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The Significance of Distance Between Stock Exchanges Undergoing the Process of Convergence: an Analysis of Selected World Stock Exchanges During the Period of 2004–2012

A b s t r a c t. The paper concerns the convergence of selected world stock exchanges from the point of view of their development in the context of geographical and economic distance between them. It presents the methodological approach which points up the necessity of taking into account spatial and economic connections among stock markets in convergence analyses. The research includes 46 largest trading floors analyzed in the period of 2004–2012. The empirical data refer to six diagnostic variables acknowledged as the important determinants of the development of stock markets.

K e y w o r d s: stock exchanges, convergence, physical and economic distance, connectivity matrix, spatial panel models.

J E L Classification: C10, C12, C58, G15.

Introduction

The paper concerns the convergence of selected world stock exchanges in the context of geographical and economic distance between them. The importance of the geographical and economic distance in revealing the linkages between stocks has already been considered in literature on the subject

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(e.g. Suchecka and Łaszkiewicz, 2011; Wójcik, 2009; Asgharianet et al., 2013). In particular, the premises of the spatial perspective on capital markets' analyses in two areas: geography of finance and capital, and behavioral finance were indicated (see e.g. Suchecka and Łaszkiewicz, 2011).

A spatial analysis of linkages between securities markets was carried among others by Asgharian et al. (2013). On the basis of their research, they stated that the similarity with regard to the economies' components is the strongest source of linkages between stock markets but the connections that result from geographical neighborhood, bilateral FDI and stability of the bilateral exchange rate are important as well.

One of the directions of the analysis of the stock exchanges' relationships is considering the convergence of these markets from the point of view of their specific characteristics. This process is strictly connected with the integration and liberalization of stock markets and their growing interdependence, which in turn is associated with the liberalization of capital flows and technological innovation. These processes are favorable for the development of stock markets, and thus the distinctions between them are becoming increasingly blurred over time.

The literature on the convergence of stock markets includes e.g. Fraser et al. (1994), Koralun-Bereznicka (2008) and Caparale et al. (2009). In the works the problem of linkages between the markets in geographical and economic spaces is particularly interesting. In the recent literature the hypotheses of convergence vs. divergence are formulated mainly in the context of the contemporary financial crisis of 2007–2010 (see e.g. Aspergis et al., 2014).

The aim of the paper is to investigate whether, in the light of the current empirical analyses, one can observe the process of convergence of main stock markets in the world. In addition the importance of distance between the markets for the process is evaluated. Particularly the role of economic distance is considered. In the research the hypothesis that in the convergence of stock markets the spatial and economic connections among them are important, and so that relative location of a stock exchange affects the growth rate of the exchange, is verified.

The structure of the paper is as follows: in Section 1 the subject and range of the investigation are defined. It qualifies the investigated stock exchanges and characterizes the specified diagnostic variables. Section 2 presents the methodology. In this section a taxonomic measure of stock exchanges' development is defined and the theoretical models of β-convergence in formulation of the regressions for the pooled time series and cross-sectional data are presented. Moreover, in Section 2 the diagnostic tests for verification of the empirical models are pointed out. Section 3 contains preliminary data analysis. The results of the research are presented in Section 4. Conclusion formulates final remarks and indicates further investigations.

1. Subject and Range of the Investigation

The subject of the investigation contains the selected worldwide stock exchanges, characterized in terms of their level of development. The study included 46 largest trading floors in the period of 2004–2012. The specification of the exchanges with the assignment to the relevant country are presented in Table 1.

The level of stock exchange development was defined by a synthetic measure based on six diagnostic variables, i.e. X1 – the capitalization of domestic shares, X2 – the capitalization of newly listed domestic shares, X3 – the total value of share trading, X4 – GDP per capita, X5 – the top 10 most heavily capitalized domestic companies, X6 – the ratio of market capitalization to GDP. It was recognized that, in the light of theory and empirical analyses, the specified variables are important determinants of the development of stock exchanges. Taking into account the connections of the capital market with the economy of the country of its location was also an important issue. The range of information provided by the World Federation of Exchanges played a significant role as well.

The capitalization of domestic shares is one of the most important parameters reflecting the situation in the securities market. It is calculated as the total number of shares issued by domestic companies. A high value of this indicator encourages large investors to invest their capital in a given market and shows its attractiveness compared to others.

From the point of view of the development of a given equity market, another important indicator is the capitalization of newly listed domestic shares. Contemporary capital market is very often treated as a short term mechanism where one can earn or lose money suddenly. In many cases, the financial performance of companies is ignored. With increasing stock quotation and improving situation in the stock market, the interest of new companies investing in a given trading floor is also growing. In practice, this means that growing prices of shares allow investors to make a profit. However, the number of initial public offerings do not affect the conditions of a stock exchange. Only on the basis of their capitalization, the development potential of a given market can be assessed (Wiśniewski, 2003).

Table 1. Specification of the stock exchanges considered

North/South America			
Brazil	BM&BOVESPA (BOV)	Chile	Santiago SE (SSE)
Canada	TMX Group (TMX)	Colombia	Colombia SE (CSE)
Mexico	Mexican Exchange (BMV)	Bermuda	Bermuda SE (BSX)
Argentina	Buenos Aires SE (BCBA)	Peru	Lima SE (BVL)
United States	Nasdaq OMX (NASDAQ) Nyse Euronext (US) (NYSE)		
Asia/Pacific			
Australia	Australian SE (ASX)	Philippines	Phillippine SE (PSE)
China	Honk Kong SE (SEHK) Shanghai SE (SHSE) Shenzen SE (SZSE) Taiwan SE Corp. (TSEC)	Japan	Osaca SE (OSE) Tokyo SE Group (TSE)
India	National SE India (NSE)	Indonesia	Indonesia SE (ISE)
South Korea	Korea Exchange (KRX)	Malaysia	Bursa Malaysia (BM)
Sri Lanka	Colombo SE (CLSE)	Thailand	Thailand SE (THSE)
Singapore	Singapore SE (SSE)		
Europe/Middle East/Africa			
Austrian	Wiener Borse (AG)	Cyprus	Cyprus SE (CPSE)
Egypt	Cairo&Alexandria SE (EGX)	Greece	Athens Exchange (ATHEX)
Spain	BME Spanish Exchange (BME)	Netherlands	Nyse Euronext (Europe) (NEE)
Iran	Tehran SE (THRSE)	Ireland	Irish SE (IRSE)
Israel	Tel Aviv SE (TASE)	Luxemburg	Luxemburg SE (LXSE)
Malta	Malta SE (MSE)	Mauritius	Mauritius SE (SEM)
Germany	Deutsche Borse (DB)	Norway	Oslo Bors (OBE)
Poland	Warsaw SE (WSE)	South Africa	Johannesburg SE (JSE)
Switzerland	SIX Swiss Exchange (SIX)	Sweden	Nasdaq OMX Nordic Exchange (NOMX)
Turkey	Istanbul SE (ISSE)	Hungary	Budapest SE (BDSE)
Great Britain	London SE (LSE)		

Other important parameter characterizing the capital market is the value of turnover. It is calculated as a total number of shares traded multiplied by their respective matching prices within a year. For a well-developed market the desired situation is that the annual turnover is higher than the total value of shares traded.

In order to connect the capital market with the country's economy the GDP per capita indicator was used. It is one of the most popular parameters which reflects the level of citizens' wealth. It has to be emphasized that most of the highly developed stock exchanges are located in developed countries. It is legitimate to use this indicator due to the fact that almost all exchanges, described as mature, are located in countries that have achieved a high level of development.

The top 10 most heavily capitalized domestic companies is one of the indicators reflecting market concentration. This parameter, as the only one out of the six variables taken into account, was treated as a destimulant. The concentration phenomenon takes place when a small number of large companies has a significant share in the capitalization of a given stock exchange. A high value of this indicator is undesirable since it characterizes poorly developed markets.

The ratio of market capitalization to GDP reflects the relationship between economic development and maturity of an equity market. It was observed that for well-developed stock markets, the value of this indicator is higher than 60 percent. It is believed that such participation allows operators to gather national and foreign capital. At the same time, the results of empirical studies demonstrate that this ratio needs to be above 2 percent for the stock exchange to have significant influence on particular processes of a national economy. On the other hand, this variable should be treated with caution because of the fact that currently one company may be listed on more than one market (Łuniewska and Tarczyński, 2006, p. 45).

2. Methodology

The research was conducted in relation to the aggregate characteristic of the stock exchanges in the form of taxonomic measure of development. This indicator is understood as a synthetic normalized formula expressed by (see Hellwig, 1968):

$$q_i^{'} = 1 - \frac{q_i}{\overline{q} + 2S_q}, \tag{1}$$

where:

q_i – the synthetic variable determining the level of development of the i-th exchange in relations to a development standard,

$\overline{q}$ – the average value of the synthetic variable,

S_q – the standard deviation of the variable.

In this approach the values of the synthetic variable q_i are calculated according to the formula:

$$q_i = \sqrt{\sum_{j=1}^{m} \left(z_{ij} - z_{0j}\right)^2}, \tag{2}$$

where:

z_{ij} – the value of j-th diagnostic variable for i-th exchange standardized to 0–1,

z_{0j} – the value of j-th diagnostic variable for the standard of development standardized to 0–1.

Thus, q_i means a distance between i-th exchange and the development standard.

Through the use of the taxonomic measure of stock exchanges' development it is possible to present the rankings of exchanges and their changes in time, the evaluation of the correlation between stock exchanges in terms of development, the identification of the linkages between markets in economic space, and finally the analysis of the stock exchanges' convergence, which is meant as equalizing their development levels.

In the analyses of the stock exchanges' convergence the econometric models of β-convergence, in particular the spatial models for pooled time series and cross-sectional data (TSCS) and spatial panel models, were used.

The model TSCS with spatial component takes the form of the spatial autoregressive model (SAR_pooled), i.e.

$$\ln\left[\frac{q'_{it}}{q'_{it-1}}\right] = \alpha + \beta \ln\left[q'_{it-1}\right] + \rho \sum_{j \neq i} w_{ij} \ln\left[\frac{q'_{jt}}{q'_{jt-1}}\right] + \varepsilon_{it}, \tag{3}$$

or of the model with spatial autoregressive residuals (SE_pooled), i.e.

$$\ln\left[\frac{q'_{it}}{q'_{it-1}}\right] = \alpha + \beta \ln\left[q'_{it-1}\right] + \eta_{it}, \ \ \eta_{it} = \lambda \sum_{j \neq i} w_{ij} \eta_{jt} + \varepsilon_{it}. \tag{4}$$

The spatial panel models used in the investigation were as follows:

$$\ln\left[\frac{q'_{it}}{q'_{it-1}}\right] = \alpha_i + \beta \ln\left[q'_{it-1}\right] + \rho \sum_{j \neq i} w_{ij} \ln\left[\frac{q'_{jt}}{q'_{jt-1}}\right] + \varepsilon_{it}, \tag{5}$$

i.e. the spatial autoregressive panel model with individual fixed effects (the spatial autoregressive fixed-effect model) (SAR_FE_IND) and

$$\ln\left[\frac{q'_{it}}{q'_{it-1}}\right] = \alpha_i + \beta \ln\left[q'_{it-1}\right] + \eta_{it}, \quad \eta_{it} = \lambda \sum_{j \neq i} w_{ij} \eta_{jt} + \varepsilon_{it}, \qquad (6)$$

i.e. the spatial error panel model with individual fixed effects (SE_FE_IND).

Elements w_{ij} in the formulas (3)–(6) come from connectivity matrix **W** which refers to the linkages between exchanges considered. Assuming that there are N stock exchanges, the matrix has as many rows and columns as there are exchanges, i.e. N by N matrix **W** is considered. Each row of the matrix contains non-zero elements in columns which correspond to the connected objects, according to the received criterion. Furthermore, the given object cannot be connected to itself, so $w_{ij} = 0$ for all $i = j$. Thus, the diagonal elements of **W** are zeros.

In the majority of the spatial analyses the starting point in establishing the spatial connections is the binary matrix of neighborhood. The neighbors are usually established according to the common border criterion. Then, the rows in the connectivity matrix are normalized, so that the row sums are equal to 1, as a result of dividing each entry on a row by the sum of the row values (the so-called row standardization to one). The weights w_{ij} that are established in this way signify that each j-th neighbour of the i-th spatial units is treated identically, and the greater the strength of its interactions with the neighbours is, the fewer neighbours it has.

A different situation occurs when the weights w_{ij} are functions of some properties of the space, e.g. of the length of the common border, of the distance between the centers of the regions or of other measures of similarity between the regions, e.g. of the so-called economic distance between them. Various types of weights w_{ij} may be pointed out according to the established criteria (see e.g. Haining, 2005, p. 83–84).

In this paper the linkages between stock exchanges will be defined with the use of two approaches. The first one uses a matrix of connections with weights established on the basis of the physical distance between the centers of the countries where the stock exchanges are located. The second one consists in that in the matrix of connections the economic distance (the essence of which is to establish similarity of the exchanges on the basis of the value of the taxonomic measure of exchanges' development) is taken into consideration.

The economic distance was expressed as:

$$d_{ik} = \sqrt{\sum_{j=1}^{m} \left(z_{ij} - z_{kj}\right)^2}, \qquad (7)$$

where:

z_{ij}, z_{kj} – the values of standardized diagnostic variables for each i-th and k-th stock exchange,

$j = 1, 2, \ldots, 6$ – the number of the diagnostic variable.

In both approaches the elements of the linkages' matrix are equal to:

$$w_{ik} = \begin{cases} \dfrac{1}{d_{ik}}, \text{if } i \neq k \\ 0, \quad \text{if } i = k \end{cases} \tag{8}$$

Then, as a result of row standardization to one, the matrixes of the connections based on the physical or economic distance are obtained.

Since the models (3)–(6) refer to the pooled time series and cross-sectional data, the block matrixes of connections were used, i.e.

$$\mathbf{W} = \begin{bmatrix} \mathbf{W}_1 & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{W}_2 & \cdots & \mathbf{0} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{0} & \mathbf{0} & \cdots & \mathbf{W}_9 \end{bmatrix}, \tag{9}$$

where: $\mathbf{W}_1 = \mathbf{W}_2 = \ldots = \mathbf{W}_9$ – matrixes of the spatial connections based on the physical distance, the same for all the considered years, and

$$\mathbf{W}^* = \begin{bmatrix} \mathbf{W}^*{}_1 & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{W}^*{}_2 & \cdots & \mathbf{0} \\ \vdots & \mathbf{0} & \ddots & \vdots \\ \mathbf{0} & \mathbf{0} & \cdots & \mathbf{W}^*{}_9 \end{bmatrix}, \tag{10}$$

where: $\mathbf{W}^*{}_1 \neq \mathbf{W}^*{}_2 \neq \ldots \neq \mathbf{W}^*{}_9$ – matrixes of connections, taking into account the economic distance between exchanges, different for successive years.

The convergence of the exchanges is confirmed by the data, if the parameter estimates β in models (3)–(6) are negative and statistically significant. In addition, if parameters ρ in models (3) and (5) and parameters λ in models (4) and (6) are significantly different from zero, then in the convergence process the spatial connections among stock exchanges are important and the hypothesis that the rate of growth of any stock exchange is related to that of its neighbors is confirmed.

The inclusion of the spatial elements in the analysis of the convergence of stock exchanges allows us to identify the relationships between them in a geographical and economic space. Furthermore, the spatial models of convergence have better statistical properties, and thus allow for wider economic interpretation.

In order to evaluate the quality of the empirical models in the investigation, the following tools were used: the Moran test for verifying spatial independence of the residuals, the Lagrange Multiplier tests (LMlag, LMerr) and their robust versions (RLMlag, RLMerr) as spatial dependence diagnostics, the Likelihood Ratio test (LR) for testing the significance of the spatial dependence, the Breusch-Pagan heteroskedasticity test, the Chow test for verifying the need for including fixed effects into the spatial panel models (on the tools see e.g. Arbia, 2006; Millo and Piras, 2012; Mutl and Pfaffermayr, 2011; Baltagi et al., 2003; Suchecki (ed.), 2012).

All calculations were performed with R (version 3.0.1) and the graphical illustrations – with the use of MapViever and Corel.

3. Preliminary Data Analysis

Figure 1 shows locations of investigated exchanges on the world map and bar charts of taxonomic measure of development (TMD) in the years 2004–2012. This presentation allows us to observe changes in the level of development of the individual stock exchanges and a comparison of the dynamics of change in the arrangement of their spatial location as well. It is interesting that some of the Asian trading floors, e.g. OSE, SZSE, KRX, PSE, did not record any decrease in the value of taxonomic measure of development after the beginning of the financial crisis in 2007. In the worst case, these stock exchanges reacted with slowdown or stagnation of growth.

Obviously, the beginning of a crisis has caused a decline in the US stock exchanges but also stimulated the process of making up the development imbalance between emerging and well-developed markets. Interestingly, the same exchanges, for which synthetic variable already showed lower values in 2008 (NOMX, SE, SHSE, BM), recorded an increase in the value of this variable the following year (as opposed to all other stock exchanges).

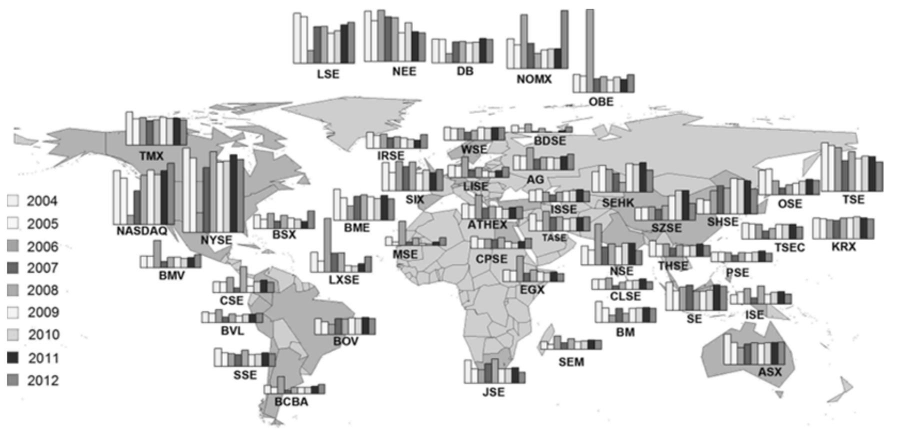

Figure 1. Bar charts of TMD for the investigated stock exchanges in the years 2004–2012

Figures 2 and 3 show the value of taxonomic measure of development (surface of the wheel) for each stock exchange included in the study for 2004 and 2012 respectively. This graphical presentation is useful for a preliminary assessment of changes in the global capital market over the considered period. In 2004, two dominant financial centers are clearly visible. In the west, it is NYSE and Nasdaq, while in central Europe, the London Stock Exchange and NYSE Euronext Europe stand out in particular. The reason for achieving such good results by the latter is certainly the fact that NYSE Euronext Europe is an example of a trading platform created by the consolidation of the stock exchanges of Paris, Amsterdam, Brussels and Lisbon. Against the background the Tokyo Stock Exchange stands out of the Asian stock exchanges in 2004. In 2012, by contrast, a slight strengthening of the position of the two largest US stock exchanges: NYSE and Nasdaq may be observed. However, the most spectacular changes can be seen in the case of the NOMX Central European stock exchange.

Comparing Figures 2 and 3 allows to observe that the Asian stock markets have strengthened themselves at the expense of the US and European stock exchanges within the nine years of the research period. Asia is currently the largest region of emerging markets in the world and is a cradle of the fastest-growing economies. The advantage of these markets arises not only from the fact that this area is inhabited by more than 60 percent of the world's population, but also from the reasonable, in comparison to other countries, fiscal and monetary policy. Economic liberalization and increasing competitiveness of these markets still attracts many foreign investors.

Figure 2. The taxonomic measure of stock exchanges' development in 2004

Figure 3. The taxonomic measure of stock exchanges' development in 2012

For the purpose of a preliminary assessment of the relationship between analyzed stock markets in the context of physical distance, for all pairs of stock exchanges the values of Pearson correlation coefficient for the TDM in the period of 2004–2012 were calculated.

Figure 4 is a graphic illustration of the relationships, for which the values of the correlation coefficient are greater than 0.9. It may be noticed that most of these connections are located on the Old Continent. On one hand, it demonstrates a high integration of European stock exchanges but also carries the risk of transmitting negative pulses occurring within a trading floor, for further linked to it causing the contagion effect. For comparison, the links identified on the basis of the value of the correlation coefficient for the period 2007–2010 crisis, are shown in Figure 5. According to some beliefs (see e.g. Login and Solnik, 2001) the strength of the relationship between the stock exchanges during the downturn increases and decreases with the improvement of the general economic situation in the world. This hypothesis is confirmed by the number of links between stock exchanges marked in Figure 5, for which the value of the correlation coefficient exceeds 0.9. Therefore, it seems that along with deteriorating sentiments in the global capital market, an increase of the correlation between securities markets might be expected, as long as the trend will not be reversed.

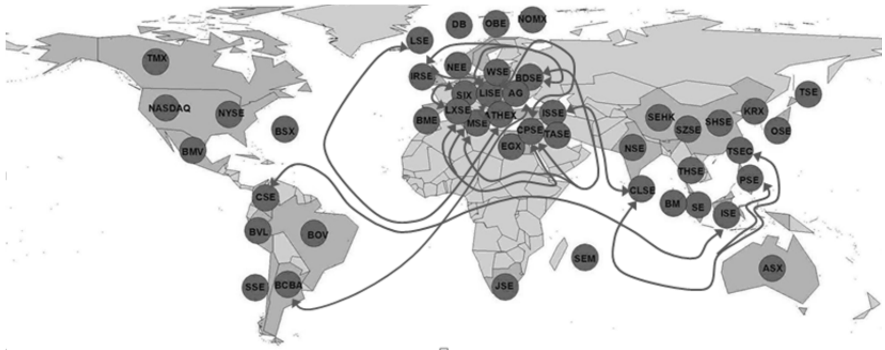

Figure 4. The significant linkages between investigated stock markets according to the Pearson correlation coefficient in the period of 2004–2012

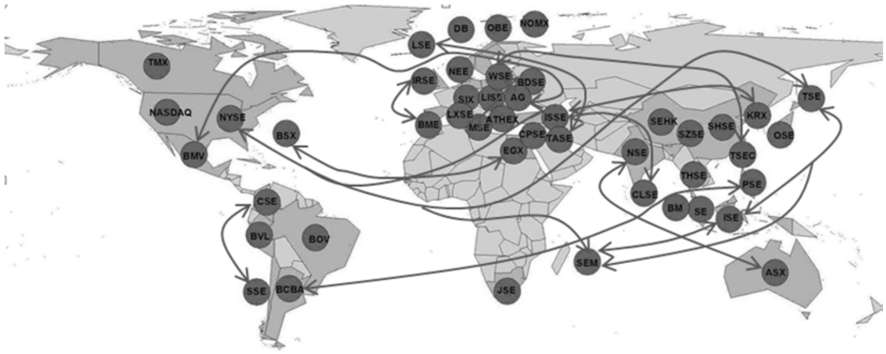

Figure 5. The significant linkages between investigated stock markets according to the Pearson correlation coefficient in the period of 2007–2010

4. Results of the Econometric Analysis

The successive tables presented below contain the information on the usefulness of various methodological conceptions expressed by the spatial models, presented in Section 3, in comparison with the linear regression model, i.e. the traditional model without the spatial effects.

Table 2. Results of the estimation and verification of β-convergence models for pooled time series and cross-sectional data – variant I

	Linear regression	Spatial autoregressive model	Spatial error model
Parameters			
α	–0.2276 (0.0000)	–0.1704 (0.0000)	–0.1702 (0.0004)
β	–0.1252 (0.0000)	–0.0965 (0.0000)	–0.0922 (0.0000)
ρ	–	0.7082 (0.0000)	–
λ	–	–	0.7255 (0.0000)
Goodness of fit			
Adjusted R2	0.0644	–	–
AIC	–161.0100	–264.4000	–261.9500
Heteroskedasticity			
Breuch-Pagan test	1.8260 (0.1766)	1.1870 (0.2759)	1.5371 (0.2151)
Autocorrelation of residuals Moran test	17.7228 (0.0000)	–0.8701 (0.1923)	–0.7309 (0.2312)
Spatial dependence			
LR	–	105.3900 (0.0000)	102.9300 (0.0000)
LMlag	316.6723 (0.0000)	–	–
LMerr	291.9936 (0.0000)	–	–
RLMlag	–	26.0514 (0.0000)	–
RLMerr	–	–	1.3727 (0.2414)
Speed of convergence	0.0167	0.0127	0.0121
Half-life	41.47	54.63	57.31

Note: Numbers in brackets refer to the p-values.

Table 2 contains the results of estimation and verification of three models for pooled time series and cross-sectional data: the linear regression model (TSCS), the spatial autoregressive model (SAR_pooled) and the spatial error model (SE_pooled). In the spatial models for the purpose of quantification of the connections among exchanges investigated the matrix **W** was used, taking into account the physical distance between them (variant I). Table 3 presents the results for the three analogical models, but in the spatial models the connectivity matrix $\mathbf{W}^*$ of the economic distance between the exchanges was used (variant II).

Table 3. Results of the estimation and verification of β-convergence models for pooled time series and cross-sectional data – variant II

	Linear regression	Spatial autoregressive model	Spatial error model
Parameters			
α	–0.2276 (0.0000)	–0.1670 (0.0000)	–0.1477 (0.0110)
β	–0.1252 (0.0000)	–0.0981 (0.0202)	–0.1221 (0.0000)
ρ	–	0.8030 (0.0000)	–
λ	–	–	0.8311 (0.0000)
Goodness of fit			
Adjusted R2	0.0644	–	–
AIC	–161.0100	–279.9800	–285.4900
Heteroskedasticity			
Breuch-Pagan test	1.8260 (0.1766)	0.4405 (0.5069)	0.2427 (0.6223)
Autocorrelation of residuals Moran test	25.8554 (0.0000)	3.0317 (0.0011)	3.3425 (0.0004)
Spatial dependence			
LR	–	120.9600 (0.0000)	126.4800 (0.0000)
LMlag	597.6765 (0.0000)	–	–
LMerr	590.0261 (0.0000)	–	–
RLMlag		9.6901 (0.0019)	–
RLMerr		–	2.0397 (0.1532)
Speed of convergence	0.0167	0.0129	0.0163
Half-life	41.47	53.69	42.57

Note: Numbers in brackets refer to the p-values.

The classical model estimated using the pooled time series and cross-sectional data does not satisfy the fundamental criterions of statistical verification (see Tables 2 and 3). This result is consistent with our prediction because the assumptions of the model, especially the same variance in the space and independence across residuals for all singled out objects, are usually unrealistic in practice. Though in this case the Breusch-Pagan statistic is insignificant, on the basis of the Moran test the hypothesis of independence of the traditional model residuals should be rejected.

As the Moran test does not admit an explicit alternative hypothesis opposed to the null, the Lagrange Multiplier tests (LM) were used (see Tables 2 and 3). The LM tests for the linear model for the pooled time series and cross-sectional data used consider the spatial lag model (spatial autoregressive) and the spatial error model as alternatives (LMlag and LMerr, respectively). Tables 2 and 3 report the results of using the robust tests (RLMlag, in which H_0: $\rho = 0$ under the assumption that $\lambda \neq 0$ and RLMerr, where H_0: $\lambda = 0$ under the assumption that $\rho \neq 0$) as well. Since the LMlag tests are more significant than the LMerr, and the RLMlag are significant while the RLMerr are insignificant, the spatial lag models should be preferred. Subsequently, the significance of the spatial effects in SAR and SE models using the Likelihood Ratio test (LR) were confirmed.

Likewise, irrespective of which connectivity matrix (of physical or of economic distance) in the spatial models has been used, parameters ρ and λ are statistically significant. It is worth noting that the fact of including the connectivity matrixes in the considered models has crucial impact on convergence parameters (β). Absolute values of the parameters for the models SAR and SE are lower than for the traditional model which does not take into account the connections across investigated stock exchanges. In turn, comparing the β parameters in the spatial models which contain the matrix of physical distance with the parameters of the models which contain the matrix of economic distance one can see that the convergence parameters are higher in the second case. It can be supposed that geographical distance has less impact on the process of equalizing the differentiation of stock markets.

Evaluation of statistical properties of the received empirical models reveals that in the models constructed with the use of economic distance between the stock exchanges the problem of autocorrelation of the residuals has not been eliminated. It is a significant drawback of these models. Solving the problem requires further investigation towards an appropriate modification of the connectivity matrix.

Tables 4 and 5 contain the results of the estimation and verification of exemplary panel models used in the investigation, i.e. the panel model with fixed effects without spatial component, the spatial autoregressive panel model with fixed effects, and the spatial error panel model with fixed effects. Just as in the pooled time and cross-sectional data models also in the panel data models the connections among the stock exchanges in two variants (connections according to geographical/economic distance) were taken into account. Fixed effects are significant in the considered models. It means that individual characteristics of every exchange are valid for their convergence.

Table 4. Results of the estimation and verification of panel models with fixed effects – variant I

	FE_IND	SAR_FE_IND	SE_FE_IND
Parameters			
α	–1.5352	–1.2475	–1.3614
	(0.0000)	(0.1027)	(0.0000)
β	–0.8535	–0.6956	–0.7559
	(0.0000)	(0.0510)	(0.0000)
ρ	–	0.5141	–
		(0.0000)	
λ	–	–	0.6723
			(0.0000)
Goodness of fit			
Adjusted R2	0.3629	–	–
AIC	–260.7000	–327.3200	–328.9800
Heteroskedasticity			
Breuch-Pagan test	98.3157	99.3100	96.7010
	(0.0000)	(0.0000)	(0.0000)
Autocorrelation of residuals	13.5916	13.5916	–0.4039
Moran test	(0.0000)	(0.0374)	(0.3432)
Spatial dependence			
LR	–	68.6220	70.2730
		(0.0000)	(0.0000)
LMlag	122.7834	–	–
	(0.0000)		
LMerr	171.3005	–	–
	(0.0000)		
RLMlag		62.2343	–
		(0.0000)	
RLMerr		–	13.7172
			(0.0002)
Chow test F	–	87.4795	482.3193
		(0.0000)	(0.0000)
Speed of convergence	0.2400	0.1489	0.1763
Half-life	2.89	4.65	3.93

Note: Numbers in brackets refer to the p-values.

Diagnostics for the considered models suggest that the classical panel model is the worst of them. In this case, the Breusch-Pagan statistic is significant, leading to rejecting the model assumption of homoskedasticity. In addition, on the basis of the Moran test the hypothesis of independence of the model residuals should be rejected.

Table 5. Results of the estimation and verification of panel models with fixed effects – variant II

	FE_IND	SAR_FE_IND	SE_FE_IND
Parameters			
α	–1.5352 (0.0000)	–1.2113 (0.0000)	–1.3165 (0.0000)
β	–0.8535 (0.0000)	–0.6740 (0.0000)	–0.7465 (0.0000)
ρ	–	0.6129 (0.0000)	–
λ	–	–	0.8174 (0.0000)
Goodness of fit			
Adjusted R2	0.3629	–	–
AIC	–260.7000	–336.8200	–350.8200
Heteroskedasticity			
Breuch-Pagan test	98.3157 (0.0000)	98.5343 (0.0000)	95.8613 (0.0000)
Autocorrelation of residuals Moran test	18.8266 (0.0000)	5.6920 (0.0000)	3.9209 (0.0000)
Spatial dependence			
LR	–	78.1170 (0.0000)	92.1220 (0.0000)
LMlag	184.0365 (0.0000)	–	–
LMerr	311.6529 (0.0000)	–	–
RLMlag		17.7730 (0.0000)	–
RLMerr		–	145.3894 (0.0000)
Chow test F	–	83.2527 (0.0000)	95.0155 (0.0000)
Speed of convergence	0.2400	0.1401	0.1715
Half-life	2.89	4.95	4.04

Note: Numbers in brackets refer to the p-values.

The necessity of model re-specifications towards the spatial panel models was also confirmed by the Lagrange Multiplier tests. All the tests are statistically significant and unfortunately robust versions of the tests do not provide unambiguous conclusions on what kind of the spatial connections, autoregressive or error, should be applied to the models. Moreover, the significance of the spatial effects with the aid of the LR test has been confirmed. For investigating the reasonableness of including the fixed effects in the spatial models the Chow test (the spatial model for pooled TSCS data vs. the spatial panel model with fixed effects) was used. The results of the Chow test have pointed out the statistical significance of the fixed effects in the spatial autoregressive panel model, as well as in the panel spatial error model (see Tables 4 and 5).

Taking into account the geographical connections (variant I) among the investigated stock exchanges in the panel convergence models has removed the problem of autocorrelation of the residuals (at the level of significance $\gamma=0.01$). However, in the case of using the matrix of economic distance (variant II) the autocorrelation of model residuals has not been eliminated. In turn, the problem of heteroskedasticity has remained in both cases. Therefore, in further investigation searching for the spatial regimes will be performed.

Conclusions

The paper's findings show that including the linkages that result from physical and/or economic distances between stock exchanges in the models of their convergence is justified and very important for the analyses of the phenomenon. In other words, the results of the investigation provide evidence of spatial effects in the empirical models of stock exchanges' convergence. As a result, it is possible to define the influence of the distance between exchanges on their economic development, the estimates of convergence parameter are more precise, and some statistical properties of the models are better.

During the investigation it was observed that geographical distance has less impact on the process of equalizing differentiation of stock markets then the economic distance between them.

Due to the heteroskedasticity, the empirical panel models for the exchanges investigated as a whole were not entirely satisfactory. It means that there are differentials in relationships between objects considered and their speed of convergence. Thus, in further investigation the spatial regimes will be searched for. For example, we will investigate the convergence of the European, Asian and American stock markets, separately. In addition, we will continue the work on improving other properties of the empirical models, e.g. on removing the problem of autocorrelation of the residuals.

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Znaczenie odległości między giełdami papierów wartościowych w procesie ich konwergencji. Analiza wybranych giełd światowych w okresie 2004–2012

Z a r y s t r e ś c i. Artykuł dotyczy analizy konwergencji wybranych giełd światowych z punktu widzenia poziomu ich rozwoju, w kontekście geograficznej i ekonomicznej odległości między nimi. Przedstawia podejście, które wskazuje na potrzebę uwzględniania przestrzennych i ekonomicznych powiązań między rynkami giełdowymi w analizach ich konwergencji. Badanie obejmuje 46 największych parkietów, analizowanych w okresie 2004–2012. Dane empiryczne odnoszą się do 6 zmiennych diagnostycznych, uznanych jako ważne determinanty rozwoju rynków giełdowych.

S ł o w a k l u c z o w e: giełda papierów wartościowych, konwergencja, odległość fizyczna, odległość ekonomiczna, macierz sąsiedztwa, przestrzenne modele panelowe.