International financial network characteristics as the measure of financial integration

The authors perform analysis of theoretical and empirical research on financial networks and disclose the peculiarities of network analysis application for evaluation of systemic financial integration. The analysed methods are tested on international portfolio investments network.

**Keywords:** connectivity of economic actors, financial network, financial integration.

These patterns of international financial markets urged researchers and practitioners to search for new measures of systemic international financial integration. As T. Oatley et al. (2011) remarks, much existing research ignores system-level considerations entirely or conceptualize the system-level indicators in terms of country-level attributes. This encouraged the application of network methodologies in the research of international financial system. Conceptualization of international financial system as international financial

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**Introduction**

The issues of systemic financial integration attains more and more attention of researchers as well as practitioners due to several reasons. The international financial market experienced a huge growth in comparison to the growth of internal economics or international trade. The allocation of international financial assets is highly unbalanced. The evidence of growing interdependence of international financial market participants were highlighted by the spread and consequences of the financial crisis of 2008.

These patterns of international financial markets urged researchers and practitioners to search for new measures of systemic international financial integration. As T. Oatley et al. (2011) remarks, much existing research ignores system-level considerations entirely or conceptualize the system-level indicators in terms of country-level attributes. This encouraged the application of network methodologies in the research of international financial system. Conceptualization of international financial system as international financial system...
The network allows researcher to analyse the topological issues of the system as well as its functioning.

Network approach is not newly founded in financial research. Developed in other disciplines, such as physics, biology or sociology, it was applied to different areas of economics. As M. Gabrieli (2012) states, the network theory was broadly applied to financial research only recently, even though international financial market is named by S. Tordoir (2013) as the most appropriate background for application of complex network model. The usage of network models in finance was restricted by the absence of bilateral financial data that is needed for mapping the networks.

Traditional measures of quantity based international financial integration incorporate only the issues of the volume of international financial transactions, but ignores their distribution. More and more researchers of international economic systems argue that not only the volume of international activity is important, but the position that a country or institution has in the system. The application of network analysis allows to adapt network measures for evaluation of additional features of international financial integration. The network analysis is also useful for its abilities to gauge the systemic perspective of international financial integration instead of individualised country or institution perspective traditionally used for systemic evaluations.

This article supports this new stance of network approach to international financial systems and analyses the possibilities to adopt the topological features of international financial network for measuring systemic financial integration. For this purpose authors have to carry out following tasks:

- to map the international financial network;
- to measure the topological characteristics of the identified network;
- to analyse the dynamics of the international financial network structure;
- to evaluate the possibilities to adapt topological network characteristics for systemic financial integration analysis.

The results of this research will help to disclose what additional features of international financial integration can be gained with the help of topological network indicators.

**Network theory and its application in finance**

The general definition of a network is originated from mathematical theory of graph, that analyses sets of nodes (or vertices) that are connected with bilateral links (or edges). Not less than three nodes and their bilateral links can be named a network (Provan et al., 2007). Network analysis is understood as structural analysis of a complex system that is conceptualised as a network (Fagiolo et al., 2009). Firstly introduced in the natural sciences the network analysis was more and more widely applied in other areas, such as epidemiology, statistics, geography, telecommunication, anthropology, psychology, sociology, management and economics etc. (Borgatti, Foster, 2003; Jackson, 2005; Schweitzer et al., 2009; Jukka-pekka et al., 2010; etc.).

The extent of network analysis application to economic system research increased in the last decade (Fagiolo, 2010). S. P. Borgatti, P. C. Foster (2003) and M. E. J.
Newman (2002) relate this growth with the trend of complex system approach takeover that was evident in all scientific areas since the second half of the 20th century. Individualized object based analysis of a system has been taken over by systemic approach that urged to evaluate not only separate objects of a system but their connectedness as well.

**Financial system as a network.** The application of network theory in finance is more recent than its application in other fields of economics. As M. Gabrieli (2012) states, although the network theory has been successfully applied to several economic fields, few attempts have been made, until recently, to use this theory to understand the workings of financial systems. Following the analysis of networks in finance by F. Allen and A. Babus (2009), we can distinguish two types of analysis: network formation and network effects. Network formation analysis scrutinizes how financial linkages between financial institutions of countries are formed. This analysis can capture tradeoff between risk sharing benefits and contagion risks or freezes in the interbank markets as well as determinants of capital misallocation. Analysis of network effects discloses what impact a network structure has on certain economic phenomena. The mostly researched area in this field is questions of systemic risk and contagion as well as fragility of financial systems.

The network definition is determined by conceptualization of nodes as well as links (Castells, 2005). The network can be identified as financial if nodes, links or both are conceptualized as financial. Connections in the financial world as well as actors are varied. The financial links are formed between different financial institutions on a different bases. These ties can be informational (the diffusion of knowledge), social (friendship), economic (trade or investment relationships), or political (membership in common organizations, allies) (Oatley et al., 2011). Different links are undoubtedly interrelated as well, but due to complexity of analysis usually one type of links is chosen for analysis in financial research. For example, two institutions that have bilateral investment flow are considered as financially linked. But as not only bilateral links gain researchers' attention but indirect links as well, network representation of financial system becomes more and more widely used.

As S. Tordoir (2013) indicates, financial industry fits all the characteristics of Castell's network theory. But only the crises of 2008 fueled the research of financial networks. The mostly disclosed area is the interbank market. The interbank network is analyzed in the local level (Iori, 2007 – Italy; Upper, Worms, 2004 – Germany; Wells, 2004 – Austria and etc.), as well as international (Minoiu, Reyes, 2011). The objectives of these researches cover problems of contagion, stability as well as identification of interbank network topological features. The financial networks conceptualized on the bases of other types of financial links are rarer.

**Topological issues in financial integration evaluation.** The issues of financial globalization and integration received an increased attention of researchers due to increased international financial activity, misallocation as well as instability of international financial flows. The evidence of growing international interdependence of separate institutions as well as countries highlighted the need for new instruments of international financial integration analysis. The higher availability of bilateral financial data as well as methodological developments in network theory let researchers
Research methodology

In order to map the international financial network the fundamental blocks of a network have to be identified. A network is a set of objects (N) and their bilateral links (A) that have some value (W). In this research the separate countries are identified as network nodes (N). The bilateral link from country i to country j \( i \to j \) is considered existing if country’s i investors hold securities issued by a country j. The value of this link is equal to the value of investment. Only economically meaningful links (with the value higher than 500 thousands USD) are considered in the analysis.

The network can be mapped as a square NxN matrix where rows represent all incoming links while columns represent all outgoing links. It must be noted that diagonal elements \( (i \neq j) \) of such a matrix has to be ignored as they have no economic meaning. If the number of network elements is limited, the network can be analysed as a graphic network. When the number of network elements is high, analysis is usually performed on a matrix basis with the help of special analysis tools (Netminer 4.0 in this case). In the context of this article the graphic analysis of a network is omitted due to high number of network elements.

The data for international network mapping is taken from the CPIS survey. 76 countries are included in the international financial network. The research period covers the years 2001 - 2011. The international financial network is mapped for every year of the researched period in order to follow the dynamics of its topological characteristics and how the degree of integration changes over time.

As the goal of this research is to evaluate the system level characteristics of international financial network, the topological...
characteristics covered in this research are the following. The two basic features that characterize international financial network is the value of assets that circulate in the network as well as the number of links that it flows through. In order for the results to be comparable these measures have to be normalised. The network value will be measured by an indicator of a network value per node. If we denote the number of countries that are included in the network as \( N \) and the value of network assets as \( \text{NET} \), we can calculate the network value intensity as \( \text{INTENS} = \frac{\text{NET}}{N} \). The value that circulates in a system is considered as traditional measure of integration. The more assets circulates in system, the more integrated it is. But as the assets can be distributed within the system in a number of different ways, other topological issues should be taken in mind.

The number of network links indicates, how much the network elements are connected. It will be measured by an indicator of network density that indicates how many links exist in the network with comparison to all possible links: \( \text{DENS} = \frac{\sum a_{ij}}{N(N-1)} \). In the context of systemic integration, the more potential links are realised in a network, the more integrated it is considered.

The network characteristics that show how much a network is directed is measured by an indicator of symmetry that counts how many links in the network are reciprocated. In the context of this article two measures of symmetry are used: binary symmetry and weighted symmetry. The latter measures how much incoming and outgoing links are reciprocated by their value. If we denote \( A \) as a matrix of network links and \( A^T \) as a transpose of a links matrix, we can measure symmetry both in binary and weighted cases by an indicator, offered by G. Fagiolo (2007) as \( \text{SYMETH} = 1 - \frac{\|A - A^T\|_F}{\|A\|_F + \|A^T\|_F} \). The higher value of symmetry indicates that more links in a network are reciprocated and the network integration is higher.

It is also important to evaluate how equally the value and number of links is distributed in a network among separate nodes. We will use the heterogeneity index (Hu, 2008) that measures how far from homogeneous is the distribution of value as well as links in a network. The \( H \) index considers the difference of every two degree (or strength) values in a degree (strength) sequence. If we denote the number of links of a country \( i \) as \( d_i \) and the average number of countries’ links as \( \bar{d} \), the heterogeneity or inequality of a network will be measured as: \( \text{HETEROG} = \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} |d_i - d_j|}{2N^2 \bar{d}} \). This indicator gains higher value when the distribution in a network is more unequal. In the context of integration we have to take a reverse value of the heterogeneity indicator, because the more homogeneous a network is, the higher is its level of integration.

Another important characteristic of network structure concerns the extent to which a given country is clustered, that is how many partners of a country are partners themselves. This feature can be measured by counting how many triangles a given country and any two of its neighbours form in comparison to all possible triangles of that kind. This indicator is called clustering coefficient that results with the percentage of a given countries’ partners that are partners among themselves. If we denote the \( d_i^{tot} \) as the number of reciprocated links, we can count the clustering coefficient as \( C_i(A) = \frac{(A+A^T)_{ii}^3}{2[d_i^{tot}(d_i^{tot}-1)-2d_i^{tot}]} \).
As S. Schiavo et al. (2010) state, researchers wish to know whether countries having many partners are likely to be linked with poorly-connected countries (this is the case of a disassortative network), or, conversely, with other well connected countries. This information can give the understanding of how links are formed in a researched network. Such kind of information is received by counting the correlation between a given country’s characteristics with characteristics of its neighbors. Both the sign of correlation and its value are important. The negative assortativity measure will indicate disassortative network while positive sign shows that the researched network is assortative. The value of this index indicates the strength of (dis)assortativity. Usually the assortativity of a network is counted assessing such features of nodes as the number of links they have \((d_i)\) or the value of these links \((s_i)\). If we denote the number of links an average neighbor of a given country has as \(ann d_i\), and the value of the links an average neighbor of a given country has as \(ann s_i\), we can count the assortativity of a researched network as Pearson correlation coefficient of \(d_i; ann d_i\) and \(s_i; ann s_i\).

It is also important to count how centralized the network is. The *centralization* of a network is a measure of how central its most central node is in relation to how central all the other nodes are (Freeman, 1979). There are a lot different measures of centralization that measure different aspects of nodes centrality even though they use the same network matrix. One of the most popular centralization measures captures how close the node with all the other nodes in a network is. The distance in this context means the number of steps (links) that has to be passed through until you reach the target node. The inverse of the sum of a node’s distances to all other nodes is called closeness centrality, while in systemic approach we use the measure of closeness centralization of a network. If we denote the maximum centrality of a network nodes as \(C(p_{max})\), centrality of any node in a network as \(C(p_i)\), we can count what are the differences of all nodes’ centrality values from the maximum centrality measure that was gained in a researched network. If we compare the sum of these differences with the possible maximum of such differences (the maximal centralization is considered to be in a star type network), we gain a measure of a given network centralization:

\[
CENTR = \frac{\sum_{i=1}^{N}(C(p_{max}) - C(p_i))}{\max \sum_{i=1}^{N}(C(p_{max}) - C(p_i))}
\]

**Research results**

In this research the international financial network was identified for every year of the researched period of 2001 - 2011 while considering separate countries as network nodes and asset trade between them as links on the bases of CPIS reports. The authors treat the identified networks as directed (every link has its direction) and weighted (every link has its value). This results in 11 unsymmetric network matrices (NxF) that were used for evaluation of topological characteristics. The network analysis was performed with the help of Netminer 4.0 program and a specially created VBA program.

The topological characteristics of the identified network are summarized in Table 1. Such descriptive statistics as average, minimum and maximum values
presents the main features of international financial network. Later on every feature is described in more detail.

**Intensity.** The international financial network can be characterized as intensive network. In 2001 - 2011 the value of a network as well as the number of links increased. 63 % of all possible links on average were realized in the international financial network. As it can be seen from Figure 1, the dynamic trend in the researched period of both indicators of network intensity is highly correlated. Both values experienced a high growth with the peak values in 2006 in 2007, while experiencing a high drop in 2008. It means that in the influence of financial crisis countries not only withdraw their international assets, but revised their partners as well. The network value experienced a higher drop then the network density, but it recovered more highly as well. The growing intensity of network value as well as links indicate that financial integration of a researched network is increasing.

**Symmetry.** The network symmetry was surprisingly constant during the researched period (even in the period of crisis). If we consider binary symmetry coefficients when only the presence or absence of financial linkages is taken into account, the network symmetry slightly fluctuated around the value of 0,76. It means that 76 % of network linkages are reciprocated. If we consider not only the existence of financial linkages but their value as well, the symmetry of a network is measured to be not higher than 0,51. It can be interpreted that even if the most financial links are reciprocated, their value does not match. This indicates that it in the case of financial integration of separate countries it is important to measure their incoming and outgoing connectivity separately.

**Heterogeneity.** This network feature is very important as it shows how the

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Average</th>
<th>Min</th>
<th>Max</th>
<th>Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Links intensity**</td>
<td>0.63</td>
<td>0.57</td>
<td>0.67</td>
<td>↑</td>
</tr>
<tr>
<td>Value intensity (mln USD)</td>
<td>336.1</td>
<td>161.8</td>
<td>471.5</td>
<td>↑</td>
</tr>
<tr>
<td>Heterogeneity (links)**</td>
<td>0.62</td>
<td>0.58</td>
<td>0.66</td>
<td>↓</td>
</tr>
<tr>
<td>Heterogeneity (value)**</td>
<td>0.90</td>
<td>0.89</td>
<td>0.92</td>
<td>↑</td>
</tr>
<tr>
<td>Symmetry (binary)**</td>
<td>0.76</td>
<td>0.74</td>
<td>0.79</td>
<td>↓</td>
</tr>
<tr>
<td>Symmetry (valued)**</td>
<td>0.49</td>
<td>0.48</td>
<td>0.51</td>
<td>↑</td>
</tr>
<tr>
<td>Clustering**</td>
<td>0.87</td>
<td>0.85</td>
<td>0.89</td>
<td>↑</td>
</tr>
<tr>
<td>Assortativity (binary)**</td>
<td>-0.93</td>
<td>-0.87</td>
<td>-0.96</td>
<td>↓</td>
</tr>
<tr>
<td>Assortativity (valued)**</td>
<td>-0.44</td>
<td>-0.39</td>
<td>-0.50</td>
<td>↓</td>
</tr>
<tr>
<td>Centralization (closeness)**</td>
<td>0.49</td>
<td>0.44</td>
<td>0.56</td>
<td>↓</td>
</tr>
</tbody>
</table>

*Note:  - low variation; ↑ - increasing trend; ↓ - decreasing trend.
*76 countries are included in the international financial network.
**this indicator can gain any value in the interval (0,1).
***this indicator can gain any value in the interval (-1,1).
network value is distributed in a network. In Figure 2 network value and network links heterogeneity is presented. The heterogeneity curves present the distribution of cumulative share of links or network value. It shows what percentage Y % of the total links or network value the top X % of countries accumulate.

It is evident from the graph that value heterogeneity is much higher than link heterogeneity. It indicates that there exist strong and weak links in the network. This indicates that there are several countries that concentrate the bigger share of the researched network that is distributed with the help of several strong ties. This tendency becomes even more evident, because in the period of 2001 - 2011 the value concentration by 10 % of network links becomes higher even though the value concentration by 10 % of countries slightly decreased.

**Clustering.** The network clustering measures how much network participants are likely to form clusters among themselves. The clustering coefficient of the researched network reached 0.87 on average. It means that countries prefer local linkages over distant ones. They form relationships with partners that are partners among themselves. This indicates that the formation of financial integration even though systemic in its nature is rather heterogeneous for different not only for different countries, but for different regions as well.

**Assortativity.** This network feature provides information about how links are formed in a network. If we compare the number of links of a given country and the number of links its average partner has, we receive binary assortativity measure. In case of the international financial network, the correlation between these two values is negative. It means that network is disassortative where countries with many links tend to form relation with countries that are poorly

*Fig. 1. The dynamics of international financial network* intensity

*Note: *76 countries are included in the international financial network.*
Connected in the network. In the weighted case of a network where not only existence of links is considered but their value as well, the network is less disassortative. Both assortativity measures are very stable over the researched period and show no structural changes of a researched network.

**Centralization.** The network centralization measure gives information about variability of individual closeness centrality scores. If every node has same closeness centrality value, the closeness centralization index is 0. If one node has especially large centrality value as in, for example, a star graph, the closeness centralization index is 1. This measure shows how far the network is from the most possible level of centralization that is considered to be the star type network. The researched network reaches 49% of full centralization. In the period of 2001 - 2011 the network centralization decreased by 11 percent points. It means that countries in 2011 gained more similar positions in the network in comparison to 2001.

**Conclusions**

The analysis of scientific research in the field of international financial integration revealed that more and more authors criticize traditional integration measures that they do not disclose the real situation. The financial crisis of 2008 highlighted that not only the size of international financial exposure is important, but its distribution as well. It is evident that the features of bilateral financial linkages network are crucial for evaluating systemic financial integration.

The analysis of scientific research in the field of international financial networks concludes that conceptualization of international systems as networks provides tools for systemic evaluation of these structures and their internal connectivity. Such topological features as linkages and value intensity, network symmetry, network heterogeneity, network clustering, assortativity or centralization disclose new insights into the issues of financial integration.

The analysis of international financial

![Graph showing heterogeneity of international financial network links and value in 2001–2011.](image)

*Note: *76 countries are included in the international financial network.*
network of 76 countries in the period of 2001 - 2011 showed that the researched network is disassortative with the core-periphery structure what means that there exists a group of countries tightly connected among themselves and sharing the biggest part of the network value. The number of links as well as the network value increased in the researched period with the exception of 2007 - 2008 when the international portfolio investments experienced a sharp decline. Countries also reduced the number of their financial partners in the same period. The latter experienced a lower recovery in the aftercrisis period. The high clustering coefficient of the researched network indicates that local ties are preferred over more distant ones in the researched network.

The analysis of topological characteristics of the international financial network and their dynamics revealed that they are useful for disclosing new features of international financial integration.

References


The paper submitted: July 19, 2013
Prepared for publication: September 1, 2013