Connections between Frontier Markets

Eliza-Olivia Lungu [1]

The global financial system presents a high degree of connectivity and the network theory provides the natural framework for visualizing the structure of it connections. I analyse the financial links established between the frontier markets and how these links evolve over a 10 years period (2001 - 2011). I identify patterns in the network looking both at the node specific statistics (degree, strength and clustering coefficient) and at the aggregated network statistics (network density and network asymmetry index).

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JEL Classifications: G01, G15

1. Introduction

Over the last decade, networks analysis emerged into a core set of tools for conceptualizing and analysing different types of systems (economic, social, financial etc.). It is employed in social studies, under the umbrella of social networks, in physics and related fields under the name of complex networks, in mathematics as graph theory and so on. Nowadays its large scale use is determined by its versatile concepts

[1] **Eliza-Olivia Lungu,** PhD, National Research Institute for Labour and Social Protection, 6-8 Povernei Street, Sector 1, Bucharest, 010643, Romania, E-mail: eliza.olivia.lungu@gmail.com

that can be easily translated from one field to another. Globalization and the current economic crisis, clearly underlined how important it is to understand the connections within and between systems and what could be consequences if these connections are unknown or ignored.

The financial systems show a high degree of connectivity, the connections between the financial institutions spreading on both sides of the balance sheets, such as direct asset linkage on interbank market and indirect connections by having similar portfolio exposures (Babus, 2007). Due to the actual economic financial crisis it became even more imperative the need of a deep understanding of the financial market interconnectedness. From a microscopic perspective, the strong interconnections between the USA banks was the main reason that kept them from failing in 2008, while from a macroscopic point of view their strong connectivity offered an "infrastructure" for the USA credit market crisis to spread all around and to put pressure on the global financial stability (Chinazzi, 2012). We can also discuss about a network of networks, because the crisis was triggered in the USA subprime mortgage market and after that spread on the credit markets from all over the world.

A network is defined as a collection of points (vertexes or nodes) connected by pairwise lines (edges or links). The nodes can be everything from individuals as in social networks to banks, companies or countries as in financial networks. A link means a direct relationship between two nodes and it can be represented graphically as undirected or directed. Also it can be weighted or not with the strength of the relationship, depending on the context. The meaning of the edge is related to the problem under study: in a social network it could mean a friendship tie, while in a global network it could mean a trade contract or a mutual defence pact. In the case of financial systems, the vertexes are the financial institutions and the links are determined by mutual exposures (Babus, 2007).

Network theory provides a framework for visualizing and analysing patterns of connectivity between nodes (e.g. network motifs, community structures, nodes centrality). According to Allen and Gale the shocks are better dissipated in fully connected networks than in sparse ones (Allen and Gale, 2000). Even thou highly connected networks are more robust, with a lower probability of contagion, when it happens the source of the contagion is difficult to isolate. This fact is summarized by the term "robust-yet-fragile", where its fragility is associated with the existence of critical nodes. As the recent crisis proved us, by understanding the network structure between financial institutions, we can stop a local crisis from becoming a global one by targeting regulations to individual institutions with high financial risk.

Frontier markets are commonly perceived as a subset of emerging markets that are less developed, less liquid and less accessible to the foreign investors. Usually, they are tackled by investors looking for high long returns and low correlation with the main financial markets (Berger et. al, 2011). Due to the lack of financial and economic information regarding this stage in a market development, just recently this subject drove into the attention of researchers.

The aim of the paper is to characterize the financial connections between frontier markets using networks and it is organized as following: Section 2 presents the International Financial Network of frontier markets and the database that I use to empirically construct it; Section 3 shows the patterns identified in the network, by looking at the node specific statistics (degree, strength, clustering coefficient) and at the aggregated network statistics (network density, network asymmetry index); and in Section 4 I present the main conclusions of this research and future directions of study.

2. International Financial Network of Frontier Capital Markets

The term frontier markets (FMs) was introduced by International Finance Corporation (IFC) at the beginning of the '90 to denote upcoming markets that are less developed, less liquid, less accessible to the foreign investors and with a smaller capitalization than emerging markets. Commonly they are perceived as a subset of emerging markets (EMs) tackled by investors looking for high long term returns and low correlation with the broad markets.

There are several institutions that provide indexes for frontier markets (FM): IMF, World Bank, MSCI Barra, FTSE, S&P, to name just a few. For the purpose of this study I considered as frontier countries the ones included in the following indices: S&P Frontier BMI, MSCI Frontier Markets Index and FTSE Frontier 50 Index.

These indices have different benchmarks and these differences are reflected in the inclusion or exclusion of a certain country from the FM set. Table 1 presents the frontier countries considered for this study. Several countries (United Arab Emirates, Pakistan and Colombia) are classified both frontier and emerging markets depending on the considered benchmark index.

Table 1

Countries classified as frontier markets according to several benchmark indexes, by regions.

EUROPE	AFRICA	MIDDLE EAST	ASIA	LATIN AMERICA
Bosnia Herzegovina[b]	Botswana[a,b,c]	Bahrain[a,b,c]	Bangladesh[a,b,c]	Argentina[a,b,c]
Bulgaria[a,b,c]	Ghana[a,b,c]	Jordan[a,b,c]	Cambodia[a,b,c]	Colombia[a]
Croatia[a,b,c]	Ivory Coast[a,c]	Kuwait[a,b]	Pakistan[a,b]	Ecuador[a]
Cyprus[a,c]	Kenya[a,b,c]	Lebanon[a,b]	Kazakhstan[a,b]	Jamaica[a,b]
Estonia[a,b,c]	Mauritius[a,b,c]	Oman[a,b,c]	Sri Lanka[a,b,c]	Panama[a]
Latvia[a]	Namibia[a]	Qatar[a,b,c]	Vietnam[a,b,c]	Trinidad & Tabago[a,b]
Lithuania[a,b,c]	Nigeria[a,b,c]	UAE[a,b]		
Macedonia[c]	Tunisia[a,b,c]			
Malta[c]	Zambia[a]			
Romania[a,b,c]	Zimbabwe[b]			
Serbia[b,c]				

Slovakia[a,c]
Slovenia[a,b,c]
Ukraine[a,b]

Source of data: S&P Frontier BMI (a), MSCI Frontier Markets Index (b) and FTSE Frontier 50 Index (c)

The countries are grouped by geographic regions, each region with its specific opportunities and challenges. Africa has recently joined the world of commerce, due to the high demand for its commodities, improved political and economic conditions and nevertheless investments from China. Asian countries such as Vietnam and Bangladesh have copied the success stories of their emerging neighbours: India and China. Eastern European frontier countries benefited from close ties with the European developed and emerging countries, while the Latin America frontier countries, such as Colombia, Jamaica, Trinidad and Tobago benefited from close connections with the United States. Middle East countries have stepped out from being a source of recycled petrodollars to an established investment destination (Speidell, 2011).

The concept of International Financial Network (IFN) was recently introduced by M. Chinazzi et al. in a working paper that investigates if the current economic crisis generated topological changes in the IFN and also if certain network indicators can be employed to explain the cross-country differences in dealing with the financial crisis (Chinazii et. al, 2012). The International Financial Network is defined as a weighted directed multigraph, where the nodes are the countries and the links are the debtor-creditor relationships in shares and short/long-run debt.

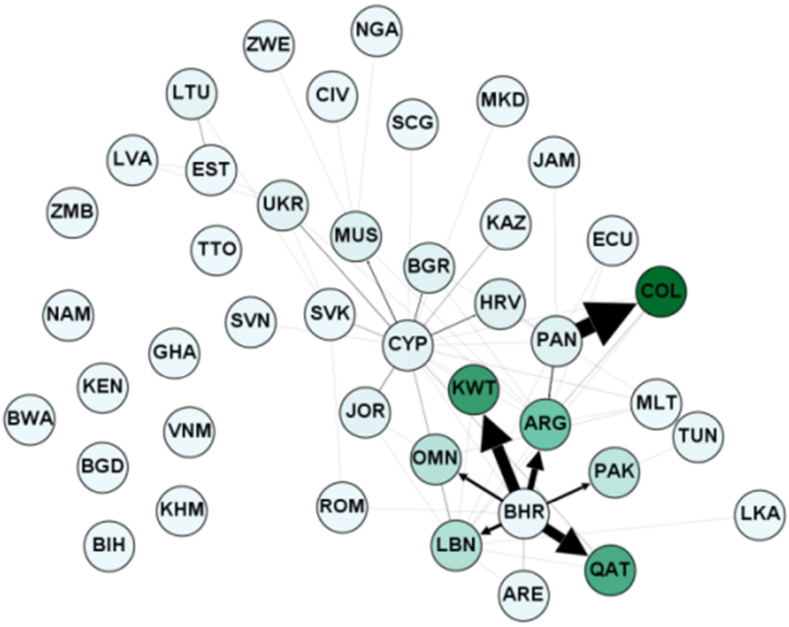
For this research I extracted a sub-network of the IFN, which includes just the frontier markets. So, the nodes of the network are represented by the countries included in Table 1 and the links match the issuing country (debtor) with the holding country (creditor), according to Coordinated Portfolio Investment Survey (CPIS).

The CPIS is a survey conducted by the International Monetary Fund (IMF) yearly, since 1997. It is a voluntary survey and the economies that want to participate have to provide information regarding their year-end holdings of securities and equities, long-term and short-term debt instrument (IMF, 2002).

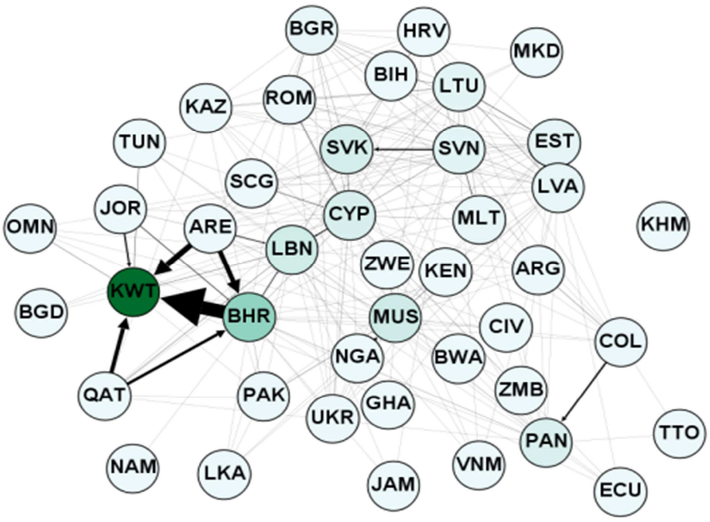
For this study I extracted from the original database just the information regarding their total portfolio investments (TPI), for the period 2001 - 2010. With this data, I constructed for each year a weighted directed financial network between the FMs. The links are weighted with the amount of money in US dollars that were transferred between the countries, in the considered year. In order to make the money flows comparable, I standardized them in [0,1]. It has to be mentioned, that the yearly networks are incomplete, since some countries did not participate at the CPIS survey, but still it offers us a relevant perspective about the degree of connectivity between FMs.

Figure 1

Total portfolio investment network of frontier countries



(a) 2001, network density (ρ) is 0.037



(b) 2010, network density (ρ) is 0.116

Source of data: Own representation based on financial data from Coordinated Portfolio Investment Survey

Figure 1 (a, b) presents in comparison the IFN for 2001 and 2010. The vertexes represent the 43 frontier countries and the weights of the links are proportional with the amount of money in US billions transferred between them. The nodes are coloured according to their in-strengths (dark green - high in-strength value, light green - low in-strength) and the thickness of the links is proportional to their weights. The connectivity of the network increased substantially over the years, in 2010 just one country (Cambodia) remaining disconnected from the rest of the countries.

3. Patterns in International Financial Network of Frontier Capital Markets

I perform the analysis in the spirit of Shiavo et. al (2010) and Chinazzi et. al (2012), tracking the time evolution of the network by looking both at node specific statistics and aggregate statistics to find relevant patterns.

Aggregate network statistics provide information regarding the overall behaviour of a system. Using the network density I quantify how dense the empirical network is. Also I employ an index of asymmetry to test if on average the links are reciprocal and with similar weights.

Node-specific network statistics provide information regarding the position of each frontier country in the IFN. The indicators that I use are: node degree (in-degree, out-degree and total degree) to see how many financial connections a specific country has with other frontier countries; node strength (in-strength, out-strength and total strength) to quantify how exposed a particular country is; centrality measures (betweenness and closeness) and clustering measures.

The network density represents the fraction of links that exist from all the possible ones. Mathematically it is defined as $\rho = \frac{2m}{n(n-1)}$, where m is the number of edges and n is the number of vertexes of the network. The density takes values between [0,1], the closest is its value to 1 the denser is the network.

The network density increased over the years (see Table 2). Still we notice a slow down around 2008, which suggests that the economic crisis determined some of the countries to reconsider their business relationships, by reducing the number of connections in the IFN. In support of this we can notice a decreasing in the securities exchanged, after 2008.

Table 2

Network statistics, by year

Network metric	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Graph Density	0.03	0.04	0.05	0.06	0.06	0.07	0.08	0.08	0.10	0.12
Average Degree	1.52	1.81	1.93	2.38	2.60	2.81	3.38	3.36	4.21	4.76
Average Strength	0.09	0.09	0.07	0.08	0.08	0.09	0.08	0.09	0.11	0.09
Network Diameter	6	5	4	5	6	4	7	6	7	5
Average clustering coefficient	0.20	0.33	0.28	0.26	0.29	0.32	0.29	0.33	0.30	0.31

Source of data: Own calculations

The degree of a node (ND) i is the number of links connected with it. In the case of directed networks, there is also defined in-degree (ND_{in}), the number of links that point to node i and out-degree (ND_{out}), the number of links that leave from node i. In the case of IFN, the in-degree could be interpreted as the number of debtors a country i has, the out-degree as the numbers of creditors of a country i and the total degree as the total number of debtors and creditors of a country.

$$ND_{in} = \sum_{i=1}^{n} A_{ij}; \quad ND_{out} = \sum_{j=1}^{n} A_{ij}; \quad ND = ND_{in} + ND_{out}$$

where A_{ij} is the adjacency matrix.

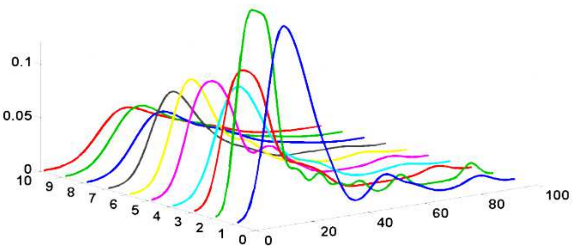
In the same manner are defined the total strength, in-strength and out-strength for the weighted directed network. The economic meaning of in-strength is the total amount of credit a country has accumulated from its neighbours, the out-strength as the total amount of debt a country i has to its neighbours and the total strength represents the amount of investment made into country i by its neighbours.

$$SD_{in} = \sum_{i=1}^{n} W_{ij}; \quad SD_{out} = \sum_{j=1}^{n} W_{ij}; \quad SD = SD_{in} + SD_{out}$$

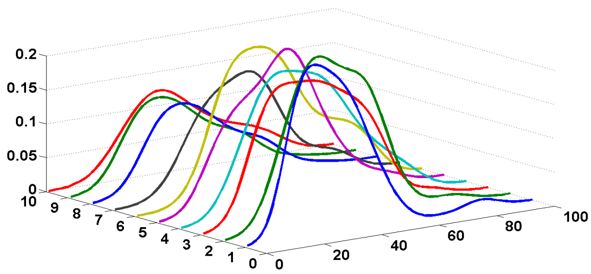
Figure 2

The dynamic of node degree distribution of TPI.

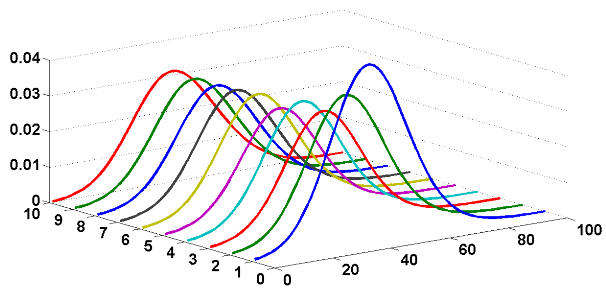
On the x-axis are represented the years (e.g. 1=2001,...,10=2010) and on z-axis the kernel density of node's degrees.



(a) Total degree (# creditors & # debtors)



(b) In-degree (# debtors)



(c) Out-degree (# creditors)

Source of data: Own graphical representation

Figure 3 shows the dynamic of node degree distribution of the TPI networks. In each of the three figures is plotted yearly, the kernel density of the degrees (total degree, in-degree or out-degree) of the nodes. First we notice that the shape of the distribution changes with time, showing that the financial relationships between the considered frontier countries are constantly changing. They are close to an unimodal distribution, since all have a thick pick. Also, we notice the presence of fat tails in the total degree distribution, more pronounced than at the other distributions.

The position of the peak changes in time for the total degree and in-degree cases and it becomes more evident around the year 2008. This shows that the crisis affected their financial relationship and they choose to deal with it by lowering the number of financial relationships (the picks moves to the left, in the area with small node degrees). While the in-degree distribution is fluctuating a lot, the debtors constantly changing their number of partner countries, the out-degree distribution is relatively stable in time.

Table 3

The most central country according to node degree and strength, by year.

Year	ND	ND_{in}	ND_{out}	SD	SD_{in}	SD_{out}
2001	Cyprus	Argentina	Cyprus	Bahrain	Colombia	Bahrain
2002	Cyprus	Argentina	Cyprus	Mauritius	Zimbabwe	Mauritius
2003	Cyprus	Argentina	Cyprus	Kuwait	Bahrain	Kuwait
2004	Cyprus	Argentina	Cyprus	Kuwait	Bahrain	Kuwait
2005	Cyprus	UAE	Cyprus	Kuwait	Bahrain	Kuwait
2006	Cyprus	Kazakhstan	Cyprus	Kuwait	UAE	Kuwait
2007	Cyprus	Cyprus	Cyprus	Kuwait	Bahrain	Kuwait
2008	Cyprus	UAE	Cyprus	Kuwait	UAE	Kuwait
2009	Cyprus	UAE	Mauritius	Kuwait	UAE	Kuwait
2010	Cyprus	Ukraine	Cyprus	Kuwait	Bahrain	Kuwait

Source of data: Own calculations

In Table 3 are listed the most central countries, according to their degree and strength, year by year. We can notice that Cyprus has the most numerous links with the other frontier countries and this is due to the efforts it puts in establishing financial relationships (node out-degree is also high over all the considered years). Similar to Cyprus, Kuwait is a central vertex, consecutively for 8 years, but its position is due to the large amount of money he invests in other frontier markers. The long term beneficiaries of Kuwait investments are Kingdom of Bahrain and United Arab Emirates (UAE).

I measure the asymmetry of the network with an index proposed by G. Fagiolo that was initially designed for testing if a directed network (binary or weighted) is symmetric enough to be treated as an undirected one (Fagiolo, 2006). I apply the index both on the binary and weighted network, first to see if the numbers of creditors and debtors are symmetric across the countries and secondly to see if the amount of money credited and debited among countries is comparable.

If we have a $N \times N$ matrix, $X = \{x_{ij}\}$ describing a binary (B) or weighted network (W), than the index has the following expression and it takes values between [0,1]:

$$S(x) = \frac{N+1}{N-1} \frac{\sum_i \sum_{j>i} (x_{ij} - x_{ji})^2}{N + \sum_i \sum_{j \neq i} x_{ij}^2}$$

In order to evaluate the performance of the index I calculate its standardized form

$$S_*(X) = \frac{S(X) - m_*(N)}{s_*(N)}$$

Where $m_{*(N)}$ and $s_*(N)$ take different values depending if the network is weighted or not (Fagiolo, 2006). We can treat the network as undirected without losing too much information, if the standardized index is above the mean $(S_*(X) > 0)$.
We observe that in the case of the binary network, we could consider it as an undirected one, while in the case of the weighted network, we cannot. As we have already seen in Figure 1 (a, b), there are countries between which the financial interactions is much more intense.

Table 2

The index S and the standardized version S_* for IFN network of total portfolio investment, by year.

Year	$S^{TPI}(B)$	$S_*^{TPI}(B)$	$S^{TPI}(W)$	$S_*^{TPI}(W)$
2001	0.54	2.14	0.05	-19.04
2002	0.59	4.76	0.05	-18.92
2003	0.58	3.92	0.03	-21.04
2004	0.60	4.91	0.02	-21.87
2005	0.59	4.55	0.02	-21.70
2006	0.63	6.27	0.03	-20.94
2007	0.61	5.57	0.02	-21.26
2008	0.64	7.01	0.02	-21.11
2009	0.57	3.80	0.03	-20.72
2010	0.62	5.91	0.03	-20.89

Source of data: Own calculations

The global clustering coefficient represents the probability that two neighbors of a node/country in our case, are also neighbors and it is calculated by computing the density of the triangles in a network.
In a random graph, with n nodes, the clustering coefficient has the following mathematical expression:

$$C = \frac{1}{n}\frac{[\langle k^2\rangle - \langle k\rangle]^2}{\langle k\rangle^3}$$

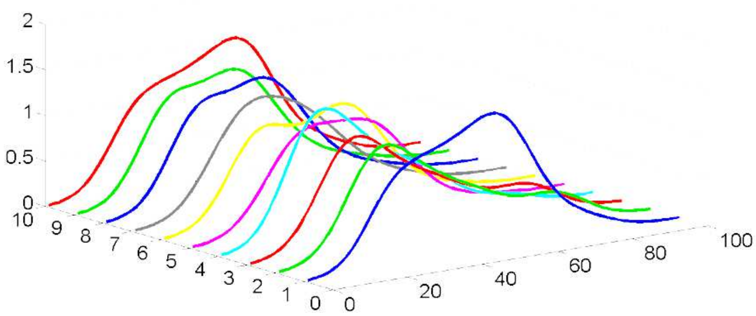
In large network, where $n \rightarrow \infty$ and $\langle k^2\rangle, \langle k\rangle^3$ have finite values, the clustering coefficient is very small. But, for example in the case of collaboration network of physicists, the clustering coefficient is 0.45, 195 times higher than its theoretical values (C=0.0023). It is considered that this huge difference is due to the social relations; collaborators may introduce to each other's their teams and the teams choose to collaborate between them in the near future (Newman, 2010).
The local clustering coefficient represents the fraction of neighbors of vertex i which are also friends between them:

$$C_i = \frac{\#\, of\ pairs\ of\ neighbours\ of\ node\ i\ that\ are\ connected}{\#\, of\ pairs\ of\ neighbours\ of\ node\ i}$$

This measure is interesting for at least two reasons. First, in numerous empirical networks the local clustering coefficient tends he exhibit a strong linear correlation with the degree, in the sense that the vertexes with a high node degree have a low local clustering. Secondly, it is helpful at identifying structural holes in a network. Structural holes appear when the neighbors of a node i are not connected between them and this makes the spread of information inefficient.
The network average clustering coefficient is as its name states, the average value of the local clustering coefficients. This measure is important in establishing if a network exhibits of not small-word behavior. If the value of average clustering coefficient is higher than the value of a random network designed with the same number of nodes, than the network can be consider a small-world one.

Figure 3

The dynamic of the local clustering coefficient for TPI network.
On the x-axis are represented the years (e.g. 1=2001,...,10=2010) and on z-axis the kernel density of the clustering coefficient.



Source of data: Own graphical representation

The dynamic of the local clustering for both the total portfolio investment network (TPI) and equity securities network (ES) is presented in Fig. 4. In a similar way to the degrees distribution, the results are presented in a 3D plot, which has on x-axis the years (e.g. 1=2001,...,10=2010) and on z-axis the kernel density distributions of the local clustering coefficients. This type of plot has the visual advantage of presenting in an explicit way the calculations and it permits us to trigger the time evolution of the variable of interest.

5. Conclusions

By looking at the plots of the evolution of node degree over time, we can admit that the actual crisis had an effect on the topological properties of the international financial network of frontier markets, by diminishing they number of business relationships. On the other had if you look at the network density, we notice that it increases with time. The connection between countries is increasing over time and this is also reflected in the average degree, which is also increasing and the average strength. The last one is growing at a lower rate, which shows that the amount of money flowing between the frontier markets is relative constant over the years.

Their geographic community structure could also explain why we obtained a positive correlation coefficient node degree and local clustering coefficient; the countries tend to interact more with the frontier markers that are their geographic neighbors.

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