COUNTRY EFFECTS IN CEE3 STOCK MARKET NETWORKS

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Abstract

The stock markets in the Czech Republic, Poland and Hungary (CEE3) are studied in the context of graph theory as stock market networks, where returns are used for calculation of rolling correlations. The resulting correlation matrices are then used to construct network models, capturing the structure of the relationships of stock returns both within and between CEE countries. The main objective of the paper is to test whether the individual assets cluster by the country to which they belong or whether the origin is of lesser importance, leading to cross-country links within the topological structure. By analyzing particularly the MST, we identify interesting relationships, providing evidence for both country and industry clustering, with the finance sector dominating the inter-country relationships. The apparent clustering identified by visual inspection is shown to be significant and non-random, as shown by the results of Erdős – Rényi, as well as Viger – Latapy simulations. The result is also confirmed by an ERGM model, where country and industry level factors are shown to significantly contribute to the way the networks are constructed.

Key words: stock market networks, country effects, industry effects, emerging markets

JEL Code: G01, L14

Introduction

Since the seminal works of Markowitz (1952), many papers have been written on the topic of portfolio diversification. The exploitation of low correlation for minimizing the risk of a portfolio within the mean-variance frameworks has led to a search for asset classes (and asset groups within these classes) that would offer the best risk-reward ratios. In stock market, a lengthy debate ensued on the benefits of international and cross-industry diversification. The general idea is simple – as each sector is affected differently by the business cycle, diversification across industries should be beneficial. International diversification should help even further, as there are fewer common factors and thus systematic risk should be lower. This effect however is mitigated by the development on internationalization of markets, globalization and growing market interdependencies (e.g. cross-listings of stocks and the rise of transnational companies). Thus, the puzzle of superiority of industry/international diversification remains.

This paper does not have the ambition to solve the long lasting puzzle. It focuses on the use of stock market network analysis tools to compare the two approaches. The paper analyzes the industry/country effects presents in the networks constructed from stock returns of CEE-3 markets (Czech Republic, Poland and Hungary), together with the neighboring major stock market of Germany.

1. Related literature

1.1 International vs. industry diversification

The discussion of country/industry effects in stock returns go back as far as 1974, as Lessard (1974) states that the country effects are more important. The work of Heston and Rouwenhorst (1995) has marked the beginning of a series of papers on the topic, with ambiguous outcome. Griffin and Karolyi (1998) confirm that little of the variation in country index returns can be explained by their industrial composition. Diermeier and Solnik (2001) analysed the proportion of domestic and foreign sales, as well as currency risk exposure. They found evidence that companies are priced globally, the location of company's headquarters is not a major determinant of stock price, and that foreign stock market exposure is more important than foreign currency exposure. Baca et al (2002) confirm the rise of industry effects, and express their view that the findings suggest that country-based approaches to global investment management may be losing their effectiveness. In Wang et al (2003), the authors analyze 7 equity markets and 22 industrial group returns indexes in the period of January 1990 - February 2001. Their results support the dominance of industry effects over country effects since 1999. They also find that country effects tend to show a cyclical trend.

More recently, much of the research focused on a related topic of contagion of markets, which may further reduce the meaningfulness of international diversification. In their notable paper, Forbes and Rigobon (2002) define contagion as the rise in correlation among stock market returns in time of crises, or an external shock in one of the economies. Although the literature on contagion is extensive (e.g. Bekaert et al., 2002; Kearney – Lucey, 2004; Goetzman et al, 2005; Bekaert et al, 2009 and others), we will not pursue this topic in more detail, but rather focus on the dichotomy of industry/country effects in stock returns within the context of stock market networks.

2. Data and methodology

The data used in the paper encompasses the major stock market index constituents in CEE-3 markets (Czech republic, Poland and Hungary) and Germany, with a total of 50 traded companies. Germany was selected as geographically closest major stock exchange. The CEE-3 countries also have strong economic ties to Germany.

The sample spans the timeframe from January 2003, with N =512. The data was obtained from Thomson Reuters Datastream. This avoids the problematic transition period before 2000, which was characterized by privatizations and market irregularities in the CEE-3 countries. The sample includes a period of market crisis and two recessions. In contrast to many other network studies, the analysis is conducted on individual stocks instead of stock market indices. This also allows avoiding several potential pitfalls, such as dealing with changes in the definition of market indices (e.g. the Czech PX index replaced the prior PX-D and PX-50 indices in March 2006).

The weekly prices were used to create the returns:

$$r_{i,t} = \ln(P_{i,t}) - \ln(P_{i,t-1}) \tag{1}$$

where $r_{i,t}$ is return and $P_{i,t}$ market price at time t = 1, 2, ... for series $i \in \{1, 2, ..., N\}$.

In order not to introduce spurious effects into the analysis, univariate ARMA-GARCH models have been fitted for all series. The ARMA part is traditional,

$$(1-\rho(L))(1-L)r_{i,t} = (1+\alpha(L))\varepsilon_{i,t} \tag{2}$$

where $\varepsilon_{i,t}$ is the error term.

The model fitting strategy was to fit ARMA-GARCH models which remove all autocorrelation from residuals and their squares, and then choose the most parsimonious model by the Bayesian information criterion (BIC). All series were checked for stationarity. The ARMA-GARCH filtering was used in order to remove all information from the series that can be explained by prior returns. The calculated standardized residuals are then used to construct the stock market networks.

A network is a graph G, defined by the set of vertices $V(G)$, corresponding to the traded companies, and set of edges $E(G) = \{\{u, v\}; u \neq v, u, v \in V(G)\}$. In this paper, we consider only correlation based networks, the edges are therefore undirected. However, it is useful for the edges to be weighted.

Tab. 1: Constituents for indices of CEE-3 and Germany

Ticker	Company	Country	Sector	Ticker	Company	Country	Sector
ERSTE	Erste group bank	CZE	Financial	BMW	Bayerische Motoren Werke	DEU	Consumer Goods
PM	Philip morris CR	CZE	Consumer Goods	BAYN	Bayer	DEU	Healthcare
CEZ	ČEZ	CZE	Utilities	BEI	Beiersdorf	DEU	Consumer Goods
KB	Komerční banka	CZE	Financial	CBK	Commerzbank	DEU	Financial
UNI	Unipetrol	CZE	Basic Materials	CON	Continental	DEU	Consumer Goods
O2	Telefónica CR	CZE	Technology	DAI	Daimler	DEU	Consumer Goods
EGIS	Egis pharmaceuticals	HUN	Healthcare	DBK	Deutsche Bank	DEU	Financial
EST	Est media	HUN	Services	DB1	Deutsche Boerse	DEU	Financial
MOL	MOL	HUN	Basic Materials	DPW	Deutsche Post	DEU	Services
MTK	Magyar telekom	HUN	Technology	DTE	Deutsche Telekom	DEU	Technology
OTP	OTP bank	HUN	Financial	EOAN	E.ON	DEU	Utilities
PAE	PannErgy	HUN	Utilities	FME	Fresenius Medical Care	DEU	Healthcare
REG	Richter Gedeon	HUN	Healthcare	FRE	Fresenius SE & Co KGaA	DEU	Healthcare
SYN	Synergon	HUN	Technology	HEI	HEICO Corporation	DEU	Industrial Goods
KGHM	KGHM	POL	Basic Materials	HEN3	Henkel AG & Co.	DEU	Consumer Goods
PEO	Bank Polska Kasa Opieki	POL	Financial	IFX	Infineon Technologies	DEU	Technology
PKN	Polski Kon. Naftowy Orlen	POL	Basic Materials	SDF	K+S Aktiengesellschaft	DEU	Basic Materials
TPS	Telekomunikacja Polska	POL	Technology	LIN	Linde Aktiengesellschaft	DEU	Basic Materials
ACP	Asseco Poland	POL	Technology	LHA	Deutsche Lufthansa	DEU	Services
BHW	Bank Handl. w Warszawie	POL	Financial	MRK	Merck KGaA	DEU	Healthcare
BRE	BRE Bank	POL	Financial	MUV2	Munich RE	DEU	Financial
BRS	Boryszew	POL	Basic Materials	SAP	SAP	DEU	Technology
ADS	Adidas	DEU	Consumer Goods	SIE	Siemens Aktiengesellschaft	DEU	Industrial Goods
ALV	Allianz	DEU	Financial	TKA	ThyssenKrupp AG	DEU	Basic Materials
BAS	BASF	DEU	Basic Materials	VOW3	Volkswagen	DEU	Consumer Goods

Source: own calculation.

The edge weights reflects the relationships of stock returns, and is given by the formula $c_{ij} = \sqrt{2(1-\rho_{ij})}$, where c_{ij} is the edge weight for the edge connecting vertices $i,j \in V(G)$ and ρ_{ij} is the Pearson correlation coefficient between stock returns of stocks i and j.

The literature defines several ways a suitable subgraph may be selected. In this paper, we will use three approaches. *Minimum spanning trees* (MST) were defined by Mantegna (1999). A spanning tree is a connected acyclic subgraph. The requirement for minimal sum of edge weights means, that given the stated conditions, the subgraphs contains the highest correlations possible. An MST has $N - 1$ edges.

Planar maximally filtered graphs (PMFG) were proposed by Tumminello et al., (2005). These subgraphs replace the condition of MST, which requires no circles to be present with a condition of planarity, which requires that the graph may be embedded into a

Euclidean plane without edges intersecting. This raises the number of edges to $3N - 6$. However, the economic reasoning behind requiring planarity is unclear.

The last option is presented by *threshold graphs* (THR). Here the subgraph is created by comparing edge weights (or their transformations) to a pre-specified threshold, and retaining only those edges satisfying the threshold condition. These graphs pose no limitations on the structure of the network (unlike MST and PMFG). The threshold is usually chosen with respect to the size, or significance of the correlation coefficient between stock returns.

In this paper we analyze all three kinds of subgraphs. Apart from creating the networks, it is also interesting to construct a model, which would explain the presence/absence of edges. Particularly, it would be interesting to see how the country and industry affiliation relate to the presence of edges between individual stocks.

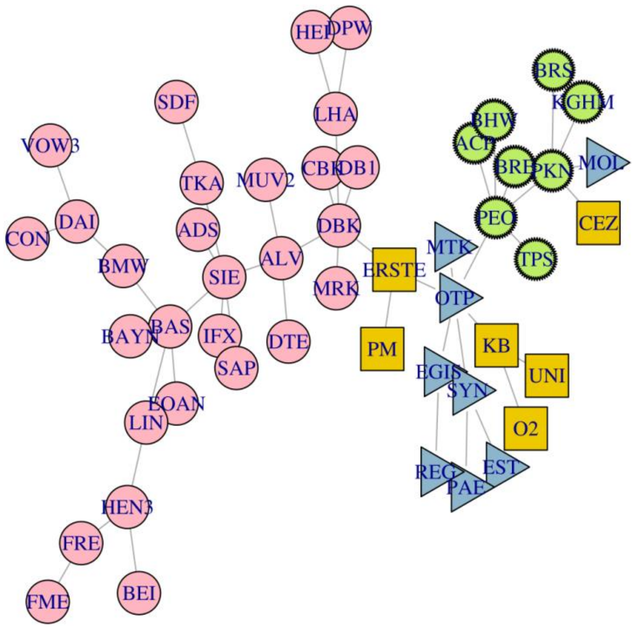
A framework that allows the incorporation of such exogenous factors into the modeling of edges is the Exponential random graph model (ERGM), as defined in the seminal work of Wasserman and Pattison (1996). Here the existence of edges and other networks structures is modeled by a logit-type model, which may (in simple cases) be modeled by maximum-likelihood estimation, or by Markov chain Monte Carlo simulations. More formally, an ERGM focuses on the probability

$$P(g = G \mid \boldsymbol{\theta}) = \frac{\exp\left(\boldsymbol{\theta}^T s(G)\right)}{c(\boldsymbol{\theta})} \qquad (3)$$

where G is the constructed stock market network, g is a randomly created graph, $\boldsymbol{\theta}$ is a vector of parameters and $s(G)$ is a vector of graph characteristics, which might be node, edge and structure related (such as number of edges, vertex degrees, number of cliques etc.).

The use of ERGM opens interesting options with respect to the modeling of the network – since the network encompasses both stock from different countries, as well as different industries, is should allow for the estimation of both the country and industry effects. Thus, it should be possible to assess whether there are country/industry effects that explain the structure and strength of the relationships between stock returns of CEE-3 countries and Germany.

Fig. 1: Minimum Spanning Tree (MST) for the stock returns from CEE-3 and Germany



Note: German stocks are color-coded pink, Poland is green, Hungary is blue and Czech stocks are yellow.
Source: own calculation.

3. Empirical results and discussion

Figure 1 shows the calculated MST networks for the ARMA-GARCH filtered standardized residuals of stock returns for the whole sample period. Even after brief consideration it is clear that the network is strongly clustered by country, which is particularly true of Germany, Poland and Hungary, with slight irregularities for the Czech republic.

The MST also has subgraphs that are economically interesting. The articulation that connects all German stock to the CEE-3 stock is DBK (Deutsche bank). It is itself connected to other German financial stocks, namely Commerzbank, Deutsche Boerse and Allianz, which is connected to Munich RE, creating a strong cluster of German financial companies.

The aforementioned DBK is connected to the Czech ERSTE bank, which is connected to Hungarian OTP bank, which in turn connect to two other banks – Czech Komerční banka (KB), but also Polish PEO (Bank Polska Kasa Opieki). The financial cluster is completed by adding BRE (BRE Bank, currently mBank) and BHW (Bank Handl. w Warszawie).

The financial cluster is very notable for two reasons: first, all the banks in the sample turn out as connected. This seems a rather strong evidence for clustering by industry. The second reason is, that the banks are the stocks which connect the individual country clusters – as explained before, all countries tend to create national cluster. But in all cases, these clusters are interlinked to other country clusters by stock from the financial sector, confirming its importance. Figure 1 also shows other interesting clusters. For example, Daimler AG (DAI), BMW, Volkswagen (VOW3) and Continental AG (CON) presents a cluster of three carmakers and a company delivering components and tires to the car industry. The last selected cluster contains Polish Kon. Naftowy Orlen (PKN), Czech ČEZ (CEZ), HungarianMOL (MOL) and Polish Boryszew (BRS), which are all oil and energy related companies.

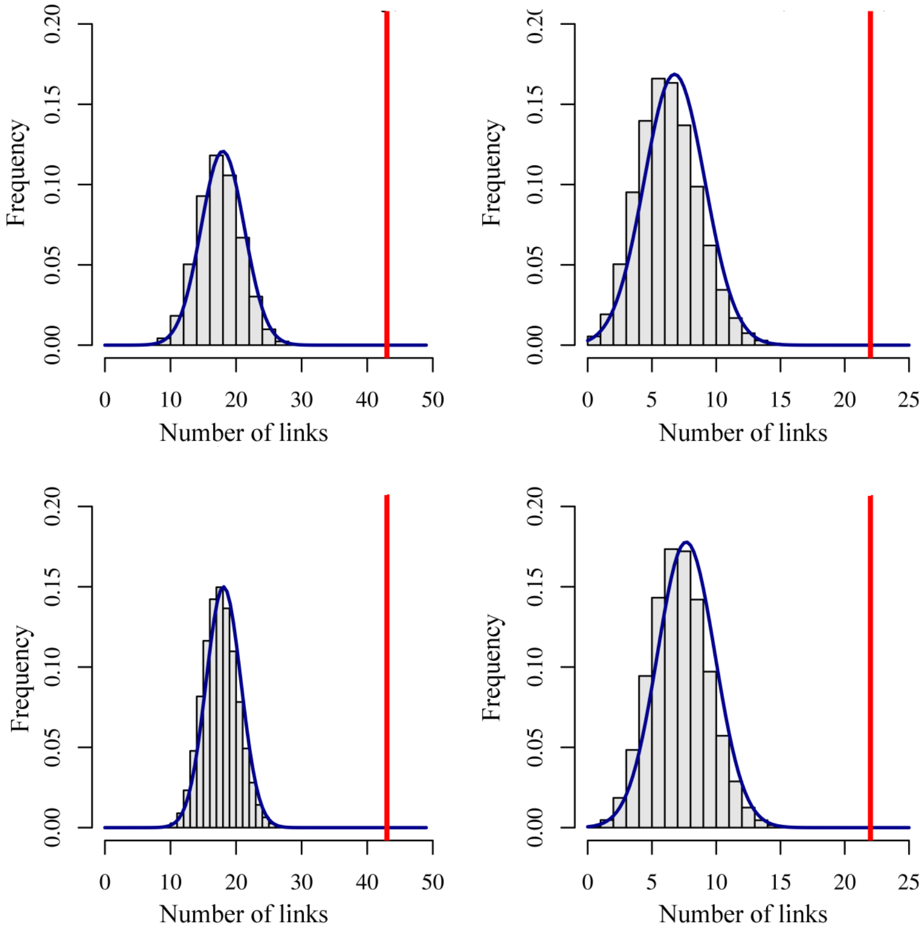
To test this more explicitly, we note that there are 43 out of 49 edges connecting vertices from the same country, and 22 edges connecting vertices from the same industry. To see, how likely a result like this would be, if the networks were created at random, two simulations have been performed. The first was the famous Erdős – Rényi model (Erdős – Rényi, 1960). This model generates random graphs on a selected number of vertices (here, $N = 50$) and given number of edges (here, 49).

Although this may be considered a classical model, it has some disadvantages. First, the structure created in the simulation might necessarily not be a tree – while the empirical network is a MST. Also, the importance and connectivity of vertices might differ. Thus, another simulation was performed, which retains the degree sequence in all iterations (Viger and Latapy, 2005). By keeping the degree sequence constant, it follows that all generated random networks are trees, and thus precisely follow the structure of the empirical network.

The necessity for a simulation stems from the Cayley formula (Aigner – Ziegler, 2010), which states that the number of trees in $N = 50$ vertices equals $N^{N-2} = 50^{48}$, which is unfeasible. Figure 2 shows the simulations results, which clearly indicates the significance of both the country and industry effects. Table 2 gives the results of ERGM models. The explanatory variables contain the number of edges, country and industry factors. Structural parameters given by the frequency of given vertex degrees were also included. The specific degrees have been chosen by the Akaike information criterion (AIC).

The results in Table 2 are again very reasonable. As all network structures have relatively few edges compared to the complete graph (the number of edges increases from MST, PMFG to THR), the coefficient by the number of edges is negative. The coefficients for Country and Industry factors are positive – hence, industry and country factor both matter, and their effect is positive. More importantly, the coefficients for all network models are higher in case of country effects.

Fig. 2: Simulations of random graphs and their relation to the MST

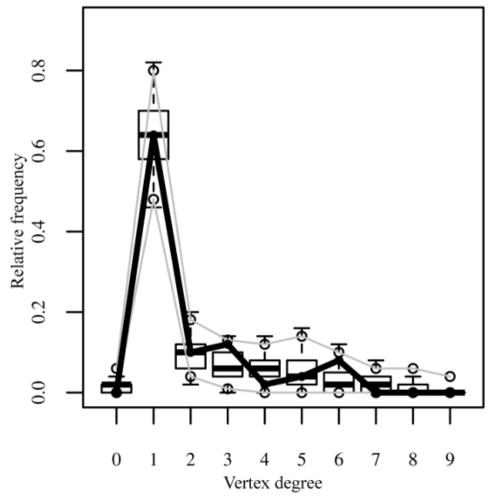


Note: The figure shows the distribution for the number of intra-country (left) and intra-industry (right) edges, obtained in Erdős – Rényi (top), as well as Viger – Latapy (bottom) simulations. The red lines represent the number of edges in the empirical MST.
Source: own calculation.

Tab. 2: ERGM for subgraphs MST, PMFG and THR

	MST			PMFG			THR		
	Koef.	**Std. err.**		**Koef.**	**Std. err.**		**Koef.**	**Std. err.**	
Edges	-4.607	0.518	***	-3.192	0.259	***	-0.659	0.081	***
Country	2.806	0.461	***	2.349	0.241	***	2.331	0.153	***
Industry	1.958	0.327	***	1.431	0.230	***	0.647	0.190	***
Degree 1	2.715	0.574	***						
Degree 2	0.527	0.617							
Degree 3				3.230	0.562	***			
Degree 4				2.137	0.549	***			

Fig. 3: Relative frequency for MST ERGM models by vertex degree



Note: The vertical axis depicts relative frequency. The boxplots describe the simulations created by the specified model. The thick line shows the vertex degrees of the empirical MST.
Source: own calculation.

Conclusion

In this working paper, we explored a previously heavily researched topic of comparison of country and industry effects for portfolio diversification. Even as we do not construct stock portfolios per se, we use an alternative methodology based on stock market networks to compare these effects.

First, we use the whole sample to construct MST, PMFG and THR networks. By analyzing particularly the MST, we identify interesting relationships, providing evidence for both country and industry clustering, with the finance sector dominating the inter-country relationships. Second, the apparent clustering identified by visual inspection is shown to be significant and non-random, as shown by the results of Erdős – Rényi, as well as Viger – Latapy simulations. Third, the result is also confirmed by an ERGM model, where country and industry level factors are shown to significantly contribute to the way the networks are constructed.

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