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Interconnectedness of Stock Market in Systemically Important Regions With VAR Model Approach

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ABSTRACT
This study explores the interconnectedness, market integration, and the intrinsic integration between countries included in Systemically Important Regions (SIRs), which are all developed countries. Countries included in SIRs are empirically showing to have a reduced degree of concentrated structure and its interconnectedness is not significantly associated to systemic risk (Fang, et al. 2019). We analyse whether there are impacts from those countries' interconnectedness to its market integration. To this end, we examine twelve countries included in SIRs, with the dataset begins on June 2000 and ends on December 2018. Some approaches, such as vector autoregressive (VAR) model, Granger-causality, and simple market model are used to estimate SIRs countries' interconnectedness and its intrinsic integration. Our key findings point to a filtered interconnectedness among SIRs' stock markets would still reduce the systemic risk, as the connected lines before and after filtering process is still above four lines, except Slovakia.

Keywords: *Stock market, market integration, vector autoregressive model*

1. INTRODUCTION

Systemic risk is usually associated with a major collapse of a company, industry, financial institution or even in a broader economy. Some big events such as the Asian financial crisis 1997 and the Global Financial Crisis (GFC) are giving a good example of how systemic risk would have impacts in a big system of economy. Since then, the studies related to systemic risk have been developing but mostly are focusing on risks in financial institution, especially in the interconnectedness analysis which is also related to the contagion analysis. The terms of interconnectedness itself means linkages between and across financial institutions; providers of financial market services; then vendors and third parties which are supporting those entities (DTCC, 2015) .

The economic collapse might be started from the financial institutions. However, Acharya et al. (2017) and Billio et al. (2012) mentioned that systemic risk is not strictly limited to individual financial institutions. Fang et al. (2019) argued that some specific regions or countries may have the strength to avoid the effects of systemic risk from its interconnectedness to each other. This is due to the global systemic risk management requires regional coordination; thus, regions have become increasingly connected to each other. Fang et al., (2019) categorized the regions into the Systemically Important Regions and Non-Systemically Important Regions. The regions classification is implying the aggregate systemic risk at global level. The classification of SIRs and NSIRs is based on the number of lines which connected to the country, which is calculated using a Minimum Spanning Tree (MST). Countries included in SIRs are defined by the connected lines equal or larger than four in each year of sample and all SIRs countries are developed countries. Fang et al. (2019) concluded that the more concentrated the network, the higher the systemic risk, even though it has no significant effects in SIRs.

Wu (2019) evaluated the intrinsic integration in stock market of ASEAN5 plus other 4 stock markets such as Japan, South Korea, China, and Hong Kong. The integration of stock markets is considered having embedded dynamic global factors, which could lead the investors to have biased investment conclusions. Factors which affect the interconnectedness are the scale of the economy proxied by GDP, exports and imports, and the international status of currency (Kali and Reyes, 2010; Muller, 2011; Armijo et al., 2014); Centeno et al., 2015).Therefore, there's a need to filter the stock markets returns and see its intrinsic integration. Once filtered, there is a decrement of interconnectedness of all stock markets. Therefore, based on these backgrounds, we hypothesize that after the stock markets of developed countries (SIRs) are filtered, the level of interconnectedness would decrease.

Our study uses VAR model to estimate the whole system interconnectedness and eventual integration. The filtering process is in line with Wu (2019) by using simple market model with below equation:

$$y_{i,t} = \alpha_i + \beta_{i.t} y_{w.t} + \varepsilon_{i.t} \quad \text{.............................} (1)$$

Where $y_{i,t}$ is the price returns stock markets i in time t, α_i is the constanta, $y_{w.t}$ is the world return (in this study, we use MSCI World Index) at time t with $\beta_{i.t}$ as the coefficient, with $\varepsilon_{i.t}$ is the error of stock i at time t.

This paper contributes two important folds. First, we observe the differences of connectedness of SIRs stock market before and after filtering process referring to Wu (2019). The results are in line with Wu (2019) which is showing that after the filtering the correlations among stock markets are decreasing, considering that the fluctuation of stock market prices is affected by the dynamic global factors. Second, after the VAR model is applied, there is a strengthened interconnectedness in a system for some European countries along with Japan and China.

2. METHODS

Our study is using daily data of SIRs countries such as USA, Japan, China, Australia, Austria, Netherlands, Belgium, Spain, Sweden, Slovakia, France, and Germany. We employ these countries' stock market indices' price return based on previous research of Fang et al. (2019) which had categorized those countries into SIRs as of year 2015. We use daily data (5 trading days) with time frame from June 2000 to December 2018; thus, we have 4,836 observation for the research.

The descriptive statistics of the twelve stock market returns are detailed in **Table 1**. For the full sample among the European countries, Slovakia owns the highest average return of 0.0339% while Netherlands' average return is showing the lowest figure of -0.0034%. There are only two Asian countries from the sample which are China and Japan. China's average return is more superior than Japan, which is 0.0089% and -0.002% respectively. USA's average return of 0.0109% and Australia's average return is 0.016%. While the standard deviations are showing each market volatilities and Sweden's stock market has the highest-level volatilities of 1.6%.

Table 1. Descriptive statistics of the price return from each stock market in SIRs

Countries	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Probability	Obs.
Australia	0.000160	0.000262	0.132318	-0.146036	0.013422	-0.651091	13.762870	0.0000	4,836
Austria	0.000211	0.000077	0.133469	-0.114955	0.015884	-0.317590	10.646630	0.0000	4,836
Belgium	0.000055	0.000187	0.103855	-0.096763	0.013834	-0.183963	8.839837	0.0000	4,836
China	0.000089	0.000000	0.094062	-0.091638	0.015290	-0.402090	8.313335	0.0000	4,836
France	0.000019	0.000058	0.118239	-0.110060	0.014513	-0.117058	9.455819	0.0000	4,836
Germany	0.000136	0.000182	0.119657	-0.096134	0.015024	-0.119563	8.684034	0.0000	4,836
Japan	-0.000020	0.000000	0.112987	-0.119479	0.013651	-0.246273	8.522895	0.0000	4,836
Netherlands	-0.000034	0.000261	0.124135	-0.116522	0.015274	-0.147013	10.448600	0.0000	4,836
Slovakia	0.000339	0.000000	0.111859	-0.151577	0.012975	-0.544774	13.779500	0.0000	4,836
Spain	0.000003	0.000018	0.139098	-0.157178	0.015806	-0.213728	10.787000	0.0000	4,836
Sweden	0.000067	0.000000	0.138687	-0.128810	0.016584	-0.165288	8.886329	0.0000	4,836
USA	0.000109	0.000412	0.132546	-0.095877	0.014938	0.081518	9.395297	0.0000	4,836

The study of interconnectedness and contagion has been developing since the 2008 financial crisis which impacts spread globally to all over countries. Based on Forbes in Bricco and Xu (2019), the understanding of interconnectedness and contagion is different. The definition of interconnectedness is manifested as financial linkages or correlations along the market prices of financial institutions, while contagion is the linkages effects from the interconnectedness magnitude or shocks to one country(ies). The contagion effects might inflict financial volatility or even some serious damage to the economy and financial system of a lot of countries. In order to conduct a comprehensive analysis about the interconnectedness of SIRs, we first see the correlations in the system using Pearson's correlation and Diebold and Yilmaz (2014) VAR model approach.

3. RESULTS AND DISCUSSION

This study's empirical analysis is exercising 12 stock market indices of countries which are included in Systemically Important Regions with 4840 observations (period ranged from 12 June 2000 to 28 December 2018). The model employed is VAR model which is to estimate final total interconnectedness among variables. We also analyse the stock markets' intrinsic integration after the filtration by using a simple market model based on Wu (2019).

3.1 Correlations of stock returns

First, we estimate the correlation among the variables of twelve countries included in Systemically Important Regions or SIRs. We have two correlation heat maps given in Table 1. The first correlation heat-maps are showing a full sample of unfiltered correlation heat maps indicating lowest value in lighter color and the highest value darker color. The table is showing that the most correlated stock markets are European stock markets, such as France and Netherlands with the highest correlation of 94.35% reciprocally. Countries' stock markets which have the least correlation to other countries are Japan, Slovakia, and China with the highest correlation. Japan and China's stock markets highest correlation is with Australia, with correlation of 44.99% and 24.57% respectively and these are below 50%. Followed by Slovakia's stock market highest correlation with Belgium of 23.31%. Before the filtered results, these three stock markets are showing an aggressive correlation among others stock markets. Wu (2019) explains that based on these pairwise correlations might indicate common influences from the global stock market dynamics, especially for ASEAN5 and 4 countries (China, Hong Kong, Japan, and Korea).

We then construct filtered stock market returns using simple market model which is employed by Wu (2019) . All results are showing decreased correlations compared to the unfiltered stock market returns. After the filtering process, all countries' stock markets are having negative correlations to USA's. This finding can lead to an argument that USA's stock market has the impacts to other stock markets' unaccounted information. However, the filtered results from stock markets of European countries are still having above 50% correlations excepting Slovakia. This comparison between the unfiltered and filtered results are showing that the stock markets of SIRs countries are embedded by the unaccounted information, since the connectedness are all decreasing.

Table 2 The correlation of raw and filtered stock returns using Pearson's correlation of full period.

Correlation of stock market returns - RAW

	USA	Sweden	Spain	Slovakia	Netherlands	Japan	Germany	France	China	Belgium	Austria	Australia
USA		0.48	0.42	0.06	0.46	0.01	0.53	0.46	0.06	0.41	0.32	0.30
Sweden	0.48		0.77	0.19	0.83	0.20	0.84	0.86	0.12	0.79	0.71	0.52
Spain	0.42	0.77		0.22	0.85	0.18	0.84	0.90	0.10	0.84	0.75	0.49
Slovakia	0.06	0.19	0.22		0.20	0.10	0.20	0.22	0.05	0.23	0.22	0.19
Netherlands	0.46	0.83	0.85	0.20		0.20	0.90	0.94	0.12	0.90	0.72	0.52
Japan	0.01	0.20	0.18	0.10	0.20		0.19	0.21	0.20	0.20	0.24	0.45
Germany	0.53	0.84	0.84	0.20	0.90	0.19		0.93	0.12	0.85	0.73	0.50
France	0.46	0.86	0.90	0.22	0.94	0.21	0.93		0.13	0.90	0.77	0.54
China	0.06	0.12	0.10	0.05	0.12	0.20	0.12	0.13		0.14	0.16	0.25
Belgium	0.41	0.79	0.84	0.23	0.90	0.20	0.85	0.90	0.14		0.76	0.53
Austria	0.32	0.71	0.75	0.22	0.72	0.24	0.73	0.77	0.16	0.76		0.55
Australia	0.30	0.52	0.49	0.19	0.52	0.45	0.50	0.54	0.25	0.53	0.55	

Correlation of stock market returns - FILTERED

	USA	Sweden	Spain	Slovakia	Netherlands	Japan	Germany	France	China	Belgium	Austria	Australia
USA		-0.30	-0.39	-0.08	-0.43	-0.33	-0.34	-0.46	-0.11	-0.44	-0.40	-0.32
Sweden	-0.30		0.50	0.13	0.59	0.02	0.58	0.65	0.01	0.52	0.45	0.16
Spain	-0.39	0.50		0.18	0.65	0.00	0.62	0.76	-0.01	0.65	0.55	0.14
Slovakia	-0.08	0.13	0.18		0.15	0.07	0.15	0.18	0.03	0.20	0.18	0.14
Netherlands	-0.43	0.59	0.65	0.15		0.00	0.72	0.85	0.00	0.75	0.46	0.13
Japan	-0.33	0.02	0.00	0.07	0.00		-0.03	0.03	0.17	0.02	0.11	0.39
Germany	-0.34	0.58	0.62	0.15	0.72	-0.03		0.79	0.00	0.64	0.46	0.08
France	-0.46	0.65	0.76	0.18	0.85	0.03	0.79		0.01	0.77	0.55	0.16
China	-0.11	0.01	-0.01	0.03	0.00	0.17	0.00	0.01		0.04	0.08	0.20
Belgium	-0.44	0.52	0.65	0.20	0.75	0.02	0.64	0.77	0.04		0.55	0.18
Austria	-0.40	0.45	0.55	0.18	0.46	0.11	0.46	0.55	0.08	0.55		0.29
Australia	-0.32	0.16	0.14	0.14	0.13	0.39	0.08	0.16	0.20	0.18	0.29	

3.2 Analysis of VAR model

Bricco and Xu (2019) mentioned that there are three ways on estimating the interconnectedness and contagion which is closely related to systemic risk, which are Diebold and Yilmaz (2014) approach using the generalized variance decomposition (GVD) of VAR model, the Conditional Value at Risk (CoVaR) indicator by Adrian and Brunnermeier (2008) and the Systemic Risk and Interconnectedness (SyRIN) tool by Cortes et al (2018). In this study, we try to analyse the interconnectedness of SIRs using the Diebold and Yilmaz (2014)[7] approach. In order to further see the stock market interconnectedness and ultimate integration, we first conduct the Augmented Dickey Fuller (ADF) test and make sure for all variables to be stationary for modelling.

This procedure is important to the whole VAR model estimation due to the non-stationary characteristic which is embedded to the time series data. The daily data of each stock market returns from June 2000 to December 2018 has a unit root, and all stock returns are stationary on the 1st difference. Then we estimate the optimal lag length which would be proper to construct the interconnectedness by using VAR model and have the optimal lag length to be in lag 4. The optimal lag length is usually to be opted based on the Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC) AND Hannan Quinnon (HQ). Beforehand, we also do the cointegration Johansen test in lag 5 for all stock market on the price level and found that there's one cointegration among all stock market indices. Since there's cointegration among stock markets in the long run, we employ Vector Error Correction or VEC model which introduced by Engle and Granger (1987). We use lag 4 on the VEC model, since the optimal lag length is subtracted by 1.

Based on Diebold and Yilmaz (2014) approach, we need to measure the connectedness as presented in Table 3 and Table 4 as a comparison between unfiltered and filtered results. This approach is providing the From, To, and Net measurements to see the variables contributions in the system.

$$\textbf{From}(i) = \sum_{j=1}^{K} \varphi_{ij} \text{, where } i \neq j \quad \text{......} \; (2)$$

$$\textbf{To}(i) = \sum_{j=1}^{K} \varphi_{ji} \text{, where } i \neq j \quad \text{......} \; (3)$$

$$\textbf{Net}(i) = \text{To} - \text{From} \quad \text{......} \; (4)$$

"From(i)" is explaining the level of connectedness which variable (i) would gain from other variables in the system. "To(i)" is explaining how much variable (i) would contribute to other variables in the system; then "Net(i)" is showing one variable's contributions to the whole system with a positive or negative figure.

Table 3. Variance decompositions of VAR model – Raw returns

	USA	**Sweden**	**Spain**	**Slovakia**	**Netherlands**	**Japan**	**Germany**	**France**	**China**	**Belgium**	**Austria**	**Australia**	**From**
USA		0.29	0.03	0.10	0.30	0.19	0.11	0.11	0.04	0.27	0.20	0.08	1.72
Sweden	37.38		0.19	0.33	2.02	1.71	1.14	0.62	0.27	2.01	0.05	2.41	48.12
Spain	24.07	24.23		0.30	1.79	1.11	0.55	0.82	0.17	1.72	0.08	1.77	56.61
Slovakia	0.58	3.76	1.51		0.06	0.05	0.04	0.01	0.04	0.01	0.00	0.04	6.10
Netherlands	36.53	26.78	9.60	0.40		1.91	0.92	0.93	0.49	2.70	0.08	2.71	83.07
Japan	18.22	13.27	1.88	0.44	1.05		0.07	0.38	0.19	0.23	0.29	0.40	36.42
Germany	36.93	26.39	8.08	0.34	3.43	0.75		0.43	0.19	1.69	0.13	1.46	79.83
France	36.25	30.04	13.46	0.53	4.09	1.80	3.68		0.38	2.22	0.07	2.69	95.21
China	2.38	2.45	0.54	0.05	0.39	0.87	0.03	0.11		0.27	0.07	0.06	7.22
Belgium	25.09	26.08	12.57	0.57	5.39	0.87	1.40	0.63	0.48		0.05	1.44	74.57
Austria	18.70	27.17	10.62	0.31	0.45	0.58	0.86	0.35	0.55	3.44		1.52	64.55
Australia	28.22	19.17	4.11	0.27	0.96	2.29	0.10	0.36	0.92	0.86	1.19		58.47
To	264.35	199.62	62.59	3.65	19.93	12.13	8.92	4.74	3.72	15.43	2.22	14.57	**50.99**
Net	262.63	151.50	5.98	-2.45	-63.14	-24.29	-70.91	-90.47	-3.50	-59.13	-62.32	-43.90	

Table 3 is showing the unfiltered results of variance decompositions from VAR model we have constructed, with H period of 10. Before the filtering, USA's stock market is in the highest level compared to others with a massive percentage of 264.35% in contributing the global factors to other, while being the least affected by other variables for only 1.72%. Sweden is the second biggest contributor of global factors to other variables but is also gaining fairly 48.12% of contributions from all other stock markets in the system. The other European countries such as Spain, Netherlands, and Belgium are contributing above 10% global factors to other markets. Using the Granger-causality approach, we constructed connected lines for unfiltered and filtered results in Fig. 1. For the full period, the US has the most significant connected lines to all SIRs countries, as US is having predictive power to have influences for the changes of other stock markets. However, after the filtering process, the US connected lines decreasing to only four lines. The lines are connected to Sweden, Spain, Japan, and France. This is showing that the US stock market has the biggest contribution to the dynamic global factors to other stock markets.

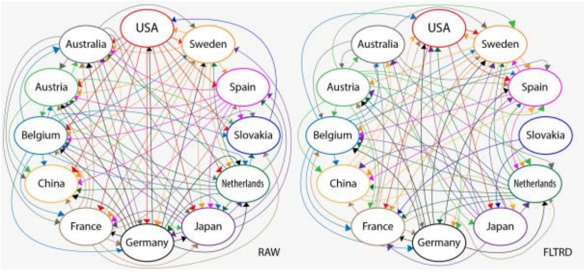

Figure 1. Connected lines before and after filtering

After the US connected lines are decreasing significantly, some other stock markets' connected lines are unexpectedly increasing, such as Austria, Japan and China's stock markets. Before the filtering, the reciprocal Granger causality between Japan and the US is only significant for US, but after the filtering Japan's stock market is granger cause to the US stock market. This condition is also happened in China's stock market.

Table 4. Variance decompositions of VAR model – Filtered returns

	USA	Sweden	Spain	Slovakia	Netherlands	Japan	Germany	France	China	Belgium	Austria	Australia	From
USA		1.87	0.78	0.01	0.73	1.86	0.04	0.32	0.04	0.05	0.02	0.22	5.95
Sweden	3.14		0.75	0.10	4.52	6.22	0.46	0.93	0.05	0.31	0.29	4.02	20.78
Spain	2.22	9.84		0.13	1.73	2.54	0.28	0.65	0.06	0.16	0.09	1.42	19.12
Slovakia	0.15	1.25	1.45		0.09	0.05	0.04	0.01	0.00	0.01	0.01	0.10	3.17
Netherlands	4.22	14.46	15.70	0.17		8.11	0.56	1.07	0.05	0.53	0.20	4.60	49.66
Japan	11.10	10.09	1.57	0.61	4.94		0.32	0.10	0.08	0.27	0.64	1.83	31.53
Germany	1.60	16.43	15.15	0.32	8.13	5.46		0.41	0.04	0.36	0.20	3.35	51.46
France	5.02	19.55	28.95	0.43	10.82	8.77	2.63		0.08	0.41	0.26	4.79	81.70
China	1.51	0.17	0.20	0.07	0.03	0.68	0.04	0.01		0.24	0.08	0.01	3.05
Belgium	3.01	10.71	17.78	0.86	10.31	4.40	0.29	1.02	0.26		0.17	3.09	51.92
Austria	4.60	9.84	12.25	0.49	0.39	1.34	0.32	0.31	0.28	3.53		0.45	33.78
Australia	7.74	5.11	0.08	1.08	2.69	2.90	0.67	0.71	1.65	1.22	5.18		29.05
To	44.31	99.32	94.65	4.27	44.37	42.33	5.66	5.54	2.59	7.09	7.14	23.88	**31.76**
Net	38.36	78.54	75.53	1.10	-5.29	10.80	-45.80	-76.16	-0.45	-44.82	-26.64	-5.17	

After all stock markets are filtered using the simple market model, the connectedness represented by the variance decompositions are massively decreasing especially for the USA's stock market but there are too increment in the interconnectedness for some stock markets. The USA's net contribution to other variables is dropping to only 38.36% compared to the figure before the filtering. This is showing that USA's stock market holds the significant impact in terms of the dynamic global factors. While there is unexpected increment of interconnectedness in all stock markets except the USA and Sweden. This result is in line with the Granger-causality approach, which is showing that the US stock market indeed hold a strong predictive power to other stock market. To some stock markets such as US and Sweden, the filtering process may give evidence that the dynamic global factors are embedded when we need to see the intrinsic integration of the stock markets. However, the integration is still happening into most European stock markets and two big developed countries (China and Japan) in the sample. In terms of the SIRs classification, the filtered results are showing that all countries are still having more than four connected lines, except Slovakia. It is explaining that even though we conduct the filtering process to see the intrinsic integration of stock markets, these SIRs stock market are still included in SIRs which its interconnectedness aggravates the effects of systemic risk.

4. CONCLUSIONS

The Systemically Important Regions or SIRs was initially introduced by Fang et al. (2019) that categorizing countries included in SIRs or NSIRs (Non-Systemically Important Regions). This is to show that the systemic risk may need to be accounted using a macro perspective. Some countries are classified as SIRs based on the average connected lines from some certain periods. Fang et al. (2019) mentioned that to be included in SIRs, the connected lines should be more than four or larger in each year. Then we try to see the intrinsic interconnectedness or eventual stock markets integration following Wu (2019) who proposes the filtering process using a simple market model. The US, Australia, and other European countries stock markets are showing a strong correlation results before filtering process, except the two Asian countries, Japan and China. While the filtered results, especially for the US stock market, are showing negative correlations to other SIRs stock markets. This explains that before the filtering, any changes or shocks happened in the US stock markets will significantly affect other stock markets in SIRs. Once the results are filtered, the correlations between the US stock markets and other markets are moving to the opposite way, even though the overall correlations are still decreasing compared to the unfiltered results.

As for the VAR model, we use the variance decompositions to see each stock market interconnectedness. Before the filtering, in line with the Pearson's correlation, the US stock market gives significant effects to other stock markets movement. While the filtered results, the US stock market's contribution to other is significantly decreasing. As for the European countries (except Sweden), Japan, China, and Austria's contribution to other stock markets are increasing. The highest contribution increment is in Spain with contribution increment of 69.55%. Then followed by Netherlands, Australia, Austria, Japan, and Germany, which contributions increment is more than 25%.

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