Abstract: This paper deals with the topology of the Hungarian large-value transfer system, known as VIBER. The paper is generally descriptive in nature, the goal of the research being the assessment of the payment topology. A graph theoretical framework is applied; by taking interdependences between institutions into account, seven centrality indices are defined. The goal of applying graph theoretical methods is twofold. Firstly, the paper aims to analyse the permanency of the network over time. It is shown that the structure of the payments was permanent in June 2005; ad hoc relationships did not dominate the topology of the payments. The most central institutions were the same; the key players did not vary across days. One interesting feature of the topology was that only 30 per cent of the existing linkages were permanent linkages, although nearly 90 per cent of the payment orders were sent or received through these linkages. The Hungarian payment system can be characterised as a structure with multiple liquidity centres. Secondly, according to certain network criteria institutions most capable of generating contagion were identified. The fact that a liquidity crisis could arise if funds are not transferred to counterparties, although the counterparties might expect it, was taken into account. A well-defined group of institutions was identified; the illiquidity of these institutions could cause the most serious disruption of the payment system. Surprisingly, the institutions most capable of generating contagion were not the largest Hungarian banks measured by asset size. Rather they were directly or indirectly active players of the USD/HUF FX swap market.

Key Words: Real Time Gross Settlement; Large-Value Transfer System; Structure; Network Topology; Centrality Indices
1 Introduction

Payment and settlement systems provide the technical infrastructure through which banking and securities market transactions are settled. The stable and safe functioning of interbank payment systems is crucial for the financial stability of the whole system. The development of the payment and settlement systems and monitoring their activities in order to achieve sound and efficient operation and smooth money circulation are listed as basic tasks of the central bank of Hungary, hereinafter MNB [1].

In Hungary, in the real time gross settlement system, known as VIBER (Valós Idejű Bruttó Elszámolási Rendszer), the moments of clearing and settlement are not separated in time; booking is managed item by item continuously and in real time. VIBER is designed to handle the payment and settlement of high value, urgent interbank transactions. In 2004 the turnover of the Hungarian interbank settlement systems was 24.7 times the projected GDP data [10].


The network theoretical framework provides an ideal tool to assess not only the structure of the payment system, but also the relationship between the topology of the system and its stability consequences. Unfortunately, the theory of complex networks can not be used in the case of the Hungarian payment system, as the number of participants is too small. Instead, a graph theoretical framework is applied, a method widely used in social network analysis. The aim of the application of centrality measures is twofold. Firstly, the paper aims to analyse the permanency of the network over time. Is the structure of the payments invariant over a longer time horizon? Or do the ad hoc relationships dominate the topology of the payments? Are the most central institutions the same or do the key players vary across days? Do randomly selected days describe the topology properly? Secondly, according to certain network criteria institutions most capable of generating contagion are determined. Which institutions could cause the most serious contagion effects if they became illiquid or insolvent? Can we find a well-defined group of institutions whose illiquidity or insolvency could generate under certain circumstances severe domino effects? Are the most important participants in the payment system those institutions that we could expect from the point of view that they are the largest banks by asset size or have the most extended retail or corporate client base?

This paper assessing the topology of the Hungarian large-value payment system is of a descriptive nature. The paper is organised as follows. Section 2 highlights the methodological background. In Section 3 the data used and some descriptive statistics of the Hungarian payment orders are provided. Section 4 deals with the permanency of the payment structure over
time. Seven centrality indices are defined and on the basis of the centrality measures the invariability of the payment topology is assessed. By examining the permanency of relations over time the constancy of exact linkages are taken into account. The visualization of the topology (Section 5) of the Hungarian payment system provides important insights into the underlying structure. In Section 6 the institutions most capable of generating contagion are determined. Section 7 provides a conclusion and highlights the area for further research.

2 Methodology

In [9] the systemic importance of an institution could be measured by several network criteria. The standard concept from graph theory states that vertices can be ranked on the basis of their centrality ([5], [13]). In the context of the payment system a central vertex is an institution that has settled payment orders with many institutions, the settled payments are of higher value, the illiquidity of the institution would directly or indirectly affect numerous banks, the counterparties of the institution are themselves important banks and finally, the institution lies on numerous potential contagion paths.

Based on these characteristics the systemic relevance of a bank can be measured by several centrality indices. Different measures capture different aspects of systemic relevance. A bank can be considered as systemically important if it is an institution that is the most capable of generating contagion, it is the one that could transmit and exaggerate the initial shock, or it is the one that could suffer from the shock and thus intermediates the initial shock to the real side of the economy. Intended by [7] and [9] the topology of the payment structure is examined by seven centrality indices: (1) in- and outdegree centrality show the number of interlinkages, (2) the valued in- and outdegree centrality refer to the size of the settlement position of a financial institutions, (3) in-closeness and proximity centrality reflect the distance from all other financial institutions, (4) the rank centrality captures the importance of counterparties, while (5) the betweenness centrality defines the position of an institution in the network.

The invariability of the payment topology is assessed in different ways. The first method is related to the centrality indices. The centrality indices are calculated for each day of the month of June 2005, and then the similarity of the indices across days is measured. Firstly, by visualizing the centrality indices we can see whether those institutions that had high (low) centrality on one day tend to have high (low) centrality on the following days as well. Secondly, the average correlations of centralities across all pairs of days also refer to the permanency of the topology.

The centrality indices are, however, not able to reveal, whether the existing linkages between banks vary across days or not. To overcome this problem the invariability of the underlying network topology is assessed by taking the permanency of exact linkages into account. This is done by means of drawing two empirical distributions.
3 Data

The data are obtained from the Hungarian large-value transfer system, known as VIBER. The VIBER statistic contains every HUF transaction of the 36 VIBER participants, mostly commercial banks on a bilateral basis. In VIBER there are four different types of payments. A payment order is considered as customer payment if its original sender or beneficiary or both are customers with an account at a direct or indirect VIBER participant. Bank-to-bank items are payments ordered by direct or indirect VIBER participants, where beneficiaries are also direct or indirect VIBER participants. The third type of transaction is related to the settlement of the cash leg of securities transactions. The fourth type of transaction includes the manual account transfer of the central bank, using the CAS workstation [12].

Table 1 shows the minimum, the average and the maximum of the daily turnover and the number of transactions settled in VIBER during the days of 2005. The bank to bank items are of higher value than the sample average, while customer payments and transactions related to securities are of lower value than the sample average.

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Average</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Daily turnover</strong> (billion HUF)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B2B</td>
<td>38,95</td>
<td>1896,60</td>
<td>3554,14</td>
</tr>
<tr>
<td>CUS</td>
<td>16,21</td>
<td>77,57</td>
<td>509,15</td>
</tr>
<tr>
<td>SEC</td>
<td>0,12</td>
<td>222,27</td>
<td>563,52</td>
</tr>
<tr>
<td>CAS</td>
<td>33,63</td>
<td>197,67</td>
<td>997,32</td>
</tr>
<tr>
<td><strong>Daily number of transactions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B2B</td>
<td>96</td>
<td>1433,03</td>
<td>2987</td>
</tr>
<tr>
<td>CUS</td>
<td>122</td>
<td>496,22</td>
<td>3652</td>
</tr>
<tr>
<td>SEC</td>
<td>5</td>
<td>545,54</td>
<td>1250</td>
</tr>
<tr>
<td>CAS</td>
<td>118</td>
<td>218,05</td>
<td>286</td>
</tr>
</tbody>
</table>

The time horizon of the analysis is the month of June 2005. The analysed month was selected randomly from the year 2005. The one month period can be considered as a short time horizon, the conclusions of the paper should be interpreted in the light of this caveat. In June no special event occurred, there was neither an idiosyncratic nor a macroeconomic type of shock that could have affected the payment system.

4 The Permanency of the Payment Topology

2.1 Centrality Indices

The position of an institution in the network can be characterised by the number of linkages it has to other institutions, that is, by the number of counterparties in the large-value transfer system. Indegree centrality shows the number of incoming edges; while outdegree centrality shows the number of outgoing edges.
Institutions with the highest indegree are either the largest Hungarian banks measured by asset size or banks that are medium-sized but active in the foreign exchange swap market. Regardless of the Hungarian Post, institutions with the highest outdegree are the same as institutions with the highest indegree. The correlation between the participants’ in- and outdegree across days is 0.8014 on average.

Looking at the figures of indegree and outdegree centrality (the relevant figures are not shown) institutions more or less vary in their in- and outdegree. The institutions have most of the time high, middle or low degree centrality. Thus, by picturing the value of the degree centralities the payment topology seems more or less permanent. Those institutions that had high (low) degree on one day tend to have high (low) degree on the following days as well.

The invariability of the degree centralities can also be captured by means of correlations. As shown in Table 2 the average of the correlations of indegrees across all pairs of days (for example the average of the 0.9380 correlation of indegrees of 1 June and 2 June, the 0.9463 correlation of indegrees of 1 June and 3 June, etc.) is 0.9473. The maximum of the correlation coefficients is 0.9784 and its minimum is 0.9097. The respective figures for outdegree centrality are also shown in Table 2.

### Table 2: Correlation coefficients

<table>
<thead>
<tr>
<th></th>
<th>Indegree</th>
<th>Outdegree</th>
<th>Valued indegree</th>
<th>Valued outdegree</th>
<th>In-proximity centrality</th>
<th>Out-proximity centrality</th>
<th>Betweenness centrality</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong></td>
<td>0.9473</td>
<td>0.9595</td>
<td>0.9582</td>
<td>0.9611</td>
<td>0.8694</td>
<td>0.8348</td>
<td>0.7959</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>0.9784</td>
<td>0.9819</td>
<td>0.9946</td>
<td>0.9936</td>
<td>0.9732</td>
<td>0.9878</td>
<td>0.9414</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>0.9097</td>
<td>0.9261</td>
<td>0.9039</td>
<td>0.8918</td>
<td>0.6850</td>
<td>0.6229</td>
<td>0.5592</td>
</tr>
</tbody>
</table>

The permanency of the structure means not only that VIBER participants have more or less the same number of counterparties in the payment system, but that they send or receive more or less the same amounts of payments. In graph theoretical terms this means that the payment linkages of an institution have similar weights across days. The valued indegree centrality equals the proportion of participant i’s incoming payments to total incoming payments. Similarly, the valued outdegree centrality refers to the proportion of participant i’s outgoing payments to total outgoing payments.

Figure 1 demonstrates the valued indegree centrality of VIBER participants. As individual bank data can not be published, the banks were coded, and they obtained a number according to their systemic importance (see Section 5). To the systemically most relevant bank code 1 was designated, to the second most relevant bank code 2 was given, and so on. The institution with the highest valued indegree centrality disposes 20.37% of all incoming payments on average, the second most dominant actor has a market share of 14.98%; while the third most important participant possesses 14.23% of the market. In the second line we can find three other banks with an average market share of 8.72%, 6.74% and 6.24%. Concerning the valued outdegree centrality of VIBER participants there are three participants – the same as in the
case of valued outdegree centrality – with significantly higher valued outdegree centrality. The high market share of the above mentioned institutions is surprising at first sight. With the exception of one bank which is among the largest Hungarian banks measured by asset size, the banks are definitely not the largest Hungarian banks. Banks with the highest valued indegree centrality are the 7th, the 11th, 12th, the 19th and the 21st in the ranking of banks according to asset size.

Previously it could have been expected (as it was expected), that the largest Hungarian banks will have the highest valued indegree centrality. The dominance of the medium and small sized banks in the Hungarian payment system can be explained by the active role of the banks in the FX swap market. The banks themselves could also be active in the FX swap market, or they are members of a large international – in the HUF USD FX swap market active – banking groups or they are correspondent banks of institutions, like JP Morgan or Morgan Stanley, that are active in the HUF-USD FX swap market. Thus, large proportion of the transactions settled in VIBER is related to the FX swaps. From another database it is known that the FX swap market is fairly concentrated and dominated by a couple of institutions, namely by the banks with the highest valued indegree centrality. Taking this into account, it is no longer surprising why medium and small-sized banks can play such an important role in the Hungarian large-value transfer system.

**Figure 1:** Valued indegree centrality
If the permanency of the structure is tackled through the visualization of valued in- and out-degree centrality, the structure seems fairly stable. On the basis of the figures (only the figure of valued indegree centrality is shown) we can see that institutions disposing high (low) percentage of the total incoming or outgoing payments on one day tend to possess high (low) market shares of the incoming and outgoing payments on the following days. The respective correlations coefficients are also high; the respective figures are presented in Table 2.

Another feature of the permanent the structure of the payment system is that the proximity of the institutions to all other institutions does not vary significantly across days. According to the proximity centrality index, a systemically relevant bank is characterised by two facts. First, it has a large influence domain, that is, the number of institutions that are directly or indirectly linked to the bank is high. Second, the average distance from all banks in the influence domain is small. Proximity centrality takes only those institutions into consideration that are directly or indirectly connected. In-proximity centrality is defined on the basis of direct or indirect incoming linkages; while out-proximity centrality is based on direct or indirect outgoing linkages. The index based on the incoming relations can be written formally as:

\[
0 \leq p_{in}(p_i) = \frac{I_i/(n-1)}{\sum_{j=1}^{n} d(p_j, p_i)/I_i} \leq 1
\]

where \( I_i \) stands for the number of institutions in the influence domain of participant \( i \).

In comparison with other centrality measures the institutions differ less in their proximity centralities. (The relevant figures of in- and out-proximity centralities are not shown.) However, we can still identify institutions that have most of the time high, middle or low centralities. The descriptive statistics of the correlation coefficients of the daily values of proximity centralities are presented in Table 2. As demonstrated by the table the relevant figures are lower than in the previous cases, although the correlation is still high. The strong, but – in comparison with the previous indices – lower correlation can be partly explained by the “passive” banks. Based on the high average correlation of proximities across days the position of VIBER participants in the network seems more or less stable over time.

The seventh centrality measure that serves to analyse the permanency of the payment topology is the betweenness centrality. According to the betweenness centrality the structure is invariable if an institution lies on the same number of potential contagion paths across days, that is, it connects the same number of institutions with each other. In the graph theoretical literature betweenness centrality is defined as:

\[
0 \leq b(p_i) = \sum_{j \neq k} \frac{g_{jk}(p_i)}{g_{jk}} \leq 1
\]

where \( g_{jk} \) is the total number of shortest paths between node \( j \) and \( k \), and \( g_{jk}(p_i) \) is the number of shortest paths between node \( j \) and \( k \) through \( i \) (\( i, j \) and \( k \) should be distinct). Betweenness
centrality of participant $i$ measures the sum of probabilities across all possible pairs of participants, that the shortest path between participant $j$ and $k$ will pass through participant $i$.

There are five institutions that dispose of a betweenness centrality higher than 5 per cent on average. (The relevant figure of betweenness centrality is also not demonstrated.) However, even in the case of the institution with the highest betweenness centrality the average probability that the institution lies on the shortest path between any two participants is 11.37%, which is fairly low. This is due to the fact that in more than 30 per cent of the potential relations there are direct relations between the participants, thus, there are no participants “between” the others.

The average correlation of the daily values of betweenness centralities is 0.7959, still high, although slightly lower than in the case of previously defined indices. This can be explained by the higher sensitivity of the measure to a new link. The maximum and the minimum of the correlation coefficient are also shown in Table 2. The higher range and standard deviation of betweenness centrality are also in line with the sensitivity of the index to small changes in the network topology. In summary, on the basis of the betweenness centrality the structure of the network seems more variable than on the basis of the previously defined indices. However, the mean correlation of betweenness centralities across all pairs of days is high.

### 2.2 Permanency of Exact Relations over Time

One drawback of the analysed centrality measures that they are not able to take the *permanency of exact linkages* into account. Do the existing linkages between banks vary across days and do the institutions send payment orders to some banks on one day and to others on the next? Or are the bilateral relations constant? The permanency of relations over time is shown in Figure 2. Note, that only those linkages were taken into account, where at least one payment order was sent or received during the month of June 2005.

**Figure 2:** Permanency of relations over time
The $x$ axis represents the number of days on which a link existed between two institutions. The maximum number of days on which an exact link could exist is 22, as in June 2005 the number of working days was 22. The $y$ axis represents the frequency of the links. Thus, for example there were 27 pairs of institutions that had linkages to each other on 10 days out of the maximum 22. The U-shaped form of the distribution presented in Figure 2 is remarkable. There are many ad-hoc linkages and many pretty constant relations. Taking only those 774 linkages into account where at least one payment order was sent during the month of June, around 20 per cent of the pairs of institutions have ad hoc relations, that is, they have linkages on less than 10 per cent of the days. On the other hand around 30 per cent of the pairs of institutions have permanent relations as they have linkages to each other on more than 90 per cent of the days.

Figure 3 depicts one interesting feature of the permanency of the payment linkages. Namely, 83.42% of the payment orders of June was sent or received through linkages that existed on each day. 88.38% of the turnover was realised through linkages which were present in more than 90% of the days.

Based on Figure 3 and 3 we can conclude that there are many linkages among banks, which existed only on a couple of days. There are nearly 200 relations (out of 774) through which payment orders were sent only on one, two or three days out of the potential 22 days. More than 50 per cent of the linkages (400 out of 774) existed on less than half of the days (on less than 11 days). However, the turnover realised through these weak linkages is extremely low. 0.53% of the turnover is related to the linkages that existed on one, two or three days. At the same time 83.42% of the payment orders of June was sent or received through linkages that existed on each day. Moreover nearly 90 per cent of the turnover was realised through the strongest linkages (linkages that were present in more than 90 per cent of the days). Thus, in June 2005 the topology seems fairly permanent in the sense that the majority of the payments are transferred through the strongest linkages.
5 Visualization

After the examination of the permanency of the payment topology, the underlying network structure is visualized. By visualizing the topology of the Hungarian payment system we can gain important insights into the network topology. The graphs of the Hungarian payment system were prepared in UCINET from Analytic Technologies, which is a software used in social network analysis [2]. The input data composed of a matrix showing bilateral payment orders based on the data of a randomly selected day, 8 June 2005. It was shown that the topology of the payment system is fairly permanent over time, thus we can assume that the topology on a randomly selected day is representative.

On 8 June 2005 the turnover of VIBER totalled 2,557 billion Hungarian forints and payment orders were settled through 295 linkages. According to Figure 4 half of the institutions have multiple connections with each other, while the other half have relationships with a few institutions in the centre. The graphs are not only directed, but also weighted, the value of sent and received payments was scaled into 20 intervals and in this way the thickness of the lines reflects the tie strength.

The payment topology of the Hungarian large-value transfer system could be best captured in a 34 dimensional frame of reference. The 34 dimensional frame of reference has many possible projections in two dimensions. Six of them are shown in Figure 4. One commonly used illustration is the circle layout. The circle layout of the Hungarian payment system is shown in Figure 4a. Figure 4b is obtained by means of principal components. The principal components are the first two eigenvectors of the adjacency matrix of the payment system. In Figure 4b banks are close to each other if they have direct relationship with the same banks. Figure 4c is based on Gower scaling, which is a metric multidimensional scaling of geodesic distances. Institutions are close together if they have short path distance to each other. Figure 4d is obtained by means of the Kruskal non-metric multidimensional scaling, which is the same as Gower scaling except that path distances are converted to rank-orders first. As a result, the relationship between path distance and distance on the map is not linear. Finally, in Figure 4e institutions are allocated on the basis of the principle of node repulsion, while Figure 4f applies the principle of node repulsion and equal edge length bias.

Based on the graphs of the Hungarian payment system we can conclude that the system is fairly centralised, the topology is dominated by a couple of institutions. These dominant institutions have very strong relations among themselves and also have many linkages to other participants. Thus, the Hungarian payment system can be considered as a structure with multiple liquidity centres. In the theoretical literature the terminology of money centre was introduced in [6]. According to the authors the structure of the interbank market can be described as an interbank market with money centre, if there is one bank, named money centre, which is symmetrically linked to the banks of the system. At the same time the banks at the periphery are only linked to the money centre. In the empirical literature in [4] the topology of the Belgian interbank market is described as a structure with multiple money centres.
**Figure 4:** The graph of the Hungarian payment system

Figure A: Circle layout

Figure B: Principal components

Figure C: Gower-metric

Figure D: Kruskal-distance

Figure E: Node repulsion

Figure F: Node repulsion and equal edge length
Different measures of centrality focus on different aspects of the payment topology. From financial stability point of view the measures refer to whether the institution

1. is capable of generating a potential liquidity crisis,
2. can play an intermediary role in distressed situations, or
3. can be affected by a potential liquidity crisis.

Liquidity crisis could arise if funds are not transferred to institutions, although the institutions have expected it. Institutions most capable of generating contagion are determined on the basis of this argument. From the point of view of the central banks it could be an important question that in the case of a liquidity shock, should it provide an emergency loan to the institution generating contagion or to the institution suffering from the shock. As the objective function of the central bank depends not only on the costs involved, this kind of analysis is beyond the scope of this paper.

Table 3 summarises whether the analysed centrality measures could be linked to the shock generating, shock transmitting or shock absorbing capacity of the institutions. From systemic point of view banks with high indegree can be easily affected by a liquidity crisis and banks with high outdegree can trigger the most severe contagious effects. However, systemically important banks should not only have many counterparties in the payment system, but they should be involved in transferring large amounts of payments. Institutions having high valued indegree centrality could be the most seriously affected by a potential liquidity crisis. By means of valued outdegree centrality institutions that are the most capable of generating contagion can be identified. In-proximity centrality is a measure of how resistant institutions to shocks are, as it shows how far institution i from those participants is, that send payment orders to institution i. In contrast, out-proximity centrality takes into account how the illiquidity of institution i would affect the institutions that expect directly or indirectly funds from participant i. According to the betweenness centrality an institution could be systemically relevant if it lies on numerous potential contagion paths. Institutions with high betweenness centrality could transmit the initial shock.

Table 3: Centrality measures and the role of the institution played in distressed situations

<table>
<thead>
<tr>
<th>Centrality Measures</th>
<th>Shock generation</th>
<th>Shock transmission</th>
<th>Lower shock absorption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indegree centrality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdegree centrality</td>
<td>⊕</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valued indegree centrality</td>
<td></td>
<td></td>
<td>⊕</td>
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<tr>
<td>Valued outdegree centrality</td>
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<td></td>
<td></td>
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<tr>
<td>In-proximity centrality</td>
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<td>⊕⊕</td>
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<tr>
<td>Out-proximity centrality</td>
<td>⊕⊕</td>
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<td></td>
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<tr>
<td>Betweenness</td>
<td>⊕⊕</td>
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</tr>
</tbody>
</table>
According to Table 3 the institutions most capable of generating contagion can be best captured by means of valued outdegree centrality and out-proximity centrality. The daily averages of valued outdegree centrality and out-proximity centralities were multiplied on bank level and the banks were ranked on the basis of this product. Let us consider 100% the product of valued outdegree centrality and out-proximity centrality of the bank with ranking 1. Banks with ranking 2 and 3 are more or less equally central. The centrality of bank with ranking 4 is so far from banks with ranking 2 and 3 as the centrality of banks with ranking 2 and 3 from bank with ranking 1. Afterwards, the consecutive differences in the relative measure are small.

The systemically most important institutions can be classified into two major groups. Banks with ranking 1, 2, 3, 4 and 6 are definitely not the largest banks by asset size, but they are the ones that play a very active role on the FX swap market. Banks with ranking 5, 7, 8, 9 and 10 are large – most of the cases foreign owned – Hungarian banks.

The central institutions of the Hungarian large-value transfer system are worth considering is all kind of systemic risk analysis. However, it is still an open question how the centrality of the institutions and the related network topology influence the probability and the severity of a potential liquidity crisis. This is clearly an area for future research.

7 Summary and Outlook

The paper dealt with the topology of the Hungarian large-value transfer system, called VIBER. A graph theoretical framework was applied, which allowed the system wide assessment of high-value payments. Seven centrality indices were defined; the different measures of centrality focused on different aspects of the payment topology. The aim of the application of graph theoretical methods was twofold.

Firstly, the paper aimed to analyse the permanency of the network over time. It was shown, that the structure of the payments was stable over the one month period. Those institutions that had high (low) centrality on one day tend to have high (low) centrality on the following days as well. The average of the correlations of the certain centrality measures across days was in each case high. The mean correlation coefficients ranged from 0.7959 to 0.9611. One interesting feature of the topology was that only 30 per cent of the existing linkages were permanent linkages, although nearly 90 per cent of the payment orders was sent or received through these linkages. The strongest linkages are not the same each day, but they are dominated by a couple of the most active banks in the payment system. The Hungarian payment system was characterised as a structure with multiple liquidity centres. In sum, the topology of the payment network seemed permanent, ad hoc relations did not dominate the topology of the payments. The most central institutions were the same; the key players did not vary across days.
Secondly, according to certain network criteria systemically important institutions were determined. Based on the measures of valued outdegree and out-proximity centrality a well-defined group of institutions was identified; the illiquidity of these institutions could cause the most serious contagion effects. Special attention should be devoted to these institutions when the payment system is monitored, and when the principles of the lender of last resort policy of the MNB is worked out. Surprisingly, the institutions most capable of generating contagion are not the largest Hungarian banks measured by asset size. Instead, they are directly or indirectly active players of the USD-HUF FX swap market.

Present paper is of descriptive nature; the goal of the research was the assessment of the payment topology. The results could serve as a good base for future research. The first challenging area is the investigation of the various banking behaviour in liquidity management. Do the behavioural differences stem from the distinct bank profiles? Do some banks manage their liquidity more efficiently? What are the most important factors influencing the timing of outgoing transactions? Do the banks cooperate and finance their transactions from the incoming payments? Are there some banks that delay their payments intentionally and free ride on the liquidity of others? Could the MNB promote the cooperation among banks if it introduced a throughput rule, similar to that of the Bank of England? It is obvious, that more research is needed to answer such questions.

Secondly, even after the topological analysis it remained an open question how the centrality of the institutions and the related network topology influence the severity of a potential liquidity crisis. As for future research, the effects of a potential liquidity crisis should be modeled and the importance of the lender of last resort function of the central bank of Hungary should be investigated. In relation with this, there are at least three distinct areas to elaborate on. Firstly, a liquidity crisis could evolve as a consequence of an operational failure of one of the VIBER participants. By means of simulations the ability of the banks to withstand certain types of operational disruptions of other banks could be assessed quantitatively. Do the banks have sufficient liquidity buffer to allow them to absorb the shocks? If not, to what extent are payments between unaffected settlement banks either delayed or prevented from being settled? Secondly, by means of simulations abnormal market conditions could also be captured. Namely, how significantly would the payment system be distorted, if the liquidity markets dried out? Thirdly, the impact of bank runs based on non-fundamental signals could also be modeled.

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