EXAMINING TIME-VARYING INTEGRITY AND INTERRELATIONSHIPS AMONG GLOBAL STOCK MARKETS

HAZAR ALTINBAS

Abstract:

This paper examines co-movements and interrelationships among 6 emerging and 5 developed stock market returns between period 2001- 2017. First, principal components are extracted from returns. Results show that, for the period analyzed, there is no strong global stock market integration and there isn't any change in patterns of correlations of returns except short-term disturbances in global financial crisis time. Second, partial least squares regression models are used for predicting each stock market returns with other stock markets' current and all markets' up to three month lagged returns. Results identify divergence between developed and emerging markets and greater number of latent transmission channels among former ones. Findings indicate a strong integrity among global stock markets is not yet appeared and considered together with previous studies, today's international market structure can be attributed to last two decades of 20th century. International investors still may benefit from international portfolio diversification opportunities.

Keywords:

Stock market integration, principal components analysis, partial least squares regression, international portfolio diversification

JEL Classification: F36, G11, G15

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1   Introduction

Last four decades have witnessed remarkable growth of global financial system. Financial liberalization of economies is an important trigger of this growth. Theoretically, the more the economies remove barriers to foreign or domestic investors, the more they are expected to become integrated to the other capital markets and consequently, this may result with highly correlated returns. Since full integration imply low or zero benefits from risk diversification, the issue of market integration and return co-movements are thus of interest to policymakers and international portfolio investors. Revealing information and updating knowledge about dynamics of recent changes in integrity is a necessity.

As shown by Bekaert *et al.* (2011) and Lehkonen (2014), it is possible to say that markets have become more integrated to the world markets during the process of developing globalization of financial systems. With the term "globalization", it is mainly pointed that non-developed markets are integrating to developed markets, which are mentioned as world markets above. Not only just liberalization acts, but also regional economic co-operations and integration are other important driving forces behind financial globalization.

One of the most important and powerful example of regional integration efforts is the formation of European Union. Syllignakis and Kouretas (2010), Caporale and Spagnolo (2012), Pasioura *et al.* (2013), and Bekaert *et al.* (2013) agree on improved linkages among most of the countries with the beginning of EU accession process. Introduction of Euro also has strong contribution for European stock markets integration. It leads to a more inter-connected structure among stock markets (Beine, Cosma and Vermeulen, 2010) with ups and downs (Hardouvelis, Malliaropulos and Priestley, 2006) but not influencing as EU accession (Bekaert *et al.*, 2013). While improved integrity is seen for many member or candidate countries, this achievement is not valid for every part of Europe. Horvath and Petrovski (2013) show that Western Europe vis-a`-vis Central European stock markets' integration is higher than South Eastern European ones. On the other hand, in their study with 17 European countries covering 45 years after 1970, Everaert and Pozzi (2016) say that neither EU nor euro area membership has increased stock market integration.

Asian and Pacific markets' integrity has been another attractive research subject in recent years. Studies of Click and Plummer (2005) and Do, Bhatti and Konya (2016) reveal increasing market integration among ASEAN countries. In conjunction with these studies, works of Shabri Abd. Majid, Kameel Mydin Meera and Azmi Omar (2008) and Srivastava, Bhatia and Gupta (2015) also document increasing correlation between Asian countries and US. Lastly, Phylaktis (1997) and Loh (2013) find greater capital market integration between Asia-Pacific region with US. In the studies presented so far, conclusions are almost similar, however, there are other aspects and findings to be considered that are going to be discussed in Section 2.

In this study, measurement of stock market integration is based on examining co-movements of stock markets' monthly returns. Reason for choosing monthly frequency is to assess relations without concerns like non-overlapping market times, end-of-week effects and intra-day/ intra-week patterns. Novelty of this study is its methodological approach. Most of the studies in the literature use structured and/or regression-based methods to examine co-movements and integration among economies. Here, without employing any analyst dependent response data or forcing the data into a pre-determined model, a data-driven strategy is utilized. Also, searching and considering statistical changes by using information extracted from data give better understanding for co-movement variation and ensures more meaningful interpretation.

The study focuses on two points. First point is to understand time-varying co-relations without distinguishing transmission channels that result upward or downward moves with principal component analysis (PCA), an unsupervised learning technique. Second point is to reveal informativeness of current and lagged market returns on each market with partial least squares regression (PLSR), which is a supervised learning technique that benefits from the advantages of component (latent feature) identification procedures of the former method. Frequently used statistical and econometric methods in the area of finance have explicit assumptions about data, which inhibit examination of unanticipated and implicit relations and behaviors of markets. With the methods used in this study, there is an opportunity to surpass these drawbacks and make more realistic interpretations about outputs.

Findings suggest that there are some correlations between markets, and they do not have a significant time-varying variation. Comparative regression models show that predictability of a country's stock market returns with the information carried by other stock markets' returns and lagged returns relies on the economy's development level; developed markets tend to be more predictable than emerging markets. Results also point two countries to be discoursed, Japan and China. Japan stock market is distinguished from other developed markets in terms of statistical inferences and positioned close to emerging markets. China, which is an economy that has immense impact on nearly all world economies, displays some contrarian co-movements with the rest of countries and has the most unpredictable market returns.

Rest of the paper is organized as follows: Section 2 presents an extended literature, Section 3 describes data and Section 4 introduces methods used. In Section 5, results are shown. Conclusions and discussions are offered in Section 6. Descriptions for supplementary materials are in Appendix.

2   Literature

As stated by Bekaert, Harvey and Lundblad (2003) and Prasad *et al.* (2005), liberalization does not have to be pursued by an increase in the market's integration or as shown by Adler and Qi (2003), Donadelli (2013) and Do, Bhatti and Konya (2016) observable effects

do not show up simultaneously and/or promptly. Many studies show evidence for increased stock market integration, especially of emerging countries, which begins after early 90s and continues until late 90s or early 2000s but not result with a complete convergence (Adler and Qi, 2003; Hardouvelis, Malliaropulos and Priestley, 2006; Carrieri, Errunza and Hogan, 2007; Pukthuanthong and Roll, 2009; Bekaert, Campbell R Harvey, *et al.*, 2011; Frijns, Tourani-Rad and Indriawan, 2012; Pasioura *et al.*, 2013; Everaert and Pozzi, 2016) Another important point is the geographical border of integration, for example, findings of Lee and Jeong (2016) for ASEAN countries and Phylaktis and Ravazzolo (2002) for Pacific-Basin countries provide evidence for a regional integration than a global one.

While big number of studies find upward and/or linear trends in integration, several interruptions and declines may exist over time. There are many events that changes left and right tail dependencies of stock markets (Bhatti and Nguyen, 2012; Guesmi, Moisseron and Teulon, 2014) but it is not possible to say impacts are identical. Graham, Kiviaho and Nikkinen (2012), who examine the integration of 22 emerging stock markets with the US market between 03 January 2001 and 28 April 2010 find that co-movements of markets have over-time changes and long-term fluctuations. Therefore, understanding time-varying structure of integration and discussing properties of every analysis period idiosyncratically is necessary.

In this context, consequences of distress and turmoil times on co-movements of returns draws special attention and create debates about how they affect the financial system. Studies on global financial crisis are not be in consensus about how the crisis affects integration. Gagnon, Power and Toupin (2016) say there is an increase in market integrity during the crisis among US, Germany, UK, France, and Switzerland. Srivastava, Bhatia and Gupta (2015) get similar findings for US, Japan, Hong Kong, Singapore and India. On the contrary, Syllignakis and Kouretas (2010) say there is a slowdown of convergence between Central and Eastern European emerging stock markets and Germany and US markets, and Lehkonen (2014) finds decreased global integration during the crisis but also points out slight differences between developed and emerging countries. Besides, Horvath and Petrovski (2013) say that the recent global financial crisis did not alter the degree of stock market integration between Western Europe vis-a`-vis Central and South Eastern Europe countries. In the study of Narayan, Sriananthakumar and Islam (2014), six emerging Asian markets against the US, Australia, China, and India are found to have different characteristics of correlations and different impacts of the crisis.

On the other hand, there are more consensus among studies on '97 Asian crisis. In his comprehensive work, Lehkonen (2014) addresses non-identical results during crises for the years between 1986- 2010. Although every period possesses its own features, '97 Asian crisis bears more common trends in terms of integrity. Supportive analyses of Huyghebaert and Wang (2010) and Boubakri and Guillaumin (2015) show enhanced integration of East Asian stock markets after the Asian crisis. In line with these findings, Shabri Abd. Majid, Kameel Mydin Meera and Azmi Omar (2008) who examines integrity of

ASEAN stock markets among themselves and with the US and Japan and Tai (2007), who focuses on India, Korea, Malaysia, Philippines, Taiwan, and Thailand, find a greater level of regional and global integration after '97. Rodriguez (2007) concludes both Asian and Mexican crises are times of increased regional dependence for Asian and Latin American countries.

More liberalized and inter-connected financial system inevitably exposes the markets to amplified consequences of spillover effects on their return co-movements. In this sense, political, economic and financial shocks may result with extreme spillover effects, which are interpreted as financial contagion. However, unveiling contagion in equity markets is a challenging subject for researchers. First of all, there is a widespread disagreement about definition of contagion; Forbes and Rigobon (2002) define contagion as a significant increase in cross-market linkages after the shock while Bekaert, Harvey and Ng (2005) define contagion as excess correlation which is not expected from economic fundamentals (For a more detailed coverage about definitions and measurements of contagion, please see Pericoli and Sbracia (2003)). Considering all, it is possible to express contagion as a source, which significantly provokes equity markets to move more closely or more separately during or after crisis periods through several known or unknown transmission channels. This is a more suitable approach since crises create uncertainty, emergent volatility spillovers between countries may result both positive and negative changes in correlations. Another issue is the problematic decomposition of contagion, because there is a necessity to reveal if conditional changes in focused channels can also be contributed to shocks or not. There are numerous uncontrollable and latent factors in any economic system that may hide impacts of investigated influencers.

China deserves particular interest due to its great contribution to World GDP with 17% of share in 2015 (Dept., 2016). Parallel to this great amount of economic output, China struggles with a huge amount of debt to GDP ratio of 250%, which leads to a fragile financial system due to problem loans. Credit overhang, which indicates potential risk in cross-country manner, is estimated around 22- 27 percent of GDP, very high in international comparison (Dept, 2016). Chiang and Chen (2016) employ a multivariate GARCH model to investigate dynamic linkages of China with international markets and find time-varying correlative relations with several Asian economies, US and Europe and suggest that after increased degree of financial liberalization, upward changes occurred in correlations. Similarly, Carpenter, Lu and Whitelaw (2015) suggest that China market become more efficient compared to past but still possesses high volatility problems.

Most of the studies use correlations as a measure about integrity; but Pukthuanthong and Roll (2009) argues about the success of this representation between stock markets and hence they use global factors estimated by principal components than simple correlation scores. This approach is also implemented in this study with some extent in terms of creating principal components (see Section 4). In this study, existence of integrity and inter-predictability of 11 countries' stock market returns (selected as 6 developed and 5

emerging) and their time-varying structure are investigated for period between 2001- 2017. Since the period includes several crises with big impacts on global economies and markets, it is also possible to discover crisis-related changes.

3   Data

This study employs monthly returns of stock markets as determinant data. Time scale choice is important since high-frequency data may cause noisy results and thus misleading remarks. A total of 11 indices around the world are selected, 5 from developed and 6 from emerging economies (Table 1). These countries produce about 75% of world GDP (68% developed, 32% emerging)[1], and responsible for 78% of world market capitalization (77% developed, 23% emerging)[2] and 90% of stocks traded in world (79% developed, 21% emerging)[3] in 2015 and are expected to represent a high portion of globalization. Sample period is 01/2001 - 01/2017, with 192 observations, which covers recent global financial crisis and Euro area crisis and thus gives an occasion to examine correlation behavior of markets during turmoil times.

Table 1 Countries included in the study. Selected indices are benchmarks for selected stock markets to gauge the performances

Country	Economy	Index	Source
Brazil	Emerging	IBOV	Yahoo! Finance
Russia	Emerging	MICEX	Moscow Exchange
India	Emerging	BSE 100	Yahoo! Finance
China	Emerging	SSE Composite	Yahoo! Finance
Turkey	Emerging	BIST 100	Yahoo! Finance
Indonesia	Emerging	JKSE	Yahoo! Finance
US	Developed	S&P 500	Yahoo! Finance
Europe	Developed	EUSTOXX	Yahoo! Finance
Japan	Developed	NIKKEI 225	Yahoo! Finance
UK	Developed	FTSE ALL	Yahoo! Finance
Australia	Developed	ASX AORD	Yahoo! Finance

Benchmark indices of each market are used as prices and logarithmic differences in closing price of each month (m) are calculated for each index (j) to obtain returns:

$$Return_{m,j} = \ln \frac{Price_{m+1,j}}{Price_{m,j}}$$

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[1] World Bank Database: http://data.worldbank.org/data-catalog/world-development-indicators. Accessed on: 02/2017.

[2] World Bank Database: http://data.worldbank.org/indicator/CM.MKT.LCAP.CD, excluding UK due to lack of data. Accessed on: 02/2017.

[3] World Bank Database: http://data.worldbank.org/indicator/CM.MKT.TRAD.CD, excluding UK due to lack of data. Accessed on: 02/2017.

4   Methods

Analysis is divided into two parts: First, PCA is used on stock market returns of the economies. Co-integrated behavior of the returns over the sampling period is examined and notable change points of relations are searched with pruned exact linear time (PELT) method. Second, a PLSR model has run to assess predictability of returns with information provided by other markets and lagged returns. This gives an opportunity to conduct a deeper examination and reveal which markets are informative for other markets and relations' direction and impact.

All models are implemented in statistical computing software R (version 3.3.1) (Team, 2016) via R Studio interface (Team, 2015) on a computer with Intel i7 2.6 GHz CPU with 16 GB memory under Windows 10 operating system.

4.1   Principal components analysis

PCA is a common technique for finding patterns in datasets; it is considered as an unsupervised learning method since there isn't any response variable provided to the model. PCA is most commonly used as a dimension reduction technique especially when the number of variables exceeds observations. Dimensions are reduced to principal components (PC), and each component is composed of normalized linear combinations of variables which are also referred as latent variables. While these constructed variables carry the information of original variables, they simplify interpretation of relations among data and most importantly, they offer meaningful results in presence of high correlation between variables.

On first principal component (PC1), linear combination of variables, which explains most of the variance on dataset, is constituted by means of calculating loading values on each variable. This combination can be written as (James *et al.*, 2013):

$$Z_1 = \varphi_{11}X_1 + \varphi_{p1}X_p$$

φ_{p1} are the loadings of variables $X_{1..p}$ on PC1. Determination of loadings is an optimization problem that is expressed as:

$$\text{maximize } \frac{1}{n}\sum\nolimits_{i=1}^{n} z_{i1}^2$$

$$\text{Subject to}$$

$$\sum_{j=1}^{p} \varphi_{j1}^2 = 1$$

in where, there are n observations of p variables. z_{i1} can be written as:

$$z_{i1} = \varphi_{11}x_{i1} + \varphi_{21}x_{i2} + .. + \varphi_{p1}x_{ip}$$

in where, z_{i1} are scores of sample observations on PC1.

Constructing second principal component (PC2) is carried out with the same procedure as PC1, but since this component must be uncorrelated with first component, Z_1, orthogonality constraint between directions of φ_1 and φ_2 is added to optimization problem; which are the loading vectors of combinations of the loadings of variables on components (k) shown as:

$$\varphi_k = (\varphi_{1k}\ \varphi_{2k} .. \varphi_{pk})^T$$

Rest of the PCs are found in similar way finding PC2, each newly constructed component must be uncorrelated with previous ones.

Interpretation of components is basically done in a subjective manner and on the purpose of analyst; in this study, understanding correlated behavior of market returns over sampling period is the main interest point. Generally, first few components are the ones which the observations vary the most; this gives a chance to visualize relationships between markets.

Identifying statistically notable change points for parameters in time series data has been a point of interest for many researchers in a vast scale. It is a challenging problem since as size of data set increases, number of possible solutions increase combinatorically. In this study, after principal components are generated, score points on each observation are used as determinants of variation over the sampling period. Significant changes on scores points out possible breaking points of co-integrated relations of stock markets.

In attempt to successfully identify sub-periods in this study, PELT method is used that is proposed by Killick, Fearnhead and Eckley (2012) and Killick and Eckley (2014) via examining changes in mean. Detailed description can be found in their works.

4.2   Partial least squares regression

PLSR is used to understand mutual relational adequacy and predictability of stock market returns along with their historical values. PLSR involves identifying the best represent of predictors with principal components introduced in Section 4.1 in a supervised way; that is, by providing a response and making principal components to explain the variability associated with that response variable along with other explanatory features. Like PCA, PLSR carries information about these relations in the definition of the scores and loadings.

PLSR finds loading of variables by setting each of them equal to coefficient of a linear regression model that has the same response variable with PLSR and the corresponding *X* variable as the determinant. Orthogonality constraint is valid in PLSR too. Ultimately, regression model is fit to the equation:

$$y_i = \theta_0 + \sum_{l=1}^{k} \theta_l + \sum_{j=1}^{p} \varphi_{jl} x_{ij} + \epsilon_i, \ \ i = 1,..,n$$

Performance of PLSR on each index is going to be evaluated through the mean squared error rates of cross-validated predictions. Relational information is extracted with coefficients of the model.

5   Empirical Results

Correlation scores between markets can be seen in Table 2 (correlations are significant with level of 95% according to Pearson's test). Scores show high positive correlations between developed countries' stock markets except Japan. China market has remarkably low correlations with all other markets. PCA will be able to offer a multi-dimensional understanding about these relations.

Table 2 Correlations between stock market indices. Developed stocked markets have higher and positive inter-correlations than emerging stock markets. Emerging stock market have positive, moderate and close correlations between both inter-group and developed ones. China stock market has weak correlation with all other stock markets

	MICEX	EUSTOXX	IBOV	S&P 500	NIKKEI 225	ASX AORD	BIST 100	FTSE ALL	JKSE	BSE 100
EUSTOXX	0.511									
IBOV	0.555	0.609								
S&P 500	0.512	0.854	0.668							
NIKKEI 225	0.498	0.644	0.457	0.644						
ASX AORD	0.544	0.730	0.633	0.769	0.624					
BIST 100	0.454	0.585	0.481	0.536	0.486	0.495				
FTSE ALL	0.561	0.875	0.656	0.864	0.620	0.782	0.551			
JKSE	0.505	0.439	0.459	0.510	0.441	0.539	0.351	0.540		
BSE 100	0.518	0.575	0.613	0.603	0.545	0.600	0.534	0.603	0.629	
SSE.Comp	0.281	0.291	0.379	0.326	0.339	0.351	0.238	0.270	0.273	0.324

Before proceeding to analysis, stationary check on time series data is necessary: Independent and identically distributed variables are needed in order to follow a more meaningful interpretation. Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979) test is used where the null is a unit root against the alternative of stationary process. All return data series are stationary at significance level of 99%. PCA performed with the function *prcomp* of the standard library. Cumulative proportion of variance explained by PCs are shown in Figure 1.
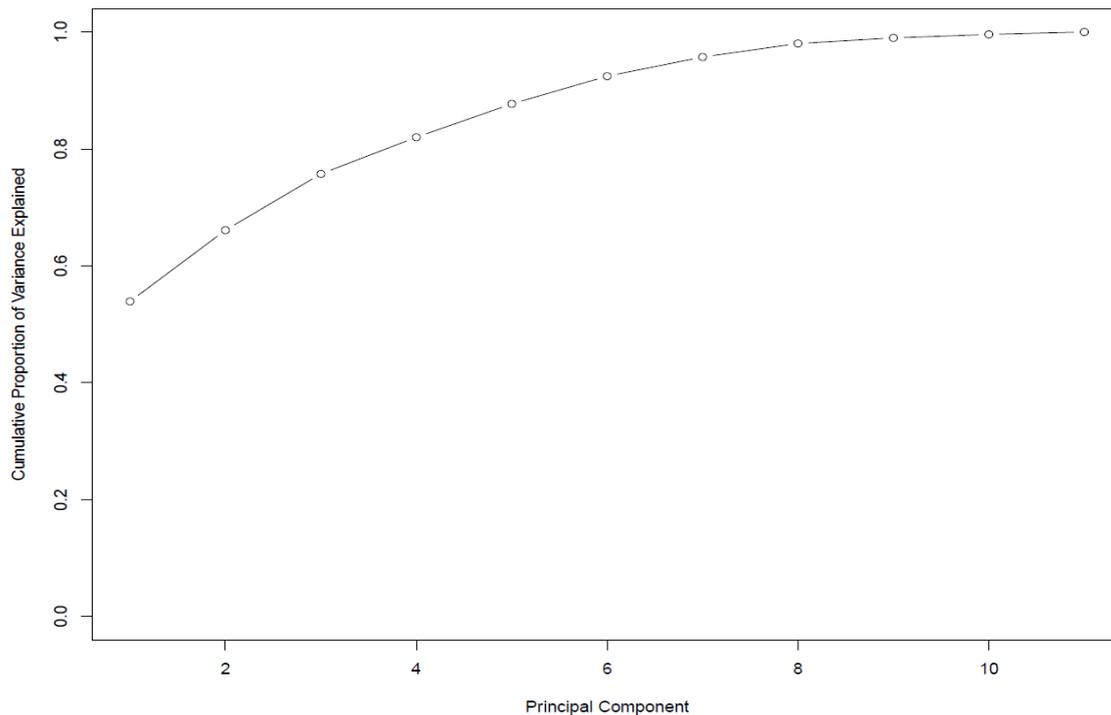
Figure 1 Cumulative proportion of variance explained by PCs

Table 3 Loadings on first three PCs. First three PCs constructed by PCA. PC1 has similar loading for all stock markets, which shows a positively correlated structure among them. Remaining PCs are dominated by Turkey and China stock markets with varying directions

	PC1	PC2	PC3
MICEX	0.362	-0.028	0.377
EUSTOXX	0.276	0.071	0.038
IBOV	0.346	-0.108	0.143
S&P 500	0.217	0.008	0.071
NIKKEI 225	0.256	-0.019	0.038
ASX.AORD	0.188	-0.024	0.081
BIST 100	0.468	0.556	-0.631
FTSE.ALL	0.207	0.040	0.098
JKSE	0.265	-0.096	0.357
BSE 100	0.362	-0.012	0.190
SSE Comp	0.249	-0.814	-0.502

First three PCs manage to explain 76% of variance; 54% by PC1, 12 by PC2 and 10% by PC3. This success is enough for further examination of relational behavior of markets. In Table 3, loadings on first three PCs are presented. PC1 mainly corresponds to procyclical structure of market returns. According to direction and magnitude of variable loadings, all markets are correlated similarly with this component. PC2 is strongly dominated by BIST

100 and SSE Comp; both have high loadings and are on opposite directions. Remaining markets have unimportant impacts. This indicates the particular positions of stock markets of Turkey and China and their oppositely directed market structures. On PC3, BIST 100 and SSE Comp are still in the foreground but unlike on second component, their directions are on the same side. Briefly, while all markets have principally correlated movements over this period, Turkey and China somehow differ slightly from the rest.

5.1   Time-varying integrity

Further investigation on scores of observations on components is necessary to understand if there is any change in trends of stock markets' co-integration. Scatterplots of observations' scores on PC1, PC2 and PC3 can be found in Figure 2.

Plots show that there are no obvious changes on patterns over time series' scores except individual ones, which can be treated as outliers. In order to investigate breakpoints, statistical approach introduced in Section 4.1 is utilized rather than an explanatory analysis, with the function *cpt.mean* of the library *changepoint* (Killick and Eckley, 2014). This function searches possible stages of changes in mean analysis.

Figure 2 Scores on first three PCs
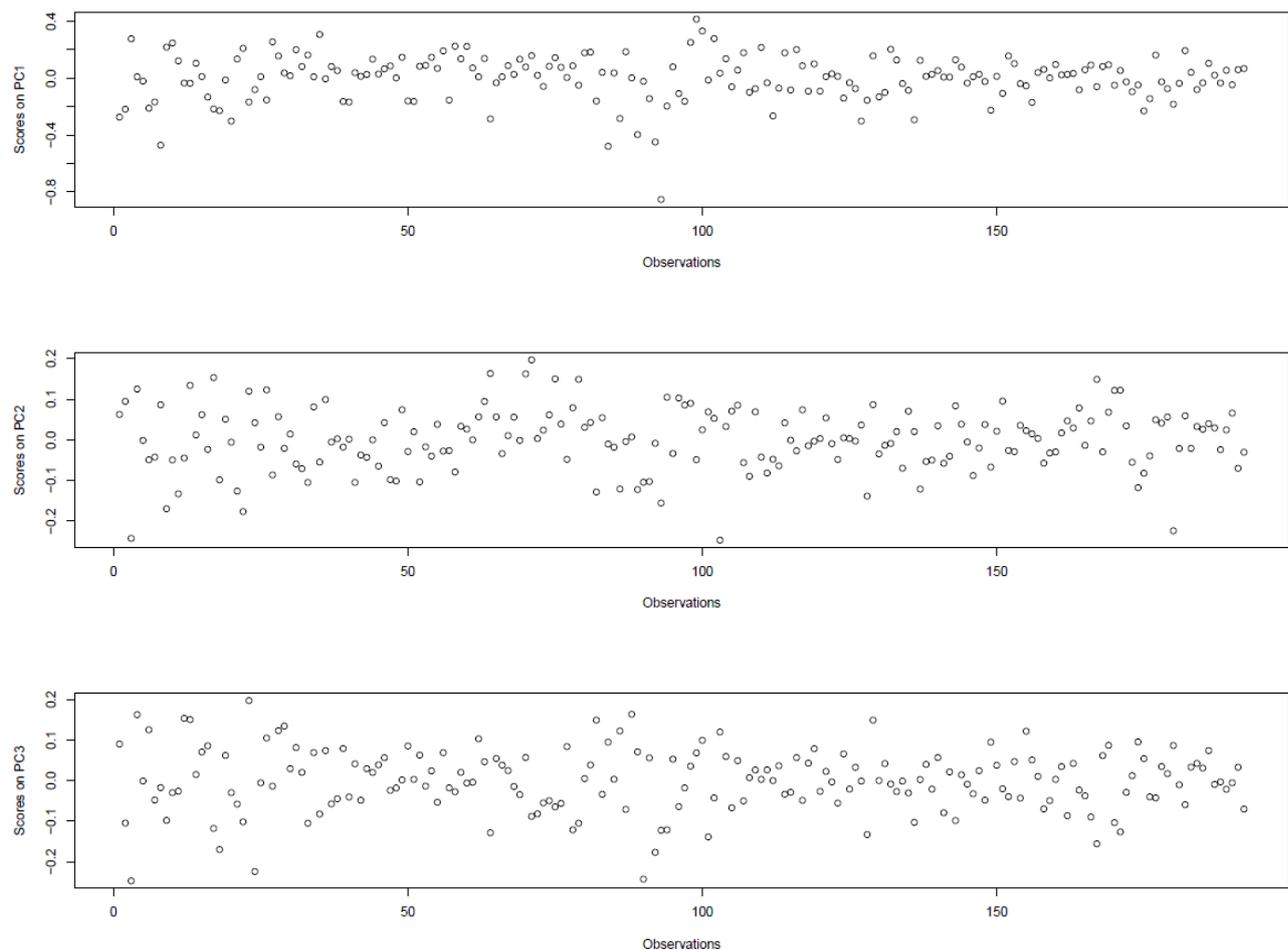
No change points in mean statistics have returned over sampling period (See Figure 3, horizontal lines show fitted mean values). Since there isn't any significant break, it can be said that integration levels among stock markets has remained same since the beginning of 2001.

Many studies that cover previous periods show boosted co-integration of stock markets. This is because most comprehensive policies opened the ways of denser financial globalization during '80s and '90s. Additionally, there isn't any significant upward or downward change in co-integrated movements of stock market returns connected with adverse effects of economic and financial crises (there were four important shocks during the study period; recent global financial crisis- also known as sub-prime mortgage crisis, European sovereign debt crisis, 2008-2009 Russian financial crisis and China stock market crash in 2015). Most conspicuous outlier in the first plot of Figure 3 indicates a very short volatility around second half of 2008 which can be associated with the global financial crisis, but this seems not disturbing the integrity magnitude phenomenon statistically. These variations are roughly stabilized within 2.5 years of crisis. Scores on PC2 and PC3 show consistent variability which can be attributed to Turkey and China markets as mentioned in Section 5, but this variation is not connected to integrity since only the first component is found related.

Figure 3 Plots of the scores with horizontal lines for the underlying (fitted) mean
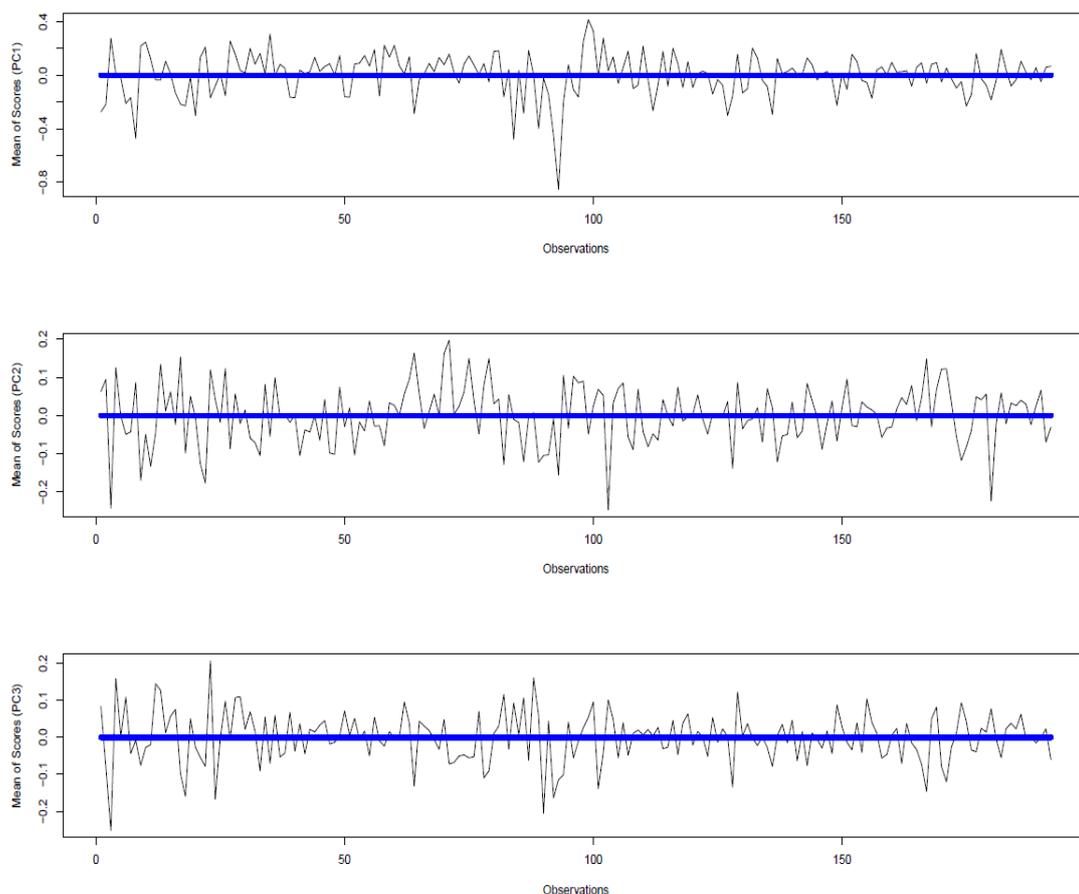
5.2   Predicting Stock Market Returns

A total of 189 observations are used in regression analyses: 3 observations lost due to usage of lagged values. Root mean squared error of predictions (RMSEP) with 10-fold cross-validations are calculated as a measure of learning performance over train data set to determine sufficient components to use. The first local minimum is chosen rather than the global minimum in the curve in order to avoid over-fitting problem. Results with the lowest RMSEP score can be seen in Table 4.

Table 4 Results from PLSR analysis with lowest RMSEP. (1) Number of Components at Lowest RMSEP; (2) Lowest RMSEP; (3) Lowest RMSEP Explanation Rate on Variables; (4) Lowest RMSEP Explanation Rate on Response; (5) Lowest RMSEP Explanation Rate on Response (Only Lagged Data). Developed stock market returns are explained with more components and explanation performances are better than emerging stock market returns, both on all data and response- except Japan. China stock market returns' explanation has the worst performance over entire set

	MICEX	EUSTOXX	IBOV	S&P 500	NIKKEI 225	ASX AORD
(1)	2	10	2	6	3	5
(2)	0.063	0.027	0.051	0.022	0.043	0.023
(3)	31.190	67.182	30.024	59.807	37.420	55.321
(4)	47.635	85.391	55.710	83.393	55.659	73.825
(5)	9.961	4.571	6.021	7.898	7.972	7.830

	BIST 100	FTSE ALL	JKSE	BSE 100	SSE COMP
(1)	2	7	2	2	1
(2)	0.074	0.019	0.050	0.048	0.079
(3)	28.990	61.877	31.595	30.308	17.057
(4)	45.382	87.372	48.389	60.399	17.300
(5)	4.150	5.997	15.148	7.173	3.867

Developed stock markets' errors seen to be lower than emerging ones, S&P 500, ASX AORD and FTSE ALL errors are lowest and BIST 100 and SSE COMP errors are highest. Explanation rates on responses also show that explaining developed stock market returns is quite successful than emerging stock market returns. Differences in the rates can be used as proxies for market structure classification. It is also explicit that developed markets are better explained by more components than emerging markets. This indicates existence of more latent factors and therefore demonstrating more linkages through the global financial system which are influencing developed markets. Lesser components also validate not so powerfully correlated return behaviors of emerging stock market indices. NIKKEI 225 is in between those two market categories; it seems to approach to emerging markets regarding distinguishing statistics. Most notably, China's stock market return explanation rate is dreadfully low. Correlation scores and PCA and PLSR results imply the

unique position of China's stock market apart from the rest of the world. Highest explanation rates in Table 5 are also in line with previous findings.

Table 5 Highest explanation rates achieved with PLSR. (1) Highest Explanation Rate Achieved on Variables; (2) Highest Explanation Rate Achieved on Response. Developed stock market returns are explained better than emerging stock market returns- except Japan. China stock market returns' explanation has the worst performance over entire set

	MICEX	EUSTOXX	IBOV	S&P 500	NIKKEI 225	ASX AORD
(1)	100	100	100	100	100	100
(2)	54.326	85.728	69.304	84.978	60.798	76.353
	BIST 100	FTSE ALL	JKSE	BSE 100	SSE COMP	
(1)	100	100	100	100	100	
(2)	58.076	88.509	61.353	69.259	35.072	

5.3   Examination of regression coefficients

Only the regression coefficients of determinant variables on first components are focused, since this component carries most of the information.

Table 6 Regression coefficients on first components in PLSR; emerging stock markets. Variable numbers depicts stock market returns and their lagged values as follows: 1: MICEX, 2: EUSTOXX, 3: IBOV, 4: S&P 500, 5: NIKKEI 225, 6: ASX AORD, 7: BIST 100, 8: FTSE ALL, 9: JKSE, 10: BSE 100, 11: SSE COMP; 12 to 22: one month lagged values with the same order as previous codding; 23 to 33: two month lagged values with the same order as previous codding; 34 to 44: three month lagged values with the same order as previous codding

Variable	MICEX	IBOV	BIST 100	JKSE	BSE 100	SSE COMP
1	-	0.127	0.156	0.088	0.116	0.064
2	0.082	0.095	0.134	0.053	0.087	0.047
3	0.116	-	0.146	0.069	0.117	0.080
4	0.064	0.080	0.092	0.047	0.069	0.041
5	0.082	0.074	0.117	0.055	0.088	0.056
6	0.062	0.070	0.080	0.044	0.062	0.041
7	0.125	0.128	-	0.077	0.141	0.068
8	0.067	0.075	0.093	0.047	0.066	0.033
9	0.098	0.084	0.108	-	0.107	0.054
10	0.113	0.124	0.172	0.093	-	0.072
11	0.067	0.091	0.089	0.050	0.078	-
12	0.056	0.027	-0.002	0.050	0.024	0.022
13	0.038	0.019	0.005	0.033	0.026	0.013
14	0.047	0.025	0.039	0.044	0.035	0.024
15	0.026	0.012	0.011	0.025	0.019	0.006
16	0.039	0.015	-0.002	0.032	0.019	0.011

17	0.030	0.017	0.016	0.023	0.015	0.011
18	0.056	0.043	-0.037	0.052	0.053	0.001
19	0.026	0.018	0.000	0.025	0.016	0.008
20	0.023	0.023	0.003	0.031	0.015	0.015
21	0.033	0.015	0.004	0.034	0.019	0.017
22	0.045	0.001	0.012	0.025	0.010	0.027
23	0.022	0.019	0.023	0.028	0.030	0.035
24	-0.005	-0.001	-0.016	0.006	0.004	0.009
25	0.023	0.005	0.002	0.024	0.017	0.020
26	-0.005	-0.007	-0.012	0.003	-0.001	-0.003
27	-0.010	-0.023	0.008	-0.009	-0.013	0.005
28	-0.003	-0.002	0.004	0.003	0.006	0.003
29	-0.006	0.004	0.008	0.010	0.004	0.030
30	0.000	-0.003	-0.001	0.004	0.001	0.005
31	-0.004	-0.009	0.012	0.001	0.019	0.020
32	0.001	0.002	0.014	0.004	-0.003	0.017
33	0.035	0.019	0.020	0.040	0.033	0.035
34	0.014	0.002	0.011	0.026	0.027	0.006
35	-0.013	-0.017	0.006	0.005	-0.002	0.017
36	0.011	0.014	0.021	0.017	0.028	0.007
37	-0.010	-0.011	0.002	0.002	0.004	0.006
38	-0.005	-0.007	-0.004	0.010	0.009	-0.001
39	0.002	0.002	0.006	0.011	0.010	0.013
40	0.007	-0.018	-0.009	0.011	-0.001	-0.001
41	-0.006	-0.005	0.000	0.004	0.006	0.011
42	0.012	0.005	-0.001	0.013	0.015	0.020
43	0.011	0.014	0.002	0.012	0.019	0.015
44	0.002	-0.020	0.002	0.010	0.002	0.008

Regression coefficients for emerging stock markets and developed stock markets are presented in Table 6 and in Table 7, respectively. While there are country specific differences in informative nature of determinant data, substantially, it is possible to say that there is a distinction between developed and emerging markets in terms of latent relation structures. There are a lot more components used for a successful prediction of developed stock market returns than emerging ones. This is a very important point to be discoursed. Existence of components captures several linkages among countries. These linkages create transmission channels that possibly constitute stock market exposures and thus increase stock market integrity among economies. Flow of market-related information through bounded markets with linkages eases correlated pricing of equities. There are many possible linkage mechanisms across the economic and financial relations like geographical position, bilateral trade volumes, bilateral investment flows. Revealing the identities of these linkages is beyond the scope of this study.

Table 7 Regression coefficients on first components in PLSR; developed stock markets. Variable numbers depicts stock market returns and their lagged values as follows: 1: MICEX, 2: EUSTOXX, 3: IBOV, 4: S&P 500, 5: NIKKEI 225, 6: ASX AORD, 7: BIST 100, 8: FTSE ALL, 9: JKSE, 10: BSE 100, 11: SSE COMP; 12 to 22: one month lagged values with the same order as previous codding; 23 to 33: two month lagged values with the same order as previous codding; 34 to 44: three month lagged values with the same order as previous codding

Variable	EUSTOXX	S&P 500	NIKKEI 225	ASX AORD	FTSE ALL
1	0.086	0.062	0.079	0.058	0.069
2	-	0.071	0.070	0.053	0.073
3	0.091	0.071	0.065	0.060	0.071
4	0.076	-	0.055	0.043	0.056
5	0.078	0.056	-	0.048	0.054
6	0.060	0.045	0.049	-	0.046
7	0.113	0.072	0.089	0.060	0.076
8	0.075	0.053	0.050	0.042	-
9	0.062	0.051	0.059	0.046	0.054
10	0.089	0.065	0.081	0.057	0.066
11	0.051	0.042	0.056	0.040	0.035
12	0.013	0.019	0.030	0.020	0.007
13	0.011	0.014	0.025	0.012	0.009
14	0.020	0.015	0.031	0.012	0.008
15	0.012	0.010	0.017	0.010	0.008
16	0.013	0.016	0.020	0.014	0.012
17	0.013	0.010	0.012	0.007	0.007
18	0.017	0.026	0.015	0.018	0.018
19	0.007	0.010	0.017	0.008	0.003
20	0.004	0.011	0.004	0.010	0.003
21	0.007	0.009	0.015	0.013	0.001
22	0.015	0.016	0.033	0.019	0.013
23	0.020	0.018	0.021	0.020	0.012
24	-0.007	-0.005	0.003	0.004	-0.005
25	-0.002	0.003	0.008	0.004	0.003
26	-0.006	-0.002	0.002	0.001	-0.004
27	-0.006	-0.006	0.004	0.001	-0.006
28	-0.003	0.001	0.004	0.004	0.000
29	-0.006	-0.008	0.006	0.014	-0.013
30	0.000	-0.001	0.005	0.003	-0.001
31	0.005	0.002	0.012	0.003	0.002
32	0.004	0.000	0.002	0.004	0.000
33	0.022	0.013	0.018	0.020	0.017
34	0.014	0.018	0.023	0.015	0.016
35	0.008	0.005	0.010	0.003	0.005

36	0.024	0.021	0.027	0.013	0.018
37	0.011	0.007	0.008	0.003	0.006
38	0.008	0.009	0.009	0.004	0.007
39	0.011	0.008	0.009	0.006	0.008
40	0.016	0.013	-0.004	-0.002	0.013
41	0.006	0.006	0.009	0.004	0.004
42	0.004	0.009	0.015	0.012	0.012
43	0.007	0.009	0.014	0.006	0.013
44	0.003	0.003	0.006	0.004	-0.001

As seen from explanation rates on response with only lagged data in Table 4, lagged returns are not seen as carrying much information about current returns. Indonesia stock market has the highest rate (15.15%), which may indicate a weaker form of market than others. Thus, current time span coefficients are mainly consulted for examination.

Russia: Two components are used for prediction of MICEX index returns. First component explains 44.21% of variance on response. Lagged returns are found less informative when compared to current returns. Most informative markets in current time span for MICEX are four emerging market indexes; BIST 100, BSE 100 and IBOV, JKSE. MICEX and BIST 100 indexes are informative in one month lagged time span.

Eurozone: EUSTOXX returns are predicted by ten components. First component explains 58.54% of variance on response and show that returns of all markets used in the analysis have positive relation with EUSTOXX returns in current time span; BIST 100, MICEX, S&P 500, FTSE ALL, IBOV are the most conspicuous markets. Lagged returns are not informative. Coefficients of developed market returns rise through the rest of components, and China market has opposite relationship with Eurozone.

Brazil: Brazil market returns are predicted by two components. First component explains 50.62% of variance on response and coefficients of the components show positive relationship between all markets in current time span. MICEX, BIST 100, BSE 100, which are all emerging markets are in the foreground. IBOV seems to be affected by lagged values at low level.

US: S&P 500 returns are predicted by six components. First component contributes to explanation of variance on response with a rate of 62.9%. In current time span, US stock market returns are associated with Eurozone, Russia, Brazil, Turkey and India stock market returns.

Japan: NIKKEI 225 are predicted by three components. First component explains 45.77% of variance on response, and in current time span, EUSTOXX, MICEX, BIST 100, BSE 100 have determinant effect on Japan stock market returns.

Australia: Australia's returns are predicted by five components. On first component, which explains 58.81% of variance on response, coefficients in current time span are not as high as others. MICEX, EUSTOXX, IBOV, BIST 100 and BSE 100 are highest determinants.

Turkey: Two components are used to predict BIST 100 returns. First component carries 39.8% of information on response and MICEX, EUSTOXX, IBOV and BSE 100 strongly effect BIST 100 returns in current time span. Lagged returns are not informative.

UK: FTSE ALL index is predicted by seven components. First component explains 65.24% of variance on response. Lagged data do not have meaningful impact and current returns have positive signs. MICEX, EUSTOXX, IBOV, BIST 100 and BSE 100 indexes get higher coefficient scores in current time span.

Indonesia: Indonesia's stock market returns are explained by two components. On first component, 44.69% of information on response is explained. MICEX, IBOV, BIST 100 and BSE 100 indexes are more determinant than others. JKSE has the highest score for explanation rate with lagged data, high coefficients in one-month time span are MICEX, IBOV and BIST 100 and in two months' time span, MICEX, IBOV, SSE COMP.

India: Two components used for India stock market return prediction. First component explains 54.96% of variance on response. Strongly related indexes are MICEX, IBOV, BIST 100 and JKSE.

China: China stock market returns are explained by only one component. For current returns, all relations are positive with MICEX, IBOV, NIKKEI 225, BIST 100 and BSE 100 leading.

6   Discussion and conclusions

As stated in Yarovaya and Lau (2016), financial integration of emerging markets have pros and cons. Integration of international stock markets reduces risks in emerging markets and allows global investors more opportunities for risk sharing. On the other hand, this integration limits benefits of international portfolio diversification and may lead to joint market crashes too (Lee and Cho, 2017). For international investors, understanding the direction of global stock market integration and its impacts on investing strategies are important.

This paper examines co-movements and interrelationships among 6 emerging and 5 developed stock market returns between period 2001- 2017 with monthly data. First, PCA is conducted and components are extracted from returns. According to PELT analysis on PCA scores, patterns of correlations of returns are found constant except short-term disturbances during global financial crisis time. While many studies show increase of integration among stock markets in last two decades of 20th century, this study finds that in 2001- 2017 period, there hasn't been a significant change in the integration level of global stock markets. This finding is in line with Bekaert, Hodrick and Zhang (2009), Akbari, Ng and Solnik (2019) and Bekaert and Mehl (2019).

Second, PLSR models are used for predicting each stock market returns with other stock markets' current and all markets' up to three month lagged returns. Results identify divergence between developed and emerging markets: Developed stock market returns are explained successfully and better than emerging stock market returns. Japan market is distinguished from other developed markets. Its predictability success is close to emerging markets' rates. Another important finding is that lowest RMSEPs are achieved for developed stock market returns with much more components than emerging ones but again, except for Japan stock market returns, which is predicted with fewer number of components compared to developed ones. It is conceivable that each component can be treated as a latent variable, or transmission channel.

Lack of channels causes emerging markets to be segmented. Numerous presences of explanatory latent variables for developed economies suggest a more connected structure for those country markets than others. A deeper examination about these latent variables and their effects is a good starting point for understanding spill-over mechanisms in the system. Chen (2018) (who also implied strong international stock market co-movements) remarked that developed market stock market volatility is better explained by global shocks and regional shocks are more reflective for emerging market fluctuations. In the light of this, it is recommended for investors to distinguish country/region specific stresses from global ones to better design their portfolio diversification and hedging strategies.

Despite the general consensus for increasing correlation during bear market states as well as extreme market conditions (Demirer *et al.*, 2018), no variation in stock market co-movements found during the Global Financial Crisis. By considering less systemic risk channels for emerging markets, it is possible for investors from developed countries to hold a well-diversified portfolio with emerging market stocks.

China stock market's unpredictability points opted out position of the country's stock market. Lau and Sheng (2018) validates China's market is the least integrated with other markets worldwide. This country can be regarded as an attractive destination for investors (Yarovaya and Lau, 2016). It's global integrity and dynamics deserves more interest to be investigated when the country's big economy and its impact on global trade are considered.

Despite globalization, benefits of international diversification have persisted (Bekaert, Hodrick and Zhang, 2009). Investors still have opportunities with many alternatives for building portfolios over several markets in the long term. Further analyses with more frequent data will uncover short-term alternatives. Still, financial institutions and market participants must be careful about spill-over effects over the system.

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Supplementary Material

Data, codes and libraries used in analysis can be found in Mendeley Data Repository: http://dx.doi.org/10.17632/chnwtj3ngn.1