information in BUBOR level decreased.

One motor of this phenomenon is the narrowing of the unsecured interbank loan's market. The institutions decreased much more their activities in this market after the crises. But after the retreat of FX loans the role of BUBOR grew and the BUBOR would be not omitted thus the market searched a benchmark which would be the base of the reference rate. This benchmark was the base rate and the other benchmarks influenced it depending from the actual market circumstances.

It is important to emphasize the BUBOR is the benchmark rate of the unsecured interbank market thus the change of the counterparty of the market players has also effect on the level of BUBOR. If the counterparty risk is growing the market players prefer much better the secured products against the unsecured market. For the BUBOR market players there is no a benchmark which is able to show fully their counterparty risk in every time thus in my analysis I use the 5 years CDS to identify the effect of counterparty risk changes.

To analyze the spread of 3 months BUBOR - base rate and the CDS of Hungary's past moves I identified that after the crisis October 2008 the level of CDS increased permanently and the 3 months BUBOR - base rate spread decreased. This spread widened only in the turbulent periods (for example in January 2012). It means that the level of BUBOR reflects some times greater the counterparty risk and in an analysis we have to calculate the change of counterparty risk of the market players.

## **5.5. Statistical modeling of possibility anomalies in the fixings of contributor banks<sup>6</sup>**

The used statistical model has three main parts.

- i. In the first part I compare the fact fixings of contributors using with relative distance measures which is a good base to analyze how similar or dissimilar the behavior of contributors.
- ii. In the second part I estimate the expected behavior of the contributors based on the available information. I would like to estimate on which trading days would have to choose a similar behavior in the fixing process and after that I compare the estimated and the fact behavior.
- iii. In the third part I use the method of first part to compare the estimated behavior.

---

<sup>6</sup> In case of three banks I will not make estimation on account of data missing.

The goal of my analysis is to explore that any systematic behavior is identifiable in the 3 and 6 months BUBOR fixing of the contributors comparing to the average value based on the internal and external market indicators.

During the statistical analysis I start from the information (benchmarks) which has effect on the behavior of the contributors' employees (trader) who were responsible for the fixing. This information has two types: market and institutional specific information. I assume the trader does not know the future market events of the fixing day at the time of fixing but these events have effect on its behavior in longer term. Therefore during the examination of a trading day's fixing I take into consideration the exponential weighted average of the past 20 trading days' value in case of market specific information. With this method I assume the trader's memory is limited (till a month) and he forgets gradually.

In case of institutional specific information I assume that the trader knows forward this information because he has knowledge about the maturity structure and the demand of hedge deals of his own institutions and it has effect on his behavior. Therefore I calculate with the exponential weighted average of the following 20 trading days' value in case of institutional specific information.

During the analysis I do not examine the exact difference from the daily average of BUBOR fixing (without trimming) I search only the direction of the difference. I would like to find that there is identifiable any systematic scheme behind a contributor's fixing over or under the daily average.

It is practically a downscaling in the model which results losing information. In our cases it is not imaginable that a trader follows a given formula in the fixing therefore its downscaling does not limit our goals. Therefore I downscale the fixings of a contributor to an ordinal scale variable which categories are the followings for the fixing of each examined trading days: under average, average, above average. Thus this variable presents the connection to the daily average fixing.

I use K-means clustering method for modeling in case of 3 and 6 months BUBOR tenor and I classify the trading days of period February 2009<sup>7</sup> – June 2012 into three clusters and the model tries to find the similar dates according to the daily fixing behavior to the daily average value.

---

<sup>7</sup> The institutional specific information was available from January 2009.

I will compare the estimated classification with the ordinal scale variables of the individual fact 3 and 6 months BUBOR fixings (control variables) thus I would like to fit the estimated clusters to the concrete behavior.

#### **5.5.1. Actual data and behavior**

First I examine the relationship of the control variables. I model the individual data with hierarchical cluster method. Because the variables are ordinals (under average, average, above average I use for similarity measure the chi-square method<sup>8</sup>. From the agglomeration methods I use the furthest neighbor (complete linkage). The attribution of this method is that the similarity of the clusters is given by the distance of the furthest elements of the clusters. This agglomeration principle is very sensitive for the outliers<sup>9</sup>.

The former descriptive analysis states that the standard deviations of daily fixings were very low and there is no identifiable permanent over fixings. Based on this fact I do not assume outliers thus to choose of furthest neighbor method is expedient because the individual differences will separated better.

At the analysis of 3 months BUBOR it can be seen the contributors' behaviors – at the 8-9 cutting value – is classified the hierarchical cluster method into a bigger group and five separated institutions. At the 6 months BUBOR the result is a little bit different. The reason of this fact that the expectations have got more effect on 6 months BUBOR fixing thus the relationship can change.

#### **5.5.2. Individual data – fact versus estimation**

In this part I estimate the behavior of contributors based on the relevant internal and external information with K-means cluster method. After the clustering I compare the estimated results with the control variables with help of simple classification tables.

The conclusion of this part there cannot identify behavioral schemes with the clusters and it means there is no sign of manipulation.

---

<sup>8</sup> Another solution can be the ordinal variable to scale down binary variables. See for example Řezanková [2009].

<sup>9</sup> See more Mooi, E. – Sarstedt, M.: A Concise Guide to Market Research, The Process, Data, and Methods Using IBM SPSS Statistics, 2011, Springer

### **5.5.3. Comparison of the estimated results**

To validate the estimated results I compare the contributor banks' estimated behavioral variables (the final classification) with the former used and presented hierarchical cluster method (chi-square similarity measure and furthest neighbor).

## **5.6. Summary of the statistical analysis**

To summarize the statistical methods the following points contain the main statement:

- At present there is only one active tenor in BUBOR fixing process thus using benchmarks or proxies are unavoidable. If the BUBOR value is exactly derivable from a well-defined list of benchmarks the reference rate can be in hundred percent replaceable because there is not any additive information in the fixed values. According to my statistical analysis the derivation is not possible thus the BUBOR is not replaceable.
- Standard deviation of individual fixed rates before the trimming is very low. Higher standard deviation is only in more turbulent circumstances (for example October 2008 or January 2012).
- The role of the trimming is very important for the robustness of BUBOR value because the elimination of the lowest and highest 25 % of fixed values decreases the risk of manipulation.
- At the examination of institutional behavior can be seen which institutions move to up or down the BUBOR. Monotone behavior shame is not definable.
- Periods can be defined in which the effect of benchmarks changed. This fact proves the BUBOR values cannot identify as a result of a formula thus they are not replaceable.
- The false fixings refer to the not appropriate control process.

The behaviors of two banks which fixed values have got the highest standard deviation without any schematic and cooperative signs are based on that they are the most active in the market and most flexible for the market changes. These points helps to set up suggestions for market development which goals is the renewing of the market, extending the partner limits and introduce the dealing obligation.

## **5.7. Connection between BUBOR and the internal banking process**

In this section I show some problems which arise from the above showed attribution of BUBOR fixing. From my study it is clear that the BUBOR market became empty and the contributor institutions started to benchmark their fixings to the base rate. This process results some banking question because the base rate is equal to the interest rate of 2 weeks CBH deposit. If the 3 or 6 months reference rate of unsecured interbank loans is equal to the 2 weeks CBH bill the following economic problems are open:

- Is it true that the counterparty risk of a participant of the unsecured interbank market is equal to the counterparty risk of CBH?
- This fact refers to a horizontal yield curve. Is it real there is no additional risk between the connected cash flow for example between a 1 and a 6 months cash flow?

With help of examples I show in details in this section the problem and mechanism of earnings' calculation, the internal settlement price, the yield curve estimation and some risk management elements. I emphasize the role of BUBOR in the banking process (for example retail mortgage loans) but the current attributions of the fixing result many hardly solvable/manageable internal problem for the institutions.

## **5.8. Possible ways in the further research**

I have shown that the descriptive statistics can be very useful in the analysis of fixing of Budapest interbank offered rate. From the results we can see the attribution of the unsecured interbank lending market and the behavior of contributor institutions.

According to the two-step cluster analysis there is no identifiable behavior scheme characterized by fixed formula but the validation part confirms the applicability of this method. However the scope of this study is not enough to cover every possible concerned methodology. From the not showed methods the cointegration is one of the most important. In this study I analyze the co-movement of the time series via the description of the differences and the standard deviation of fixed values. But with the analyses of the co-movement of the individual fixings, the fixed BUBOR tenors and the benchmarks we can get interesting results from another aspect. To this many statistical tests are available. For example the methods suggested by Engle and Granger (Engle-Granger [1987]), Johansen (Johansen [1991]) or Phillips and Ouliaris (Phillips-Ouliaris [1990]) can be useful. In the analyses I emphasize the

co-movement is very strong between the time series (between the base rate and BUBOR or between the BUBOR tenors. On account of the special structure of fixing in the cointegration analyses it can be useful split the time series and analyze the change of the strength of the connection between the disjunct periods. In my way I defined for the primary cutting point 2008 the starting point of the global crises. However in some cases the availability limited my options. Only for the definition of these cutting points can be a base of an individual study because it is not obvious what kind of indicators is the most useful to identify the cutting points. Depending from these the results can be very different.

Another interesting approach of this problem is the extension of game theory model (cooperative or non-cooperative) to examine the assumptions of the assumptions of the fixing process. Which assumptions do ensure the truthfulness? Are there any assumptions which are incentives for the contributors to change their behavior? Do the possible new elements of reference rate regulation contain incentives or can they strengthen the fixing process?



## 6. Conclusion

One of the main conclusions of the LIBOR scandal is that the international money markets are how strictly correlated. The news of LIBOR manipulation has started worldwide processes – the operation of contributor institutions investigated by not only the English regulators. Europe wide – in Hungary also – the local competent authorities started investigations about the local reference rates to refute the suspicion of manipulation and calm down the markets. This emphasized attention revealed to an uncovered segment of the former connected scientific studies.

In this study I highlighted more facts which were not on the focus in the former studies and these appeared it maximum tangentially. The Budapest interbank offered rate was set up to model the LIBOR but there are very character differences between the definitions. The incentives for manipulation are weaker in the BUBOR. But my study shows even near the low level of incentives there were deficiencies in the fixing process. The scope of former studies about reference rates (for example De Jong-Driessen-Pelsser [2001] or Jagannathan-Kaplin-Sun [2003]) have not been enough to ensure the transparency of the fixing process because it focused on the application of reference rate.

Take into consideration the fact that under the global crises the interbank unsecured lending market became almost empty in some cases the fixed values are considered as a theoretic estimation. Therefore the statistical analyses prevented by the fact that the assumptions of the chosen methodology are not met. With the gradual decline of the interbank unsecured lending market the co-movement between the base rate and BUBOR would be stronger. From October 2008 the contributor institutions did not change their fixed value between two following trading days in more than 75% of the examined cases thus the applicability of difference time series is limited. This also shows that the BUBOR would be a very strong AR(1) process.

With examination of the individual fixing of contributors I identified there was not such a contributor which permanently under or over fixed the Budapest interbank referenced rate. Beyond this due to the drying up of the BUBOR market the contributors approached their fixing increasingly to the base rate. This is very important for those consumers whose loan is reprising according to the BUBOR because the contributors did not turn to a riskier benchmark thus they did not bear cost growth. The base rate displays figuratively the risk of

Hungarian state and therefore it does not include any additive risk which can result in increasing cost for customers.

Also the legislative citations shown there is real demand on BUBOR. In particular from that point the Budapest interbank offered rate will be set up by Hungarian experts in Budapest and not a fully indifferent expert from abroad. In case of a possible London forint fixing for the big international investment banks the presented incentives would be much higher. In case of these investment banks the Hungarian forint market is not in their main profile therefore the disturbances of forint market and the reputational risk arising from BUBOR fixing would be less impact on their operation than those banks which have an active subsidiary in Hungary. For the more transparent BUBOR values there is need to monitor and analyze continuously the fixing process. The weaknesses of BUBOR fixing which presented above are met the found weaknesses of EURIBOR fixing. The chosen statistical methods are good fundamentals for the future analyses which can support the analysts with additive information to elaborate detailed methodology for this problem.

Based on the Hungarian analyses and the guideline of competent authorities the Magyar Forex Társaság started the reform of Budapest interbank reference rate. Its result would be a new BUBOR regulation (MFT [2014]) which describes more precisely the fixing process than the former version (MFT [2013]). The Central Bank of Hungary participation in the fixing process ensures a significant transparency because the competent local regulatory authority is also an active part of the fixing.

Beyond these the position of BUBOR is strengthened by the new local legislation for credit institutions. The changes in the local regulation with connection to the new Europe wide capital requirement directive (European Parliament and Commission [2013]) could be allow bypassing the BUBOR but it has remained integral part of the legislation. This position can be stronger with sufficiently internal and external controlled process and avoid searching alternative benchmarks to ensure a long life for the BUBOR.

## 7. Main references

- Ábel I. – Kóbor Á. [2008]: Kamatkülönbözet, spekulációs profit és árfolyam-változékonyság, Közgazdasági Szemle, 2008/11, 941-961.
- Abrantes-Metz, R. M. - Kraten, M. - Metz, A. D. - Seow, G. [2008]: LIBOR Manipulation?, Social Science Research Network, 2008. <http://dx.doi.org/10.2139/ssrn.1201389>
- British Bankers Association (BBA) [2014]: bbalibor website, BBA Enterprises Ltd and BBA LIBOR Ltd., <http://www.bbalibor.com/>
- Csávás Cs. – Varga L. – Balogh Cs. [2007]: A forint kamatswappiac jellemzői és a swapszpredek mozgatórugói, MNB Tanulmányok 64.
- De Jong, F. – Driessen, J. – Pelsser, A. [2001]: Libor Market Models versus Swap Market Models for Pricing Interest Rate Derivatives: An Empirical Analysis, European Finance Review, 2001, 5: 201-237. <http://dx.doi.org/10.1023/A:1013816921237>
- Erhart Sz. – Ligeti I. – Molnár Z. [2013]: A LIBOR-átvilágítás okai és hatásai a nemzetközi bankközi referenciakamat-jegyzésekre, MNB Szemle, 2013. január
- European Banking Authority – European Securities and Markets Authority (EBA-ESMA) [2012]: ESMA and the EBA take action to strengthen Euribor and benchmark rate-setting processes, ESMA <http://www.esma.europa.eu/news/ESMA-and-EBA-take-action-strengthen-Euribor-and-benchmark-rate-setting-processes> [letöltés: 2014. március 8.]
- Financial Services Authority (FSA) [2012d]: The Wheatley Review of LIBOR, FSA, [http://cdn.hm-treasury.gov.uk/wheatley\\_review\\_libor\\_finalreport\\_280912.pdf](http://cdn.hm-treasury.gov.uk/wheatley_review_libor_finalreport_280912.pdf)
- Financial Services Authority (FSA) [2014]: Principles for Businesses, FSA <http://www.fca.org.uk/static/documents/handbook-releases/high-level-standards136.pdf> [letöltés: 2014. június 10.]
- Fliszár V. [2013]: A BUBOR-hoz köthető állományok és a BUBOR jegyzések részletes statisztikai elemzése, PSZÁF, 2013. február 13.
- Fliszár V. [2015]: A BUBOR-piac kiszáradásának jelei, avagy mi olvasható ki a 2006 és 2012 közötti BUBOR-jegyzésekből, Statisztikai Szemle, 2015/03, 243-259.
- Forgó F. – Pintér M. – Simonovits A. – Solymosi T. [2005]: Játékelmélet, BCE, elektronikus jegyzet, 2005
- Franke, J. – Haerdle, E. K. – Hafner, C. M. [2011]: Statistics of Financial Markets, Springer, 3rd Edition
- Fraser, I. [2013]: Stephen Hester: The great escape artist, 2013. február 10. <http://www.ianfraser.org/the-great-escape-artist/> [letöltés: 2014. szeptember 10.]
- Global Financial Market Association (GFMA) [2012]: Principles for financial benchmarks, GFMA <http://www.gfma.org/correspondence/item.aspx?id=350> [letöltés: 2014. június 10.]
- Gordon, A. D. [1999]: Classification, 2nd ed. Boca Raton: Chapman & Hall/CRC
- Hartigan, J. A. [1975]: Clustering algorithms. New York, John Wiley and Sons

- Horváth Cs. - Krekó J. - Naszódi A. [2004]: Kamatátgyűrzés Magyarországon, MNB füzetek 2004/8.
- Huang, Z. [1998] Extensions to the k-means algorithm to clustering large data sets with categorical values. *Data Mining and Knowledge Discovery*, 2, 283–304. <http://dx.doi.org/10.1023/A:1009769707641>
- Hull, J. C. [1999]: Opciók, határidős ügyletek és egyéb származtatott termékek, Panem-Prentice Hall
- International Organization of Securities Commissions (IOSCO) [2013]: Consultation Report on Financial Benchmarks, IOSCO, <http://www.iosco.org/library/pubdocs/pdf/IOSCOPD399.pdf> [letöltés: 2014. június 10.]
- Jagannathan, R. – Kaplin, A. – Sun, S. [2003]: An evaluation of multi-factor CIR models using LIBOR, swap rates, and cap and swaption prices, *Journal of Econometrics*, 2003, Volume 116, 113-146.
- Jamshidian, F. [1997]: Libor and swap market models and measures, *Finance and Stochastics* 1, 293-330. <http://dx.doi.org/10.1007/s007800050026>
- Johansen, S. [1991]: Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models, *Econometrica* 59 (6): 1551–1580. <http://dx.doi.org/10.2307/2938278>
- Kovács E. [2011]: Pénzügyi adatok statisztikai elemzése, Tanszék kft
- Magyar Forex Társaság (MFT) [2013]: BUBOR szabályzat, 2013. január 1. [letöltés: 2013. szeptember 2-án]
- Magyar Forex Társaság (MFT) [2014]: BUBOR szabályzat, 2014. február 1. [http://www.acihungary.hu/doc/bubor\\_szabalyzat.pdf](http://www.acihungary.hu/doc/bubor_szabalyzat.pdf) [letöltés: 2014. március 10.]
- Miltersen, K. – Sandmann, K. – Sondermann, D. [1997]: Closed form solutions for term structure derivatives with log-normal interest rates, *The Journal of Finance* 52, 409-430. <http://dx.doi.org/10.1111/j.1540-6261.1997.tb03823.x>
- Mollenkamp, C. [2008]: Bankers Cast Doubt On Key Rate Amid Crisis, *Wall Street Journal*, 2008.04.16., <http://online.wsj.com/news/articles/SB120831164167818299> [letöltés: 2013. szeptember 15.]
- Mollenkamp, C. [2012]: Exclusive: U.S. conducting criminal Libor probe, *Reuters*, 2012. február 28. <http://www.reuters.com/article/2012/02/28/us-libor-probe-idUSTRE81R1ZG20120228> [letöltés: 2013. szeptember 15.]
- Mollenkamp, C. – Enrich, D. [2011]: Banks Probed in Libor Manipulation Case, *Wall Street Journal*, 2011.03.16., <http://online.wsj.com/news/articles/SB10001424052748704662604576202400722598060> [letöltés: 2013. szeptember 15.]
- Mooi, E. – Sarstedt, M. [2011]: A Concise Guide to Market Research, The Process, Data, and Methods Using IBM SPSS Statistics, Springer
- Pintér K. – Pulai Gy. [2009]: Kamatvárakozások számszerűsítése piaci hozamokból: aktuális kérdések, *MNB Szemle*, 2009/07, 34-42.
- Řezanková, H. [2009]: Cluster analysis and categorical data, *Statistika*, 216-232.

- Snider, C. – Youle, T. [2010]: Does the LIBOR reflect banks' borrowing costs?, Social Science Research Network, 2010
- Tirole, J. [2006]: The Theory of Corporate Finance, Princeton, NJ, Princeton University Press

## **8. Own publications**

### **8.1. In the topic of the dissertation**

- Fliszár V. [2013]: A BUBOR-hoz köthető állományok és a BUBOR jegyzések részletes statisztikai elemzése, PSZÁF, 2013, study
- Fliszár V. [2015]: A BUBOR-piac kiszáradásának jelei, avagy mi olvasható ki a 2006 és 2012 közötti BUBOR-jegyzésekből, Statisztikai Szemle, 2015/03, 243-259.
- Fliszár V. [2016]: Csökkenthető a referencia-kamatok manipulálásának valószínűsége? – lehetséges irányok egy egyszerűsített modell alapján a Barclays adatainak felhasználásával, Közgazdasági Szemle, received
- Fliszár V.: [2013]: In the shadow of LIBOR – the Attribution of BUBOR market, Annual, Annual Financial Market Liquidity Conference 2013, BCE, conference-presentation
- Fliszár V. [2013]: A LIBOR árnyékában – a BUBOR piac, Tanszéki Szeminárium, BCE Operációkutatás és Aktuáriustudományok Tanszék, 2013, presentation

### **8.2. In the topic of the used methodologies**

- Kovács E. – Fliszár V. – Szüle B. – Vékás P. [2011]: Pénzügyi adatok statisztikai elemzése (szerk.: Kovács Erzsébet), Tanszék Kft., Budapest, 2011, book chapter
- Szüle B. – Kovács E. – Fliszár V. – Szepesváry L. [2015]: Többváltozós statisztika feladatgyűjtemény, BCE, book chapters, under lectionation