PERMANENCY AND KEY PLAYERS:
THE HUNGARIAN LARGE-VALUE TRANSFER SYSTEM

Abstract: The 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. Methods from social network analysis are applied; by taking interdependences between institutions into account, seven centrality indices are defined. The goal of applying measures from social network science is twofold. Firstly, the paper aims to analyse the stability of the network over time. This is achieved by depicting the centrality measures, examining the correlation coefficients of the centrality indices across days and drawing empirical distributions. It is shown that the structure of the payments was stable 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 stable 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 the value of total assets. Rather, they were directly or indirectly active players of the USD/HUF FX swap market. The findings of the paper are of crucial importance for, among other things, the monitoring of the payment system and the establishment of the principles of the lender of last resort policy.*

Keywords: real time gross settlement, large-value transfer system, structure, network, topology, centrality indices

*I am indebted to all those who supported the four-month research contract at the Magyar Nemzeti Bank. As the paper is based on numerous data sources, I would like to express my gratitude to Gabriella Bajkai, László Víg and Anna Morvayné Aradi for their professional assistance in helping to understand the underlying data. I am also thankful to Gergely Kócza, Katalin Méró, Eszter Tanai and Marianna Valentinyiné Endrész for their invaluable help and remarks. Comments by two anonymous referees are also greatly acknowledged. Any views expressed herein are my own and do not necessarily reflect those of the MNB. I am also grateful for the support of the National Office for Research and Technology (Grant No.: NAP 2005/KCKHA005). My e-mail address: agnes.lubloy@uni-corvinus.hu.
1 Introduction

The paper focuses on the stability of payment linkages over time. The linkages are formed by interbank payments transferred between commercial banks over the Hungarian large-value payment system. In the Hungarian payment system the number of participants is rather low, but the functioning of the system is similar to those operated in many other countries.

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, henceforward MNB (Act LVIII of 2001 on ... 4. § (5), 2001).

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 operated by the MNB and is designed to handle the payment and settlement of high value, urgent interbank transactions. In 2005 the turnover of the Hungarian interbank settlement systems was 30 times the GDP data (MNB, 2006). In real time gross settlement systems each settlement takes place by examining whether the bank has provided sufficient liquidity. If so, the payment orders are settled immediately. If the participant does not have sufficient liquidity, then the payment will be queued. When new entries are placed on the payment queue, they are inserted in a FIFO (first in first out) order by banking priority. Payments with a high priority are always queued closer to the front in comparison to those with a lower priority. In Hungary the liquidity of direct participants consists of the positive balance available on the accounts of participants and the intraday credit line, which can be obtained from the central bank by providing collateral (in the form of securities). VIBER functions in a way very similar to the operation of the national TARGET components of the euro area countries, e.g. ARTIS in Austria, ELLIPS in Belgium, New BIREL in Italy, RTGS$^+$ in Germany and TBF in France.

Network theory would provide 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. Barabási et al. (2000) argue that the structure of the network influences the stability, the dynamic behaviour and the fragility of the underlying system. According to the classical analytical framework, one key feature of networks is the connectivity distribution $P(k)$, giving the probability that a node in the network is connected to $k$ other nodes. Based on the connectivity distribution complex networks can be divided into two major classes. The first class of networks is characterised by a connectivity distribution that peaks at an average $k$ and decays exponentially for large $k$. The most investigated examples of such exponential networks are the random graph model of Erdős and Rényi and the small-world model of Watts and Strogatz. The connectivity distribution of exponential networks follows normal distribution, most of the nodes dispose of the average number of links, while only a limited number or even none of the nodes have only a few or lots of links. In contrast, results on large networks indicated that many systems belong to a class of inhomogeneous networks, called scale-free networks, for which $P(k)$ decays as a power law. The connectivity distribution follows a Pareto distribution, that is, many nodes have few links and a few nodes have many links. Whereas the probability that a node has a very large number of connections is practically prohibited in exponential networks, highly connected nodes are statistically significant in scale-free net-
works. Barabási et al. (2000) found that scale-free networks display a surprisingly high degree of tolerance against random failures, a property not shared by their exponential counterparts. The exponential networks are more fragile; in the case of malfunctioning of its nodes (which could also be banks) the network can break easily into many isolated fragments, which can reduce the efficiency of the network dramatically. The scale-free networks are more resistant; from these networks we can eliminate a large number of nodes randomly and the network will not fall into fragments. However, the error tolerance comes at the expense of attack survivability. The diameter of scale-free networks increases rapidly and they break into many isolated fragments when the most connected nodes are targeted.

A few recent papers describe the actual topologies observed in the financial system, building on the theory of complex networks or on graph theory. The studies focus on networks formed either by interbank lending or by interbank payments. (Note that the latter network – in addition to many other transactions – also contains the settlement of the transactions in the former network.) Boss et al. (2004a) provide an empirical analysis of the network structure of the Austrian interbank market. The authors find that the degree distributions (indegree, outdegree, degree) of the interbank market follow power laws; there are very few banks with many interbank linkages, and there are many banks with only a few links. The clustering coefficient of the network is low and the average shortest path length is relatively short. This network is found to be robust against the random breakdown of links, for example the default of single institutions due to external shocks. It was also shown that the interbank network showed a community structure that exactly mirrored the regional and sectoral organization of the Austrian banking system. Inaoka et al. (2004) analyze the network structure of financial transactions, using the logged data of financial transactions through the Current Account of the Bank of Japan. The authors show that the network of financial transactions between financial institutions possesses a fractal structure. Note, that the power-law distribution implies the fractality of the network structure. Moreover, it was found that financial institutions situated in the middle of the network structure hold more links than those institutions on the periphery of the network, implying that the formed structure is a result of the pursuit of efficiency rather than stability. Iori et al. (2005) analyse the network topology of the Italian segment of the European overnight money market and its time evolution. The objectives of the authors were to identify structural changes of the network over time, particularly close to the end of the maintenance periods, and to compare the lending and borrowing behavioural patterns of different types of banks. Iori et al. (2005) argued that the connectivity structure had changed over the years with network degree increasing and strength decreasing close to the end of the maintenance period. It was also demonstrated that the banking network was fairly random, preferential lending was limited and funds flowed directly from the lender to the borrower without intermediaries. The paper of Soramäki et al. (2006) describes the network topology of the interbank payments transferred between commercial banks over the Fedwire Funds Service in the United States. The authors find that the network is compact, despite low connectivity. It is also shown that the network includes a tightly connected core of money-centre banks to which all other banks connect. The degree distribution is scale-free over a substantial range. Soramäki et al. (2006) also proved that the properties of the network changed considerably in the immediate aftermath of the attacks of 11 September 2001. Müller (2006) assesses contagion in the Swiss interbank market using data on bilateral bank exposures and credit lines. In the paper – based on a graph theoretical framework – banks that are, according to certain network criteria, systemically relevant are identified. In addition to the assessment of the network topology of the interbank market, by means of simulations the vulnerability and fragility of the interbank market are also captured and the spill-over effects of a bank failure on the liquidity and solvency of other banks are measured. The main findings are that the structure of
\[ \text{the interbank market has a considerable impact on its resilience against spill-over effects; centralised markets are more prone to contagion than homogenous ones.} \]

It is important to note that in addition to the structure of the interbank relations there are many other factors that might influence the stability of the system. In the case of the interbank market (where links correspond to interbank assets and liabilities) the most important factors influencing contagion include the capital of the banks, the proportion of collateralized credits, the existence of netting agreements, bilateral limits in place and the transparency of the market (Lublóy, 2005). In relation with the interbank market the stability of the system and the factors influencing contagion are tested by means of simulations e.g. in Sheldon and Maurer (1998), Furfine (1999), Elsinger et al. (2002), Wells (2002), Degryse and Nguyen (2004) or Upper and Worms (2004). For an overview of the models see Lublóy (2005). With regard to the payment system, several studies assess quantitatively the ability of the system to withstand certain types of operational shocks. The studies of e.g. Bedford et al. (2004), Bech and Soramäki (2005) or Schmitz et al. (2006), address the question of whether the inability of a participant to submit payments would lead to serious disturbances in the system. Thus, the concept of complex networks should be combined with simulations in order to properly judge the resilience of a financial system.

Unfortunately, the theory of complex networks can not be used to assess both the systemic importance of an institution and the stability consequences of the underlying network structure in the case of the Hungarian payment system, as the number of participants is too small. Instead, measures from social network analysis are adopted. The aim of the application of centrality measures widely used in sociology is twofold.

Firstly, the paper aims to analyze the stability of the network over time. It addresses the often-voiced concern that the network is not stable over time. Is the structure of the payments invariable 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? When working out the MNB’s principles of the lender of last resort policy, it is important to see whether the network is invariable over time, or not. Should the MNB focus on the same banks on each day? Or is there any regularity with which one group of banks has priority over other groups of banks on certain days? Does the payment pattern change e.g. on the days of T-bill auctions or at the end of maintenance periods? Can we observe preferential attachment in the network or is the network rather random?

Secondly, the paper aims to determine – according to certain network criteria – institutions most capable of generating contagion. 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? Answering these questions is again important from a regulatory point of view, because special attention should be devoted to systemically important institutions, when the payment system is monitored and when the principles of the lender of last resort policy of the MNB are worked out. Also, the identification of the systemically most important institutions would be an absolutely necessary input for the simulations that assess the ability of the system to withstand certain types of operational shocks. By identifying the institutions most capable of generating contagion and highlighting their roles as key players in the payment system, individual banks could also assess whether they have a well-diversified payment portfolio, or whether they should take steps to decrease liquidity risk arising from the concentration of
incoming payments. Furthermore, we could also see whether the most important participants in the payment system are those institutions that we would expect from the point of view that they are the largest banks measured by the value of total assets or have the most extended retail or corporate client base. In this way, it would be possible to point out whether looking at the network structure has indeed any added value in comparison to striking with single bank data.

The paper assessing the topology of the Hungarian large-value payment system is of a descriptive nature. It is organised as follows. Section 2 highlights the methodological background of investigating the topology of the Hungarian large-value system. In Section 3 the data used and some descriptive statistics of the Hungarian payment orders are provided. Section 4 deals with the stability 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 stability 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. From the point of view of financial stability not all the centrality measures are relevant. A liquidity crisis could arise if funds are not transferred to institutions, even though the institutions might have expected it. The systemically important institutions are determined on the basis of this assumption. Section 7 provides a conclusion and highlights the area for further research.

2 Methodology

Due to the limited size of the network, methods from social network analysis are applied in the paper. Application of graph theoretical methods has a long tradition in social sciences (Barabási, 2002). The psychologist Stanley Milgram carried out, for example, its small world experiment as early as in 1967. Shortly after this the famous concept of the six degrees of separation was formulated. However, it is important to note that the most important contributions to network theory over the last few decades have been made by the natural science community.

By carrying out a graph theoretical analysis of the payment data of VIBER, financial institutions that are, on the basis of their relations to other banks, systemically relevant could be identified. It is not sure that the largest banks (measured either by the value of total assets or tier 1 capital) are the most important institutions in the payment system. According to Müller (2006) 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 (Watkins and Wilson, 1990, Faust and Wasserman, 1994). In the context of the payment system, a central vertex is an institution that has the following characteristics:

1 The terms graph and network are used as synonyms in this paper. A directed graph with weighted edges is called a network in the context of graph theory. Networks have many applications in the practical side of graph theory. Network analysis refers to the application of graph theoretical methods to real data. Within network analysis, the definition of network varies, and may often refer to a simple graph.

2 In Milgram's experiment, a sample of US individuals was asked to reach a particular target person by passing a message along a chain of acquaintances. The majority of chains in the experiment actually failed to complete; however, the average length of successful chains turned out to be about five intermediaries or six separation steps.
(1) The institution has settled payment orders with many other institutions.
(2) The institution has settled large amounts of payment orders.
(3) The illiquidity of the institution would directly or indirectly affect numerous banks or, on the contrary, the institution can be affected – directly or indirectly – by the illiquidity of many other banks.
(4) The counterparties of the institution are themselves important banks.
(5) 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. As it will be pointed out in Section 6, a systemically important bank does not have to fulfil all criteria of centrality. A bank may be considered central in one dimension, and stand on the periphery in another. Following Müller (2006) and Hanneman and Riddle (2005) the topology of the payment structure is examined using seven centrality indices:

(1) In- and outdegree centrality indices show the number of linkages.
(2) Weighted in- and outdegree centrality indices refer to the size of the settlement position of a financial institution.
(3) In- and out-proximity centrality indices reflect the distance from all other financial institutions.
(4) Betweenness centrality defines the position of an institution in the network.

The *invariability of the payment topology* is assessed in different ways. The first two methods are 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. Second, the high average correlations of centralities across all pairs of days could also refer to the stability of the topology.

The centrality indices describe different dimensions of the underlying network topology. However, the indices cannot 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 stability of exact linkages into account. This is done by means of drawing two empirical distributions. The first distribution shows how many links existed on a certain number of days (e.g. 1, 2, 3 or 22 days) out of the maximum 22 days. The second distribution highlights the distribution of the turnover of payments on the linkages that existed on a certain number of days (1 to 22 days).
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 on a bilateral basis. In addition to the 29 commercial banks the MNB, the Hungarian Central Securities Clearing and Depositary, the Hungarian State Treasury, the Hungarian Development Bank, the Hungarian Export Import Bank, the Hungarian Post and one savings co-operative are also members of VIBER. In the VIBER there are four different types of payments. A payment order is considered as customer payment (CUS) if its original sender or beneficiary or both are customers having an account at a direct or indirect VIBER participant. Bank-to-bank items (B2B) 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 (SEC). The fourth type of transactions is manual account transfers by the central bank (CAS), using the CAS workstation. For a more detailed description of the payment orders settled in VIBER see VIBER System Description, Version 3.3 (VIBER System…, 2005).

Table 1 shows the minimum, the average and the maximum of the daily turnover and the number of transactions settled in VIBER during the business 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>Daily turnover (billion HUF)</th>
<th>Minimum</th>
<th>Average</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<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>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Daily number of transactions</th>
<th>Minimum</th>
<th>Average</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<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 and thus 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 Stability of the Payment Topology over Time

4.1 Centrality Indices

A primary use of graph theory in social network analysis is to identify the “important” actors. The concept of centrality seeks to quantify graph theoretic ideas about an individual actor’s prominence within a network by summarizing structural relations among the nodes. If an actor is in a central position, then it has high involvement in many relations. The three most widely used centrality measures are degree, closeness and betweenness (Freeman 1977, 1979).

In the social science literature an actor with high degree centrality maintains contacts with numerous other actors (Faust and Wasserman, 1994). Actors have higher centrality to the extent they can gain access to and/or influence over others. A central actor occupies a structural position in the network and acts as a source or conduit for larger volumes of information exchange and other resource transactions. In contrast, peripheral actors maintain few or no relations and, thus, are located at the margins of the network.

In line with the concept of degree centrality, the position of an institution in the network of payments 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 shows the number of incoming edges. An institution has high indegree if it received payments from many other banks. Outdegree shows the number of outgoing edges. An institution has high outdegree, if it sent payments to many other banks.

Institutions with the highest indegree are either the largest Hungarian banks measured by the value of total assets or banks that are medium-sized but active in the foreign exchange swap market. Except one VIBER participant, 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 0.80 on average.

Having a look at the figures of indegree and outdegree, institutions more or less vary in their in- and outdegree (the corresponding figures are not indicated, however). The institutions have most of the time high, middle or low degree centrality. By picturing the value of the degree centralities the payment topology seems more or less stable. 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 be also captured by means of correlations. As shown in Table 2 the average of the correlations of indegrees across all pairs of days (e.g. the average of the 0.94 correlation of indegrees of the 1st of June and the 2nd of June, the 0.95 correlation of indegrees of the 1st of June and the 3rd of June, etc.) is 0.95. The maximum of the correlation coefficients is 0.98 and its minimum is 0.91. The respective figures for outdegree centrality are also shown in Table 2.

Table 2: Correlation coefficients
The stability of the structure over time 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 \textit{weighted indegree centrality} of participant $i$ equals the proportion of participant $i$’s incoming payments to total incoming payments. Formulating it differently, weighted indegree centrality sums the weights of incoming linkages of participant $i$. \textit{Weighted outdegree centrality} refers to the proportion of participant $i$’s outgoing payments to total outgoing payments.

Figure 1 demonstrates the weighted 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 6). To the systematically most relevant bank code 1 was designated, to the second most relevant bank code 2 was given, and so on.

\textbf{Figure 1:} Weighted indegree centrality

The institution with the highest weighted indegree centrality accounts for 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%.

The weighted outdegree centrality of VIBER participants is illustrated in Figure 2. Again, there are three participants – the same as in the previous case – with significantly higher weighted outdegree centrality. The high market share of the above mentioned institutions are surprising at first sight. With the exception of one bank which is among the largest Hungarian banks measured by the value of total assets, the banks are definitely not the largest Hungarian banks. Banks with the highest weighted indegree centrality are the 7th, 11th, 12th, 19th and the 21st in the ranking of banks according to the value of total assets.

**Figure 2:** Weighted outdegree centrality

Previously it could have been expected (as it was expected), that the largest Hungarian banks would have the highest weighted in- and outdegree 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 large international banking groups active in the USD/HUF FX swap market, or they are correspondent banks of institutions such as JP Morgan or Morgan Stanley which are active in the USD/HUF FX swap market. Thus a large proportion of the transactions settled in VIBER is related to FX swaps. From another database it is known that the FX swap market is fairly concentrated and dominated by a few institutions, namely by the banks with the highest weighted in- and outdegree 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.
Csávás et al. (2006) argue that the FX-swap market is the only money market segment actively used by both resident and non-resident participants in Hungary. The most important functions of the FX swaps include liquidity management along various currencies, taking the required intra-year yield positions or intra-year yield speculation. Furthermore, the facts that the market of government securities with maturity of less than 1 year are not liquid enough and that the hedged FX swaps enjoy priority over unsecured interbank deposit transactions, also play an important role in explaining the significance of the FX swaps. In the FX swap segment the breakdown by denominations reflects the dominance of the US dollar: swaps conducted vis-à-vis the dollar make up 93% of turnover (MNB, 2004). This currency denomination is surprising in the sense that the Hungarian economy is much more oriented towards the European Union then towards the United States. The dominance of the dollar is an international feature of the FX swaps explained by market participants as a market tradition.

If the stability of the structure is tackled through the visualization of weighted in- and outdegree centrality, the structure seems fairly stable. On the basis of Figures 1 and 2 we can see that institutions disposing high (low) percentage of the total incoming or outgoing payments on one day tend to posses high (low) market shares of the incoming or outgoing payments on the following days. The respective correlations coefficients are also high; the relevant figures are presented in Table 2.

Another feature of the stable 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 characterized 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. The index takes only those institutions into account which, directly or indirectly, send payment orders to bank $i$. The group of institutions defined this way is called the influence domain of bank $i$. Out-proximity centrality is based on direct or indirect outgoing linkages. The index takes only those institutions into account to which bank $i$ sends payment orders directly or indirectly.

Proximity centrality takes not only the number of institutions in the influence domain into account, but also the average distance from all other institutions in the influence domain. Thus, the index is defined as the ratio of the fraction of institutions in the influence domain of participant $i$ and the average distance of the institutions in the influence domain from participant $i$. The proximity index based on incoming relations ($p_{in}$) for participant $i$ can be written formally as:

$$p_{in} = \frac{\text{fraction of institutions in the influence domain of } i}{\text{average distance of institutions in the influence domain from } i}$$

One commonly used measure would be closeness centrality. A central actor in the closeness concept has minimum path distances from the others, quickly interacting and communicating with few intermediaries involved. Thus, if two actors are not adjacent, needing only a small number of steps to reach each other, it is important to attain higher closeness centrality. As closeness is inversely related to distance, the closeness of participant $i$ equals the reciprocal of the sum of geodesic distances from bank $i$ to each actor $j$, where $i \neq j$. The centrality measure should be normed by the theoretically most central actor, that is, by $(n – 1)$. Closeness centrality, however, can only be calculated for strongly connected networks. If in the directed graph there is at least one institution that is not reachable from an institution, the distance between these institutions would be infinite. Since in the payment system not all the institutions are strongly connected, the index of closeness centrality cannot be used. Instead, proximity centrality is calculated.
\[
0 \leq p_m(p_i) = \frac{I_i/(n-1)}{\sum_{j=1}^{n} d(p_j, p_i)/I_j} \leq 1
\]

(1)

where \(p_i\) represents participant \(i\), \(n\) refers to the number of participants in the payment system and \(I_i\) stands for the number of institutions in the influence domain of participant \(i\). In Equation 1, \(d(p_j, p_i)\) represents the geodesic distance between participant \(j\) and participant \(i\), that is, the minimum number of linkages required to reach participant \(i\) from participant \(j\).

In comparison with other centrality measures the institutions differ less in their proximity centralities. (The corresponding 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 corresponding 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 analyze the stability of the payment topology is the betweenness centrality. In social network analysis a central actor is claimed to occupy a “between” position, if it connects many pairs of other actors in the network. As a cut point in the shortest path connecting two other nodes, a “between actor” may control the flow of information or perhaps charge a fee for transaction services rendered. In the graph theoretical literature betweenness centrality of participant \(i\) \(b(p_i)\) can be defined formally as:

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

(2)

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 participant \(i\) (\(i\), \(j\) and \(k\) should be distinct). Thus, the betweenness of participant \(i\) is the sum of the proportion of all geodesics linking participant \(j\) and participant \(k\) which pass through participant \(i\). The 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% on average. (The corresponding 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% of the potential relations there are direct relations between the participants, that is, there are no participants “between” the others.

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. The average correlation of the daily values of betweenness centralities is 0.80, which is still high, though 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 sensi-
tivity 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. That is, the structure is a more variable, but still stable.

4.2 Stability of Exact Relations over Time

One drawback of the analysed centrality measures is that they are not able to take the permanency of exact linkages into account. It might happen that the network seems to be stable if the centrality indices are taken into account: e.g. bank A has 15 outgoing linkages on one day and it is also linked to 15 banks on the following days. However, these 15 banks may be totally different or only partly overlapping. Thus, stability of a network over time from the point of view of centrality indices is a necessary, but not sufficient condition of a stable structure. We should address questions like: 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? Are the bilateral relations constant? The permanency of relations over time is shown in Figure 3. 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. In 486 out of 1260 cases (38.57%) no payment orders were sent between the institutions on any of the days. These links were disregarded.

The x axis represents the number of days on which a link existed between two institutions. The maximum of the 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 3 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 send during the month of June, around 20% of the pairs of institutions have ad hoc relations, that is, they have linkages on less than 10% of the days. On the other hand around 30% of the pairs of institutions have stable relations as they have linkages to each other on more than 90% of the days.
Figure 3: Stability of relations over time

Figure 4 depicts one interesting feature of the stability 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 realized through linkages which were present in more than 90% of the days.

Figure 4: Turnover of the ad hoc vs. stable linkages

Based on Figures 3 and 4 we can conclude that there are many linkages among banks which existed only on a few 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% 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. The turnover realised through the linkages that existed on less than half of the days does not reach 4% of the total turnover. In the light of Table 1 it is a reasonable assumption that these weak linkages are dominated by customer payments. At the same time, 83.42% of the payment orders of June were sent or received through linkages that existed on each day. Moreover, nearly 90% of the turnover was realised through the strongest linkages (linkages that were
of the turnover was realised through the strongest linkages (linkages that were present in more than 90% of the days). Thus, in June 2005 the topology seems fairly stable in the sense that the majority of the payments are transferred through the strongest linkages. These strongest linkages are the most likely signs of preferential attachment; banks prefer to transact with the same banks on each day. According to the literature (e.g. Boot, 2000), this banking behaviour results in lower transaction and monitoring costs. Note, that the high percentage of the turnover realized through stable linkages is a sufficient condition of an invariable structure. If a node has, for example, eight stable and three ad hoc relations, the structure may be considered as stable as the majority of the funds transferred through stable linkages.

In short, the topology of the payment network may be considered stable over the one month period. The most central institutions were the same; the key players did not vary across days. The continuity of interbank relations was verified empirically by visualizing the centrality indices, by calculating the mean correlations of centralities across all pairs of days and by taking the stability of exact linkages into account. However, it is still an open question how the topology would change if we either looked at a longer time horizon or at a crisis situation. Although this kind of research is beyond the scope of the paper, two empirical papers may give us some guidance in this respect. Iori et al. (2005) employed methods of statistical mechanics of complex networks and showed that the connectivity structure had changed in the Italian overnight money market over a four year period. The authors proved that close to the end of the maintenance period the network degree increased and strength decreased. Thus, if we take a longer time horizon, e.g. a few of years into account, then the banks may alter their behaviours, leading to changes to the underlying network structure. We should be aware of this fact, although it is reasonable for us to assume that in the absence of shocks no significant topological changes are to be expected in the short run. Soramäki et al. (2006) analysed the network topology of the Fedwire transactions both under normal market conditions and in a crisis situation. The immediate aftermath of the attacks of 11 September 2001 was considered as a crisis situation. The authors assessed the properties of the network both before and during the crisis and found that the network structure changed considerably under distress. The number of nodes and links in the network and its connectivity dropped, while the average path length between nodes increased significantly. In Hungary it would be hard to analyse the topological properties of the payment network in a crisis situation, because in the near past, similarly to the randomly selected month of June, no shock has taken place in the payment system.

5 Visualization

After examining the stability of the payment topology over time, 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 was prepared in UCINET from Analytic Technologies, which is a software used in social network analysis (Borgatti et al., 2002). The input data of Figure 5 produced 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 stable 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 5 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 directed and 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.

Figure 5: The graph of the Hungarian payment system

The payment topology of the Hungarian large-value transfer system could be best captured in a 36 dimensional frame of reference. This 36 dimensional frame of reference has many possible projections in two dimensions. Six of them are shown in Figure 6. One commonly used illustration is the circle layout. The circle layout of the Hungarian payment system is shown in Figure A. Figure B 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 B banks are close to each other if they have direct relationship to the same banks. Figure C is based on Gower scaling, which is a metric multidimensional scaling of geodesic distances. Institutions are close to each other if they have short path distance to each other. Figure D is obtained by means of the Kruskal non-metric multidimensional scaling, which is the same as Gower scaling except that path distances are first converted to rank orders. As a result, the relationship between path distance and distance on the map is non-linear. Finally, in Figure E institutions are allocated on the basis of the principle of node repulsion, while Figure F 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 being dominated by a few 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.
by Freixas et al. (2000). 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 Degryse and Nguyen (2004) describe the topology of the Belgian interbank market as a structure with multiple money centres.

In Hungary liquidity centres correspond to banks with the highest centrality indices. Interestingly, liquidity centres are not the most important market players in the retail or corporate segments. Instead, liquidity centres are either middle-sized or even small banks measured by the value of total assets. Their importance in the payment network stems from their active roles in the USD/HUF FX market. Liquidity centres manage their liquidity along various currencies, speculate on intra-year yield changes or act as intermediaries for foreign banks, like JP Morgan.

6 Institutions Generating Contagion

As we have previously seen that the payment structure is stable, the scene is set for identifying the institutions most capable of generating contagion. Different measures of centrality focus on different aspects of the payment topology. A bank does not have to fulfil all criteria of centrality listed in Section 2. It may be considered central in one dimension and be on the periphery in another. From the 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.

A 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 a central bank it could be an important question whether, in the case of a liquidity shock, it should provide an emergency loan to the institution generating contagion or to the institution suffering from the shock. As the objective function of a central bank depends not only on the costs involved, this kind of analysis is beyond the scope of this paper.

Table 3 summarizes whether the analyzed centrality measures could be linked to the shock generating, shock transmitting or shock absorbing capacity of the institutions. One could argue that banks with high indegree can be easily affected by a liquidity crisis and that banks with high outdegree can trigger the most severe contagious effects. (Accordingly, sign ⊕ in the intersection of indegree centrality and lower shock absorbing capacity in Table 3 implies that banks with higher indegrees are more prone to a crisis and dispose of a lower shock absorbing capacity.) However, in- and outdegree centrality are not meaningful measures of systemic importance. If an institution has many in- or outgoing relations it does not necessarily mean that the institution can have a high impact on the others. Let us consider an institution that sends nearly all VIBER participants payments, although the amounts transferred are low.
The illiquidity of the institution could not undermine the liquidity position of the others. (This drawback of the measure is stressed by a single ⊕ sign.)

Systematically 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 weighted indegree centrality could be the most seriously affected by a potential liquidity crisis. By means of weighted outdegree centrality institutions that are the most capable of generating contagion can be identified. This latter measure takes into account the fact that a liquidity crisis could emerge if an institution with a huge amount of debit items (sent payment orders) becomes illiquid.

Another feature of an institution playing an important role in the payment system is that liquidity problems arising at the institution could affect several other institutions directly or indirectly. In this case the importance of an institution depends on how close the institution is to all other institutions. In-proximity centrality is a measure of how resistant institutions are to shocks, as it shows how far institution \( i \) is from those participants which 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 \( i \). Thus, the index defined on the basis of the outgoing edges captures the ability of banks to trigger contagion.

According to the betweenness centrality, an institution could be systematically relevant if it lies on numerous potential contagion paths. Institutions with high betweenness centrality could transmit the initial shock. Betweenness centrality assumes that a participant is playing a crucial role in the network due to its intermediary role. The focus is not so much on the number of institutions a failed institution could affect, but rather on the probability that the institution is involved in a systemic event at all. The importance and potential use of betweenness centrality in interbank asset/liability networks has been explicitly studied by Boss et al. (2004b). The authors assessed the contagion potential of Austrian banks by eliminating banks one by one from the network and counting the number of banks that have become insolvent as a result of the initial default. By taking many possible network measures into account, the authors found that the betweenness of the defaulting banks could be directly related to the contagion impact. Above a certain threshold of vertex betweenness a linear relation was demonstrated between the betweenness of bank \( i \) and the contagion impact of bank \( i \). Despite the fact that Boss et al. (2004b) argue that systemically important banks may be reliably identified by vertex betweenness, the measure of betweenness centrality is disregarded when institutions most capable of generating contagion are determined in the Hungarian banking system. The reasons for this are the following: 1) Theoretically, betweenness centrality measures institutions’ capability to transmit, rather than to generate shock. 2) The Austrian and Hungarian banking systems may be characterized by very different structures. 3) In Hungary the betweenness centrality of banks is fairly low due to the high number of direct relations. It would require more empirical evidence to prove that betweenness centrality is directly related to contagion impact.

According to Table 3 the institutions most capable of generating contagion can be best captured by means of weighted outdegree centrality and out-proximity centrality. The daily averages of weighted outdegree centrality and out-proximity centralities were multiplied on a bank level and the banks were ranked on the basis of this product. Figure 7 shows the relative value of the ranking, the product of weighted outdegree centrality and out-proximity centrality of the bank with ranking \( l \) was considered as 100%. It can be seen from the figure that
banks with ranking 2 and 3 are more or less equally central. The centrality of bank ranking 4 is far from banks with ranking 2 and 3, as is the centrality of banks with ranking 2 and 3 from the bank with ranking 1. Beyond this, the consecutive differences in the relative measures are small.

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

<table>
<thead>
<tr>
<th></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>Weighted indegree centrality</td>
<td>⊕⊕</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weighted outdegree centrality</td>
<td>⊕⊕</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-proximity centrality</td>
<td>⊕⊕</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out-proximity centrality</td>
<td>⊕⊕</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Betweenness</td>
<td></td>
<td>⊕⊕</td>
<td></td>
</tr>
</tbody>
</table>

The systematically most important institutions can be classified into two major groups. Banks with ranking 1, 2, 3, 4 and 6 are not definitely the largest banks measured by the value of total assets, 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 Hungarian banks – in most cases foreign owned.

Figure 7: Institutions capable of generating contagion

The central institutions of the Hungarian large-value transfer system are worth considering in 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

This paper has dealt with the topology of the Hungarian large-value transfer system, known as VIBER. Due to the limited number of participants, tools widely used e.g. in physics or biology to analyse complex networks, could not be employed. Instead, similarly to Müller (2006), social network analysis was applied. The methods we used enabled us to conduct a system wide assessment of high-value payments. Seven centrality indices were defined; the different measures of centrality focussing on different aspects of the payment topology. Degree centrality took the number of direct linkages into account and disregarded the line values and indirect relations. Valued degree centrality indices considered solely the aggregate payment orders (the sum of the line values) and disregarded the number of direct and indirect linkages. Proximity and betweenness centrality measures took both direct and indirect linkages into account, although they disregarded the line values. The aim of the applying methods from social network analysis was twofold.

Firstly, the paper aimed to analyze the stability of the network over time. As far as I know, this is the first attempt to measure the invariability of the payment structure under normal market conditions by methods adopted from social network analysis. It is worth mentioning that the time horizon of the analysis was fairly short: only one month. Albeit, the randomly selected month of June 2005 could be considered as a representative month. In this respect, within a year or so we could presumably extrapolate the findings of the research for other periods. Further research will, however be needed to prove this conjecture. In this paper, the continuity of interbank transfer relations was estimated empirically; 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 certain centrality measures across days was in each case high. The mean correlation coefficients ranged from 0.80 to 0.96. One interesting feature of the topology was that only 30% of the existing linkages were stable linkages, although nearly 90% of the payment orders was sent or received through these linkages. The strongest linkages were not the same each day, but were dominated by a few banks most active in the payment system. The Hungarian payment system was characterized as a structure with multiple liquidity centres. In sum, the topology of the payment network seemed stable, 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, similarly to Müller (2006), according to certain network criteria systemically important institutions were determined. The graph theoretical approach provided an ideal tool to determine the institutions most capable of generating contagion through the Hungarian large-value payment system. It was taken into account that a liquidity crisis could arise if funds are not transferred to counterparties, although the counterparties might have expected it. 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. Being aware of the key players in the payment system, individual banks are also able to judge better, whether they have a well-diversified payment portfolio or whether they should take steps to reduce liquidity risk stemming from the concentration of incoming payments. Surprisingly, the institutions most capable of generating contagion are not the largest Hungarian banks in terms of asset size. Instead, they are directly or indirectly active players...
of the USD/HUF FX swap market. This finding demonstrates that it is important for the analysis of single bank data to be complemented by the evaluation of the network structure of payment transactions.

The paper could serve as an important input in assessing FX settlement (or Herstatt) risk. In VIBER a large proportion – at least one quarter – of transactions settled are related to the Hungarian forint (HUF) leg of FX swaps. Neither the spot nor the forward legs of the FX swaps are settled simultaneously. The HUF leg of the swap is executed in VIBER during VIBER operating hours (8 a.m. – 4.30 p.m. Central European Time), while the USD leg of the swap is completed in the Fedwire during the Fedwire operating hours (8.30 a.m. – 5 p.m. Eastern Time). Accordingly, we can assume that the HUF leg of an FX swap is sent before the USD leg of an FX swap. It would be important to measure the significance of the settlement risk that the banks may face. Could it generate serious liquidity or solvency problems? Should VIBER operating hours be extended? Would such lengthened operating hours really mitigate the risks involved? What should the MNB do if the settlement risk is high, but the risk is not of an intraday nature?

The results obtained highlight various banking behaviour in liquidity management. Do the behavioural differences stem from the distinct bank profiles? Do some banks manage their liquidity more efficiently? Is the efficient liquidity management conscious or enforced by the course of business? What are the most important factors influencing the timing of outgoing transactions? Do the banks time their outgoing payments at all? 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 cooperation among banks if it introduced a throughput rule, similar to that of the Bank of England? Is the functioning of the system optimal or could it be more efficient, for example by altering the timing of payments? It is obvious that more research is needed to answer such questions.

Finally, 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 modelled and the importance of the lender of last resort function of the MNB should be investigated. In relation to this, there are at least three distinct areas needing elaboration. 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? The findings of the research, namely the identification of the systemically most important institutions, similarly to that of Schmitz et al. (2006), could serve as an important input for this kind of simulations. Secondly, by means of simulations abnormal market conditions could be also captured. Namely, how significantly would the payment system be distorted if the liquidity markets dried up? Thirdly, the impact of bank runs based on non-fundamental signals could also be modelled. In the literature the sunspot phenomenon is widely discussed; the occurrence of a signal which co-ordinates the expectations of the public without being actually related to the health of financial institutions. It is shown that sunspots can lead to self-fulfilling bank runs. However, the quantitative assessment of a potential bank

---

4 8.30 a.m. – 5 p.m. Eastern Time corresponds to 1.30 p.m. – 10 p.m. Central European time. Thus, during a normal working day there are three hours when both the VIBER and the Fedwire are open.
However, the quantitative assessment of a potential bank run on the liquidity of other banks is not handled.

References


Csávás, Cs., Kóczán, G. & Varga L. (2006). Key players and typical trading strategies in the most important Hungarian money market segments. MNB Studies No. 54, Magyar Nemzeti Bank.


