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Asian Financial Linkages: The Case of Japan

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

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Abstract

This work reviews the topic of international financial linkages, including theoretical definitions and the main methodological approaches of the empirical measurement based on vector autoregressive models. One of the approaches, the Spillover Index methodology based on Diebold & Yilmaz (2009), is then used to analyze the developments of financial linkages of the Japanese stock market in the period from 1995 to 2012. The attention is paid both to the relations with western developed economies and within the region of East Asia. The main contribution of this paper is the fact that it comprises a complete review of international relations of Japanese stock market during the era of unprecedented financial liberalization. The results of the empirical study confirm the opening of Japanese stock markets towards foreign influence. Even though USA have been the major driving force behind the movements in East Asian stock markets, Japan has become a significant regional player, whose influence on East Asian countries has been growing. The developments in the Japanese stock market are on the other hand driven solely by the western developed countries, which further supports the view of Japan as the regional financial leader.

JEL Classification: G15, C440, O160

Keywords Financial Linkage, Stock Market, Japanese Economy, East Asian Integration

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Abstrakt

Práce se zabývá tématem finanční provázanosti, včetně teoretických definicí a hlavních metodologických přístupů pro její empirickou analýzu založených na vektorových autoregresivních modelech (vector autoregressive models). Jedna z popsaných metodik, Spillover Index představený Dieboldem & Yilmazem (2009), je pak použita k provedení analýzy zahraniční finanční provázanosti japonského burzovního trhu v období 1995 – 2012. Pozornost je přitom věnována jak vztahům se západními vyspělými ekonomikami, tak vztahům v rámci regionu Východní Asie. Hlavní přínos práce je fakt, že představuje kompletní přehled zahraniční provázanosti japonského burzovního trhu během bezprecedentního období finanční liberalizace. Výsledky empirické studie potvrzují, že v případě japonské burzy skutečně došlo k otevření vlivům zahraničních trhů. Přestože Spojené státy americké zůstávají hlavním hybatelem dění na východoasijských trzích, Japonsko si vybudovalo roli významného regionálního hráče, jehož vliv na ostatní země v regionu roste. Japonský burzovní trh je naopak ovlivňován výlučně západními vyspělými ekonomikami, což jen dále potvrzuje jeho roli regionálního finančního hegemona.

Klasifikace	G15, C440, O160
Klíčová slova	Finanční provázanost, Burzovní trhy, Japonská ekonomika, Integrace Východní Asie

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Acronyms

ADF – Augmented Dickey-Fuller (Test)

AIC – Akaike Information Criterion

ARCH – Autoregressive Conditional Heteroscedacticity

ARIMA – Autoregressive Integrated Moving Average

ASEAN – Association of Southeast Asian Nations

BIS – Bank for International Settlements

BP – Breusch-Pagan

CMI – Chang Mai Initiative

DAG – Directed Acyclic Graph

DGP – Data Generating Process

EAC – East Asian Countries

ECU – European Currency Unit

EGARCH – Exponential General Autoregressive Conditional Heteroscedasticity

EU – European Union

FDI – Foreign Direct Investment

FEV – Forecast Error Variance

HQ – Hannah-Quinn Criterion

IMF – International Monetary Fund

LM – Lagrange Multiplier

LS – Least Squares

NEAC – Non East Asian Countries

OSE – Osaka Stock Exchange

RMB – Renminbi

SC – Schwartz Criterion

TSE – Tokyo Stock Exchange

UK – United Kingdom

US – United States (of America)

USD – US Dollars

UTC – Coordinated Universal Time

VAR – Vector Autoregression/Vector Autoregressive

VECM – Vector Error Correction Model

WTO –World Trade Organization

1. Introduction

The importance of researching the international interaction of financial markets is evident for multiple reasons. First of all, the interdependence of international stock and bond markets has serious implications for potential gains from international portfolio diversification. More importantly however, can the financial markets serve as a transmission channel for economic crises, such as we have seen several times in the recent history. It is therefore desirable to understand the dynamic of these interactions, all the more so considering globalization and liberalization of financial markets across the globe. In the context of East Asia, the matter also relates to the changing balance among the economic powers in the region. Japan that has been the regional economic leader for past three decades seems to slowly be handing its position over to China. Moreover, the development of the dependence of the region on the Western economies, mainly the US, has also been subjected to discussions[1].

The aim of this work is twofold. Firstly, it is to review the issue of empirical analysis of financial linkages in general, including an overview of main methodological approaches to measure it. Secondly and more importantly, it is to use the Spillover Index (concept introduced by Diebold and Yilmaz, 2009) to examine the degree of stock market linkages in East Asia with special attention being paid to the position of Japan. There are several questions of interest. First of all, whether Japan maintains its hegemony in the region and to which extent is this position threatened by the rising economic importance of China. Second of all, it is the task to determine whether the intraregional stock market linkages in East Asia have been strengthening and whether this might be happening at the expense of financial

[1] So called Decoupling Theory (Park Y. , 2011).

linkages towards western developed economies. Thirdly, we will deal with the question, which markets have been the main sources of financial fluctuations in the Japanese stock market and on the other hand, which markets are the ones influenced by Japan the most.

The work is divided into multiple parts. The first part reviews the topic of financial linkage and its empirical measurement. It introduces theoretical definitions of the terms financial contagion and financial linkage, mentions main channels through which the financial markets influence each other, provides an outline of existing literature dealing with financial linkages and also offers to the reader an overview of main methodological approaches of measuring them. The second part introduces the international relations of Japanese financial markets with special attention being paid to the stock market. Moreover it also provides a literature review of empirical studies dealing with East Asian financial linkage. Finally, the third part concentrates on the empirical analysis of Japanese stock market linkages. For the purpose of the empirical analysis, the time series of daily stock price indices of 16 countries, consisting of the East Asian countries and major world economies in the time span 1995-2012 are analyzed. The data are extracted from the website stooq.pl. The attention is therefore paid not only to the status quo but also to the historical developments since 1990's with regards to the events such as the Asian financial crisis, international liberalization of East Asian economies or recent global financial crisis.

Apart from the methodological review, the main contribution of this work is the fact that it offers a complete picture of international interactions of Japanese stock market and its developments in the last two decades. While the existence of a different study of this scope is not known to the author, it is important to have such an understanding, most of all regarding the integration and liberalization processes that have been taking place in East Asia and that could affect the economic conditions in the region.

The main findings of the work suggest that while Japanese stock market has been opening towards predominantly western impacts, it has been exercising growing influence on East Asian countries. Moreover, even though the driving force behind

regional stock market movements has stem from the US, it is Japan and not China that intensifies its position of regional financial leader.

2. International Financial Linkages

2.1 Definitions

Intuitively, the financial linkage is understood as a degree in which the financial markets of different countries tend to move together.[2] While for some authors, who deal with the topic, is this intuition enough (e.g. Park and Fatemi, 1993), large part of the literature distinguishes between long-term and short-term interdependence. The short-term interdependence is then associated with periods of market unrest, while the long-term interdependence should be based on more or less permanent setting of international financial markets. Forbes and Rigobon (2002) define the ***financial contagion*** as increased cross-market interdependence after a shock to one country, which corresponds more to the short-term view. To describe the long term relationship, we will use the term financial linkage. ***Financial linkage*** can be understood as a broader term in a sense that it comprises the comovement during both periods of stability and shocks. In other words "*it is only contagion if cross-market comovement increases significantly after a shock. (...) any continued high level of market correlation suggests strong linkages between the two economies that exist in all states of the world."* (Forbes & Rigobon, 2002, p. 2224). As for the interaction between the two forms of financial interdependence, it seems plausible that high financial linkage in the long term increases the intensity of financial contagion when there is a large shock to one of the countries. On the other hand, it can happen that the effects of a shock are permanent, which causes not only contagion, but also increased financial linkages.

[2] In this sense, some authors (Pukthuanthong & Roll, 2009) also speak about ***financial market integration.***

An alternative definition of the financial contagion looks at the transmission channels through which the international financial markets influence each other. It rests on the idea that several of the transmission channels are well understood and that financial contagion is the interdependence that takes place in excess of these fundamental channels (Rigobon, 2002, p. 36). Consequently, financial linkage could be understood as the interdependence via the well explored channels. Unfortunately, this definition is quite vague and therefore does not offer much ground to the empirical testing. Nevertheless as it is of interest to this study, we will explore the main transmission mechanisms of the financial interdependence in the next sub-chapter.

2.2 Transmission channels

It is the capital mobility and free trade that have been perceived as hallmarks of cross-country market interdependence (Pukthuanthong & Roll, 2009, p. 214). Rigobon (2002, p. 6) further distinguishes between several kinds of transmission channels in relation to financial markets. They are the channels given by the ***real economic linkages*** (fundamental and financial channels) and channels given by the ***spread of information*** (investor behavior and liquidity channels). Rigobon (2002) relies these channels namely to financial contagion, however given our understanding of the relation between financial linkage and financial contagion mentioned earlier, they are very well the channels that influence financial linkages too.

The ***fundamental channels*** include international trade and setting of monetary and fiscal policies. Having significant volumes of mutual trade, the stock markets of the countries are likely to get influenced by the change in exchange rate of their currencies. An example of the causation is as follows. Currency devaluation in country A will reduce the cost of home goods vis-à-vis goods of the country B. The change in relative prices shifts demand toward country A and away from country B. Consequently, this increase in demand raises the expected future cash flow of

domestic companies and therefore increases their stock prices. Of course, the situation gets much more complicated in the context of globally interdependent markets. The transmission between two countries can then also take place e.g. through export of similar goods to the common third market,[3] however the causation stays similar. Common trade therefore increases the financial linkage of the countries and in the case of large shock to the exchange rate acts a transmission channel for the stock price contagion.

The theory also assumes that stock prices and interest rates of countries that share similar macroeconomic policies tend to move together. The precise mechanisms are difficult to summarize, as there is a wide range of examples. Rigobon (2002, p. 43) states that the most prominent is the one, where two countries have fixed exchange rate and high capital mobility. As soon as the foreign country for some, possibly internal, reason increases its interest rates, the home country is forced to increase its interest rates as well in order to prevent a capital outflow. Consequently, the home stock market falls, as the increased cost of funding reduces the expected future capital flows for domestic companies. The conclusion is therefore similar to the effect of foreign trade, similar macroeconomic policies are a factor that increases financial linkage and can act a transmission channel for both interest rate and stock price contagion.

The ***financial channels*** focus on the organization and functioning of the financial markets. The simplest case is the deregulation of financial markets with respect to the foreign capital. With the foreign capital coming to the country, the financial markets become susceptible to influences of the foreign economies. Moreover the financial regulation of the foreign country can then influence the home financial markets as well. Let us use the example of Rigobon (2002), who supposes the existence of a ***common lender*** for two countries[4] A and B, which is the banking sector of a third country C. If for some reason the default rate in the country A increases, to satisfy the regulations, the banking sector of the country C is forced to

[3] For details see Rigobon (2002, p. 42).

[4] Theory based on Kaminsky, Reinhart (1998).

call back the outstanding loans from the country B. However, for the country C this means a capital outflow that must be offset by increase in interest rates, which in turn puts pressure on the local stock markets. The existence of the common lender therefore increases the financial linkage of the two countries, because of the *"lack of sensitivity of the regulation toward the business cycle* (that) *creates the comovement in asset prices."* (Rigobon, 2002, p. 48) In case that the shock is of a larger extent, the extent of the financial contagion would most likely be also quite big.

The ***investor behavior*** channels drive the markets through investor beliefs. There are several basic theories that work with the concept of investor behavior, from which we will mention two. ***Multiple equilibrium models*** are models, where the investors *"use the crisis in one country as a signal that they should shift their thinking to expect* (the same) *in another country"* (Rigobon, 2002, p. 50), which pushes e.g. the stock prices in this country down as well. The easier it is to influence each other's beliefs among the investors from different countries, the bigger also the financial interdependence. Important is that those beliefs do not necessarily have to be based on economic reality. ***Herding*** on the other hand is investor collective behavior that causes inefficient market outcomes as a result of asymmetric information. Clearly the investor behavior channels are influenced by the information availability. If the investors are rational, higher information availability, e.g. with spread of IT technologies, could decrease the possibility of financial contagion. On the other hand, the spread of IT technologies also means excess of information, some of them of dubious quality that can be difficult for the investors to interpret correctly. In that case spread of IT technologies could have the opposite result.

Liquidity channels are the constraints on the activities of security market participants that affect the pricing of securities markets. According to Rigobon (2002, p. 54), the channels are given by the behavior of foreign investors. If for some reason a foreign investor e.g. a big hedge fund decides to reduce its holdings in the market (given some liquidity constraints), the domestic market participants can evaluate the situation in a way that the fund is arbitraging. The result is a drop in the prices. In other words the presence of foreign investors can result in an increase of the financial linkage.

To conclude the discussion on the transmission channels, the main factors that influence the financial linkage of a country seem to be the openness of the market towards international influences – such as liberalized trade and capital markets, but

also the investors' opinion on what the influence of foreign markets on the domestic one is.

2.3 Empirical testing

Financial linkage is usually measured either by interest rates or stock prices. Ji and Kim (2009) for example use different proxies for interest rates in one data sample - government bonds interest rates, money market interest rates, call rate and interbank rate. Majority of the literature however uses the stock prices (stock indices) returns. Moreover, because the stock prices are available both on intradaily and interdaily basis, it is possible to easily access daily returns data as well as daily variance of returns data. Coming back to the two forms of financial interdependence, intuition is that given its short time nature, it should be convenient to explore the financial contagion by measuring the interdependence of variances, whereas the linkages by measuring the interdependence of the returns themselves.

Methodologically, the very first attempts to assess financial linkages were built on the concept of gains from international portfolio diversification (Grubel 1968, Levy and Sarnat 1940, Gruber and Fadner 1971). The basic logic is that the more significant the gains from international portfolio diversification are, the smaller must the comovement of the concerned financial markets be. However, because the concept works on an indirect principle, its reliability is questionable. The most intuitive direct method to assess the financial interdependence is the use of ***correlation coefficients*** (Haney an Loyd 1978, Maldonado and Saunders 1981). The principle of these tests is straightforward, the bigger the absolute correlation between the markets, the higher their interdependency. While being limited in the beginning, the credibility of these tests increased substantially with the usage of more sophisticated methodology that enabled to deal with issues such as variable omission or heteroscedasticity bias (Forbes & Rigobon, 2002). This method has been most widely used to test explicitly for the financial contagion (Forbes & Rigobon, 2002, p.

2229), because assessing the correlation of stock markets can help us to get the answer on the question whether and to which extent there is a contemporaneous comovement in prices[5].

On the other hand, a large group of literature aiming more at explaining the long term relationships among international financial markets, i.e. the financial linkage, uses ***cointegration tests*** (Dwyer Jr & Hafer, 1988) and ***autoregression*** (Cheung & Mak, 1992)**.** These methods allow testing for financial linkage on multivariate level and they can also explain more about causal relationships between the countries.[6] From the econometric point of view, the financial linkage between two countries is then understood as the ability of past values of stock prices of a country *i* to explain movements in stock prices of a country *j*.

In conclusion, even though different approaches exist that can be more suitable to test for contagion or for linkages, neither of the approaches is able to distinguish clearly between the two forms of financial interdependence. It is because there is a good reason to believe that they influence each other. While the strong long term financial linkages between two countries can cause the contagion to spread more easily and increase thus its extent, on the other hand the financial contagion can increase the comovement of international financial markets in a longer horizon as well (Arshanapalli, Doukas, & Lang, 1995, p. 58).

We have seen that the empirical literature dealing with international financial interdependence is rich, nevertheless conclusive results are missing. Whereas researchers can usually agree on whether a financial contagion is present (Rigobon, 2002, p. 1), results of empirical studies dealing with financial linkage are mixed. Awokuse et al. (2009) argue that this might be given by the time-varying nature of international financial markets. For example, it is clear that market linkages might be strengthened by a financial crisis, but there is still no consensus in which extent this

[5] This type of relation is referred to as ***contemporaneous linkage*** (Kim, 2005, p. 340).

[6] This type of relation is referred to as ***dynamic linkage*** (Kim, 2005, p. 340).

crisis-induced strengthening is transitory or permanent. That is why some authors try to account for this possible time-variation by estimating the interdependence on a rolling basis (Awokuse et al. 2009, Yilmaz 2009, Fujiwara and Takahashi 2011). This enables them to assess the dynamic development of international financial linkage.

2.4 Methodological review

One of the aims of this work is to review the main methodological approaches that are used to measure international financial interdependence. We will therefore reserve the next few paragraphs to do so. As the term refers to the relations among several markets, we will look at the methods in a multivariate setting. We will first describe the vector autoregressive model and then explore different perspectives that this framework offers while dealing with stock market linkage. More concretely, we will look at correlation analysis, causality analysis and cointegration analysis. The purpose of this chapter is twofold. First, we want to give the reader the intuition on what are the main principles of the methods and second of all some parts of the chapter will serve as a methodological basis for the empirical part of this study.

2.4.1 Vector autoregressive model

One of the most powerful tools used to capture the interdependencies between multiple times series is called ***vector autoregressive model*** (VAR). As described by Tong et al. (2011, p. 301), all of the variables in a VAR are treated symmetrically by including for each variable an equation explaining its evolution based on its own lags ad the lags of all the other variables in the model. The use of VAR has been advocated by Sims (1980) as an alternative to structural models that does not suffer from identification restrictions. *"Sims also criticized the exogeneity assumptions for some of the variables in simultaneous equations models as ad hoc and often not backed by fully developed theories. In contrast, in VAR models all observed variables are treated as a priori endogenous. Statistical procedures rather than subject matter theory are used for imposing restrictions."* (Belsley & Kontoghiorghes, 2009, p.

281). Moreover as we will show, the major advantage of the VAR models is that they can account for causal relations between the variables in the system.

In the standard praxis, time series are assumed as a sum of deterministic and stochastic part (Belsley & Kontoghiorghes, 2009, p. 285)

$$y_t = \mu_t + x_t \qquad (2.1)$$

,where μ_t is the deterministic part and x_t is a purely stochastic process[7]. In other words *"the observable process y_t inherits its deterministic and stochastic properties from μ_t and x_t. In particular, the order of integration and the cointegration relations are determined by x_t."* (Belsley & Kontoghiorghes, 2009, p. 285). As we will see, both mentioned properties of stochastic processes – the order of integration and cointegration are of a central interest when dealing with the interdependence of time series.

Let us first formally state the definition of the **VAR process** and describe its estimation. Let us have a multivariate process given by (2.1), where y_t is a $N \times 1$ vector of N variables and $t = 1,2,\dots,T$ is the sample period. The i-th element of the vector y_t denoted as $y_{n,t}$ will therefore be the time *t* observation of variable $n = 1,2,\dots,N$. Furthermore the deterministic part μ_t is assumed to be zero, constant or linear trend and x_t is a purely stochastic process with a 0 mean that is assumed to be VAR process. Literature (Tong, Kumar, & Huang, 2011) defines a p-order VAR, denoted as *VAR (p)* by the following equation,

$$x_t = A_1 x_{t-1} + A_2 x_{t-2} + \dots + A_p x_{p-1} + \varepsilon_t \qquad (2.2)$$

, where A_i is a $N \times N$ parameter matrix for every $i = 1,2,\dots,p$ and ε_t is a $N \times 1$ vector of error terms satisfying following conditions:

$$E(\varepsilon_t) = 0$$

$$E(\varepsilon_t \ \varepsilon'_t) = \Omega$$

[7] For details on model and estimation for processes with deterministic part, consult e.g. Lütkepohl (2005).

$$E(\varepsilon_t \ \varepsilon'_s) = 0 \text{ , for every } s \neq t$$

, Ω is a $N \times N$ positive definite matrix and ε'_s is the transposition of ε_s for $s = 1,2, \dots, T; s \neq t$. In other words ε_t is zero mean white noise process such as that $\varepsilon_t \sim i.i.d.(0, \Omega)$. The *l*-periods back observation x_{t-l} is called the *l*-th lag of *x*. Thus a *p*-order VAR is also called a VAR with *p*-lags

As explained in (Belsley & Kontoghiorghes, 2009, p. 282), the stochastic process x_t can contain stochastic trend with properties similar to a discrete random walk (non-stationary stochastic component without tendency to revert to a fixed mean). A time-series variable x_t is called ***integrated of order d***, denoted $I(d)$, if this stochastic trend can be removed by differencing the variable *d* times. In other words, the series then becomes stationary. A process that is $I(0)$ is called ***stable***. For the VAR process x_t holds that it is stable if all roots of the determinantal polynomial are outside the complex unit circle:

$$\det(I_N - A_1 z - \dots - A_p z^p) \neq 0 \text{ for } |z| \leq 1.$$

The process x_t then has time-invariant means, variances, and covariance structure and it is called ***levels VAR***.

Estimation

Following Belsley & Kontoghiorghes (2009), we will show the estimation process on the levels VAR with omitted deterministic terms as given by the equation (2.2). Given our sample of size T, $x_1, x_2, \dots, x_T$, and p pre sample values $x_{-p+1}, \dots, x_0$, let us define following vectors.

$$X = [x_1, \dots, x_T,], \ \boldsymbol{X} = [X_0, \dots, X_{T-1},] \text{ where } X_{t-1} = \begin{pmatrix} x_{t-1} \\ \vdots \\ x_{t-p} \end{pmatrix}$$

$$A = [A_1, \dots, A_P,] \text{ and } U = [\varepsilon_1, \dots, \varepsilon_T,].$$

The model can be then written as

$$X = A\boldsymbol{X} + U$$

Estimating the N equations separately by the multivariate LS results in the estimator

$$\hat{A} = \left[\hat{A}_1, \dots, \hat{A}_P, \right] = X\boldsymbol{X}'(\boldsymbol{X}\boldsymbol{X}')^{-1}.$$

The stability of the process ensures the multivariate LS estimator $\hat{A}$ has an asymptotic normal distribution and its covariance matrix can be estimated consistently by

$$\hat{\Sigma}_{\hat{A}} = (X\boldsymbol{X}'/T)^{-1} \otimes \hat{\Sigma}_{\varepsilon} \qquad (2.3)$$

, where $\otimes$ is Kronecker product and $\hat{\Sigma}_{\varepsilon}$ can be estimated by

$$\hat{\Sigma}_{\varepsilon} = \frac{1}{T}\sum_{t=1}^{T} \hat{\varepsilon}_t \hat{\varepsilon}'_t \qquad (2.4)$$

According to Belsley & Kontoghiorghes (2009, p. 290) , it is possible to use this covariance matrix in the usual way to set up t, χ^2 and F statistics.

Model Specification

Levels VAR model specification involves the selection of the VAR lag order. The most often used method is the application of model selection criteria. Model selection criteria chooses the VAR order that minimizes them over a set of possible orders $m = 0, \dots, p_{max}$. Standard examples of these criteria are Aikaike information criterion (AIC), Hannan-Quinn criterion (HQ) and Schwarz criterion (SC).

$$AIC(m) = logdet\left(\hat{\Sigma}_m\right) + \frac{2}{T}mN^2$$

$$HQ(m) = logdet\left(\hat{\Sigma}_m\right) + \frac{2loglogT}{T}mN^2$$

$$SC(m) = logdet\left(\hat{\Sigma}_m\right) + \frac{logT}{T}mN^2$$

, where $\hat{\Sigma}_m$ is the residual covariance matrix for a model of order *m* given by (2.4). Denoting $\hat{p}(SC), \hat{p}(HQ), \hat{p}(AIC)$ the orders selected by SC, HQ and AIC respectively, the following inequality holds:

$$\hat{p}(SC) \leq \hat{p}(HQ) \leq \hat{p}(AIC) \quad (2.5)$$

Inequality (2.5) implies that the order selected by the three criteria might or might not be the same. As Belsley and Kontoghiorhes (2009, p. 296) put it, HQ and SC criteria are both consistent, that is, the order estimated with these criteria converges in probability or almost surely to the true VAR order *p* under quite general conditions, if p_{max} exceeds the true order. On the other hand, AIC tends to overestimate the order asymptotically.

Application to stock market linkage

In the context of analyzing stock market prices, usage of the level VAR is quite widespread. Even though stock prices are rarely stationary, looking at the behavior of stock returns rather than the price levels themselves usually fixes the problem. Let P_t be the price of a stock in time *t*, then the ***simple net return*** is defined as

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}}$$

Moreover, ***continuously compounded returns*** also called ***log returns*** are widely used as well. They are given by

$$r_t = log(1 - R_t) = logP_t - logP_{t-1}$$

Therefore, if P_t is a *I(1)* process, r_t is then *I(0)* process and the VAR levels model may well be an appropriate one to use. To simplify the matter, we will assume the stock prices time series to be pure stochastic processes when assessing the stock market linkages. The model is then given by the equation (2.2), where x_t is a vector of log returns of stock indices and *1,…,N* stand for different stock markets.

2.4.2 Correlation Analysis

The simplest and most intuitive method to research the comovements between variables is to look at its correlations. The correlation analysis itself can give us

evidence about the presence and degree of comovement, it cannot however serve as means to interpret causality between the variables. Having a simple two variable framework, the correlation between two random variables *X* and *Y* is defined as

$$\rho_{XY} = corr(X,Y) = \frac{cov(X,Y)}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_x)(Y-\mu_Y)]}{\sigma_X \sigma_Y}$$

, where σ_X, σ_Y are standard deviations and μ_x, μ_Y expected values of *X* and *Y* respectively. To mitigate the effect of variable omission, it is also possible to estimate mutual correlations of two variables that are part of some multivariate system such as levels VAR. In that case the estimates of pairwise correlations are to be calculated from the variance-covariance matrix given by (2.3).

Standard method of assessing the interdependence of stock markets analyzing the correlation is to compare the development of the correlation coefficients across time. If the VAR is used for estimating the correlation coefficients, the method is however subjected to a serious bias if the time series is heteroscedastic. It is because the estimates of the covariances are biased and conditional on variances of the time series. An increase in variance in the given period therefore disproportionally increases the estimation of correlation coefficients. In the case of stock market time series, which are often heteroscedastic, this can lead to misinterpretations. Because stock market turmoil periods are characterized by higher volatility, the financial interdependence during such periods can seem higher than it is. Forbes and Rigobon (2002) formally prove the bias and propose a correction. Because the correlation analysis is not the methodological approach used in the empirical part of this work, we will ask the reader to refer to their work for further details.

2.4.3 Causality Analysis

As already mentioned, an important feature of VAR model is the fact that it offers the possibility to analyze causal relations between the variables. The causality analysis can however not only determine whether the variables are in a causal relationship, but also give an insight on the intensity of such causality. Causality analysis is therefore an ideal tool to research development of financial linkages.

Granger Causality

Granger (1969) defined causality (hence Granger causality) in the context of VAR model as described by (2.2) stating that a variable $x_{1,t}$ is causal for a variable $x_{2,t}$ if the information in $x_{1,t}$ is helpful for improving the forecasts of $x_{1,t}$. Hence the Granger Causality is a measure of the presence of causality and it does not tell us much about its extent.

More formally Belsley & Kontoghiorghes (2009, p. 305) show that in a bivariate setting

$$\begin{pmatrix} x_{1,t} \\ x_{2,t} \end{pmatrix} = \sum_{i=1}^{p} \begin{bmatrix} \alpha_{11,i} & \alpha_{12,i} \\ \alpha_{21,i} & \alpha_{22,i} \end{bmatrix} \begin{pmatrix} x_{1,t-1} \\ x_{2,t-1} \end{pmatrix} + \varepsilon_t$$

, variable $x_{1,t}$ is not Granger-causal for a variable $x_{2,t}$ if and only if $\alpha_{21,i} = 0$ for $i = 0, \dots, p$, or in other words, $\alpha_{21,i}$ does not appear in the x_{2t} equation of the system for $i = 0, \dots, p$. Given the process stability, the testing for Granger causality would then be conducted as F test of the null hypothesis $H_0: \alpha_{21,i} = 0$ for $i = 0, \dots, p$. In the case that we are interested in the causal links between two variables in a higher dimensional system, the situation gets more complicated. The detailed overview of the methodology can be found in Lütkepohl (2005, p. 49).

Impulse Response Analysis

The impulse response analysis looks at the interdependence of multivariate time series in a different perspective. It tries to give an answer to the question what happens to an economic system, when an exogenous shock is given to it. The exogenous shock is understood as a unit change in one of the variables, while holding all the other variables non-changed. The responses of individual variables, which are specified as changes in their forecast errors given the shock to the system, are then examined. Let us now define the impulse responses more formally.

Following Belsley and Kontoghiorhes (2009, p. 307), given the Wold decomposition theorem, (e.g. Tong, Kumar, & Huang, 2011, p. 301) and ignoring the

deterministic term, any mean zero $I(0)$ VAR process can be represented in the infinite MA form

$$x_t = \sum_{j=0}^{\infty} \phi_j \varepsilon_{t-j}$$

, where $\phi_0 = I_N$ and the ϕ_j ($j=1,2,\ldots,$) are $N \times N$ coefficient matrices computed recursively as $\phi_j = \sum_{i=1}^{j} \phi_{j-i} A_i$, $A_i = 0$ for $i > p$. As explained by Lütkepohl (2005), the marginal response of $x_{n,t+j}$ to a unit change in $x_{m,t}$ holding constant all past values of x_t, is given by the (n,m) element of the matrices ϕ_j, viewed as a function of j. In other words the elements of ϕ_j represent responses to ε_t innovations (forecast errors). Since $\phi_j \to 0$ as $j \to \infty$ for stationary processes, the effect is not permanent.

However as Lütkepohl (2005, p. 58) adds, if the components are contemporaneously correlated, i.e. their covariance matrix Σ_ε is not diagonal, the impulse responses given by ϕ_j may be flawed. Therefore the orthogonalized shocks are used. A method widely used in literature is to apply the Cholesky decomposition on the noise covariance matrix to get $\Sigma_\varepsilon = PP'$ where P is a lower triangular matrix[8]. The orthogonalized shocks are then defined as $\xi_t = P^{-1}\varepsilon_t, \xi_t \sim (0, I_N)$ and the impulse response is given by

$$x_t = \sum_{j=1}^{\infty} \phi_j P P^{-1} \varepsilon_{t-j} = \sum_{j=1}^{\infty} \psi_j \xi_{t-j} \qquad (2.7)$$

Given (2.7) a visual representation of impulse response of a variable x_n on a shock to variable x_m can be constructed as a succession of *(n,m)*th elements of ψ_j, denoted as $\psi_{nm,j}$, where $j \to \infty$.

Applying impulse responses on the stock market dependence analysis using VAR is methodologically straightforward and similarly to correlation analysis a comparison of impulse responses given across time can be used to assess the intertemporal developments in causal relationships. The limitations of the method are however given by the problematic interpretation of the results. As Lütkepohl (2005, p.

[8] In theory any nonsingular matrix fulfilling the criteria $\Sigma_\varepsilon = PP'$ can be used (Lütkepohl, 2005).

59) argues, the orthogonalized impulse responses are dependent on the ordering of the variables in the system. In other words it is important which variable in the system stands for x_{1t} which for x_{2t} etc. The ordering cannot be determined by statistical methods, but has to be specified by the analyst. Lütkepohl (2005, p. 59) further claims that the ordering should be such that the first variable is the only one with potential immediate impact on all the other variables. The second variable may have an immediate impact on the last *N-2* components of x_t but not on x_{1t} and so on. Obviously, to specify such an ordering might be very difficult, especially for unknown complex systems in the context of stock market linkage.

Variance Decomposition and Spillover Index

Variance decomposition builds further on the impulse responses. It is however not the marginal responses, but the variance in marginal responses that stands in the center of attention. Put differently, the variance decomposition tries to *"explain how much of an observed variation in response is attributable to each of several shocks that are given to the system simultaneously"* (Tong, Kumar, & Huang, 2011, p. 306). The method therefore looks in detail on the dynamics of the forecast errors.

As Belsley & Kontoghiorghes (2009, p. 310) show, using the MA representation (2.7), the h-step forecast error can be expressed as

$$x_{T+h} - x_{T+h|T} = \psi_0 \xi_{T+h} + \psi_1 \xi_{T+h-1} + \cdots + \psi_{h-1} \xi_{T+1}$$

From this expression the forecast error variance of the *n*-th variable in the system can be shown (e.g. Lütkepohl, 2005, p. 63) to be

$$\sigma_n^2(h) = \sum_{j=0}^{h-1} \psi_{n1,j}^2 + \cdots + \psi_{nN,j}^2 = \sum_{m=1}^{N} \psi_{nm,0}^2 + \cdots + \psi_{nm,h-1}^2 \quad (2.8)$$

, where $\psi_{nm,j}$ again denotes the *(n,m)*th element of ψ_j. The term $(\psi_{nm,0}^2 + \cdots + \psi_{nm,h-1}^2)$ can be interpreted as the contribution of the *m*th innovation to the *h*-step forecast error variance of the variable *n*.

In the context of stock market linkages, Diebold and Yilmaz (2009) use the variance decompositions of a levels *VAR(p)* process and aggregate it into one single measure called the ***Spillover Index***. Let us first define variance shares to the *h*-step forecast error. ***Own variance share*** of a variable n is defined as $(\psi_{nn,0}^2 + \cdots +$

$\psi^2_{nn,h-1}$), whereas ***cross variance share*** of variable $m \neq n$ on variable n as $(\psi^2_{nm,0} + \cdots + \psi^2_{nm,h-1})$. The ***Global Spillover Index*** is then defined as

$$S_G = \frac{\sum_{j=0}^{h-1} \sum_{n,m=1(n\neq m)}^{N} \psi^2_{nm,j}}{\sum_{j=0}^{h-1} trace_{nm}(\psi_j \psi_j^T)} \times 100 \qquad (2.9)$$

, where the nominator stands for the ***Total Spillover***, i.e the sum of all the cross variance shares in the *VAR(p)* process, and denominator for the sum of all the variance shares, which is by construction of the error variance decomposition equal to *N*. The Global Spillover Index measures the share of cross variance shares on the total variation within the *VAR(p)* process and can be thus understood as a measure of interdependence among all the variables.

Following the same logic and fixing the variable *m* in the formula, the ***Individual Spillover Index*** (Fujiwara & Takahashi, 2011, p. 5) for the *m*th variable can be defined as

$$S_I^m = \frac{\sum_{j=0}^{h-1} \sum_{n=1(n\neq m)}^{N} \psi^2_{nm,j}}{\sum_{j=0}^{h-1} trace_{nm}(\psi_j \psi_j^T)} \times 100 \qquad (2.10)$$

The Individual Spillover Index then measures the contribution of the *m*th variable to the forecast error variance of all the other variables in the system.

To understand the principle of the methodology, let us state an example of a simple two-countries VAR, i.e. *N=2*, with forecast of *h*=1. The forecast error variances can be then written as

$$\sigma_1^2(1) = \psi^2_{11,0} + \psi^2_{12,0}$$

$$\sigma_2^2(1) = \psi^2_{21,0} + \psi^2_{22,0}$$

, where $\psi^2_{12,0}$ and $\psi^2_{21,0}$ are cross variance shares and $\psi^2_{11,0}$ and $\psi^2_{22,0}$ represent own variance shares. The total spillover is then defined as the sum of cross variances, in this case $\psi^2_{12,0} + \psi^2_{21,0}$, and the Global spillover index is given by

$$S_G = \frac{\psi^2_{12,0} + \psi^2_{21,0}}{\psi^2_{11,0} + \psi^2_{12,0} + \psi^2_{21,0} + \psi^2_{22,0}} \times 100 = \frac{\psi^2_{12,0} + \psi^2_{21,0}}{2} \times 100$$

Furthermore the Individual Spillover indices are

$$S_I^2 = \frac{\psi^2_{12,0}}{\psi^2_{11,0} + \psi^2_{12,0} + \psi^2_{21,0} + \psi^2_{22,0}} \times 100 = \frac{\psi^2_{12,0}}{2} \times 100$$

$$S_I^1 = \frac{\psi_{21,0}^2}{\psi_{11,0}^2 + \psi_{12,0}^2 + \psi_{21,0}^2 + \psi_{22,0}^2} \times 100 = \frac{\psi_{21,0}^2}{2} \times 100$$

The variance decomposition and spillover index represent a powerful tool while analyzing stock market linkage in multivariate setting. Not only the influence of one country on another, but also the influence of one country on a set of other countries and finally the general level of linkage within the system can be examined. Moreover, applying the methodology intertemporally, e.g. in a rolling data window, enables to analyze the developments across time as well. Unfortunately, because the forecast error variance builds on the same principle as impulse responses, its interpretation is also subject to similar criticism. In other words, the results can again vary depending on the ordering of the variables in the system.

2.4.3 Cointegration Analysis

Up until now, only stationary stable processes corresponding to the VAR levels representation have been considered. Transforming the stock indices price levels into returns enables to apply the associated methods as the transformation removes possible trends and deterministic patterns. In the same time however the transformation can cause a loss of possibly important information that these trends and patterns contain. This is why a different approach to the stock market linkage analysis that allows analyzing non-stationary processes has been used. The approach is based on a special property of nonstationary processes called cointegration.

Engel and Granger (1987) came up with the term cointegration to describe a state, where two or more processes are driven by the same stochastic trend. This trend ensures that there is a particularly strong relation among them. Such variables *"move together in the long run, although they can drift apart in the short run"* (Belsley & Kontoghiorghes, 2009, p. 283).

Let us define the term more properly. Engel and Granger (1987) defined that a vector of processes x_t is called ***cointegrated*** if

1) all the processes in x_t are $I(d)$

2) a vector $c \neq 0$ exists such as there is a linear combination $c'x_t$ that is of integration order $b < d$

Given of $I(0)$ and $I(1)$ processes that are most widely mentioned in praxis, a leading example of cointegration would be a vector x_t that is $I(1)$ and for which exists a vector *c* such that $c'x_t$ is $I(0)$. The linear combination $c'x_t$ is then called a cointegration relation and the components of x_t are cointegrated.

Testing for cointegration in a multivariate setting can be done given the ***vector error-correction model (VECM)***, which is a special form of VAR(p) for $x_t \sim I(1)$ process. The basic idea is that *"a proportion of disequilibrium* (of a model) *from one period is corrected in the next period."* (Engle & Granger, 1987, p. 254). More formally, following Belsley et al. (2009, p. 286) let us reparametrize the expression (2.2) by subtracting x_{t-1} on both sides of the equation and rearranging terms to obtain the VECM. We get

$$\Delta x_t = \Pi x_{t-1} + \Gamma_1 \Delta x_{t-1} + \cdots + \Gamma_{p-1} \Delta x_{t-p+1} + \varepsilon_t \quad (2.11)$$

, where $\Pi = -(I_K - A_1 - \cdots - A_p)$ and $\Gamma_j = -(A_{j+1} + \cdots + A_p)$ for $j = 1, \ldots, p-1$. Thus the term Πx_{t-1} is the only one that includes $I(1)$ variables and consequently contains the cointegration relations. The term is therefore referred to as the ***long-run parameter*** or the ***error correction parameter*** of the model. On the other hand the short run movements of the variables are determined by the Γ_j, which are sometimes called ***short-run parameters***. The rank *r* of the matrix Π states the number of linearly independent cointegration relations among the components of x_t and it is called the ***cointegrating rank***. It is those cointegration relations that represent the long term equilibrium economic relations among variables. The higher the rank of the matrix, the stronger the common long run stochastic trend that drives the variables.

As Belsley et al. (2009, p. 297) point out, while a great number of proposals have been made for determining the cointegrating rank of a VAR process, the most general seem to be the Johansen likelihood ratio. Johansen approach considers the following hypotheses:

$$H_0(r_0): rk(\Pi) = r_0$$

$$H_1(r_0): rk(\Pi) > r_0 \, , r_0 = 0, \ldots, N-1$$

The cointegrating rank specified in the first null hypothesis that cannot be rejected is then chosen as the estimate for the true cointegration rank *r*. If all the null hypotheses can be rejected, no cointegration relations among the variables are present and the process should be treated as *I(0)* by the levels VAR model[9].

In the context of financial linkage, Forbes and Rigobon (2002) claim that testing for intertemporal changes in cointegrating rank is especially suited to examine the relations between markets over long periods of time, because by construction it does not account for the short term increases. Even though it is plausible that cointegration could test for long term effects such as greater trade integration or higher capital mobility, the intertemporal application is somewhat problematic. It seems not to have such an informational value as other mentioned methods when analyzing the financial linkage for two reasons. Firstly it does not deal with the causality issue and secondly its power to quantify the cointegration that is derived only from determining the number of cointegrating relations is quite poor (see e.g. Awokuse et al. (2009), who apply the tests for cointegration rank on a rolling window basis on stock indices data set).

[9] For more details on VECM see e.g. Lütkepohl (2005, p. 237).

3. International relations of Japanese financial markets

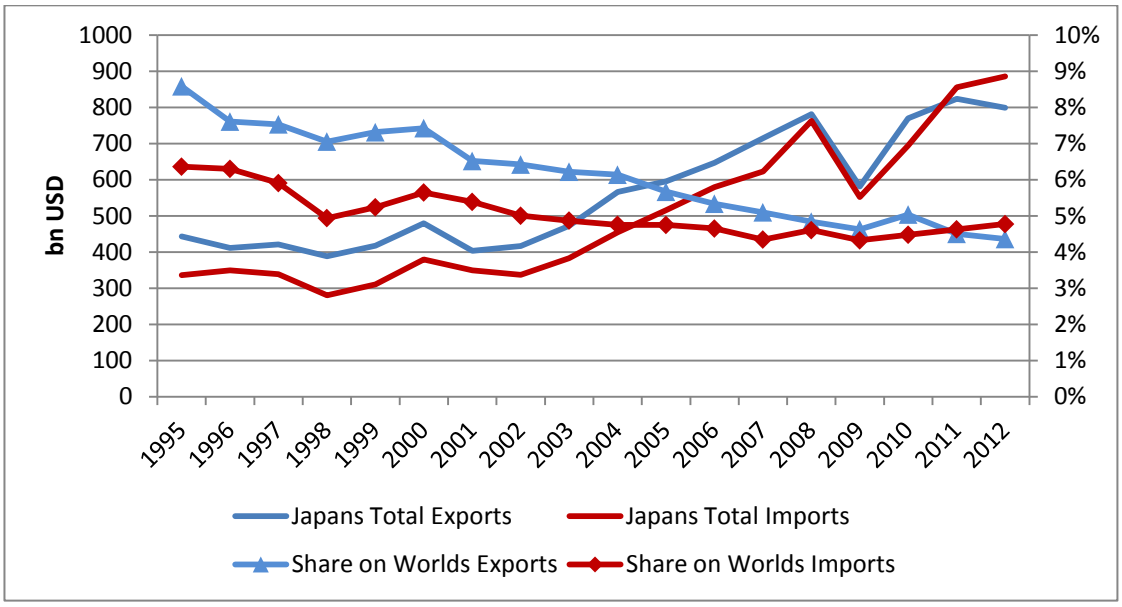
In the Chapter 2.2, we have given an overview of various channels that allow financial markets of different countries to have impact on each other and concluded that it is mainly the openness towards influences of the trade and capital markets that plays significant role. Because the empirical part of this work aims at examining the financial linkages of Japanese stock markets, we will now explore the international setting of Japanese economy concentrating on the stock markets. This chapter will then serve us as a basis for interpreting the empirical results.

We will pay attention to the foreign trade, financial markets and their development since the mid 1990's. Moreover, because we focus on the position of Japan within East Asia, we will also look at the intraregional trade and financial integration process in this region including the main empirical literature. In this context it is interesting to point out the decoupling theory. The term decoupling here relates to the weakening of linkages between East Asia and the rest of the world, manly the western developed economies. Park (2011, p. 3) states that the term decoupling *"refers to the phenomenon of a weakening of the impact of demand and supply shocks emanating from the advanced countries on the economic performance of East Asian economies or their growth, which has become more independent from cyclical developments of the global economy."* The process then involves both trade and financial linkages. As Park however adds *"to some it* (East Asian decoupling) *is a reality; to many it is a myth"*, because no conclusive resolution has been agreed yet among the researchers. In the empirical part of this work we will among other take notice of this phenomenon and try to determine if it concerns East Asian and Japanese stock market.

3.1 Japanese Foreign Trade

International trade relations are one of the factors that can influence financial linkages. When we look at the developments of Japanese foreign trade flows during the observed period depicted in the Figure 3.1.1, we see that while they were on a quite stable level up until 2002, both exports and imports grew substantially in the years preceding the slowdown of Japanese economy that was a result of the global financial crisis. Nevertheless, the growth in trade has been since then resumed. We can summarize that the yearly levels of both imports and exports were in between USD 300 bn and 500 bn in the mid 1990's, but reached twice as much 17 years later. This strengthening of international trade could have a potential to increase Japanese financial linkages. In the case of exports, it means that Japanese companies and their stock might have gotten more dependent on the developments in foreign markets. However, in the case of imports, it is important to notice that the growth of Japanese trade relatively to the rest of the world was not that prominent. While the Japanese import stood for more than 6% of the total world imports in 1995, it has been less than 5% in 2012. This could be interpreted in a way that the potential of Japanese markets to influence foreign stock through foreign trade was rather diminished during the period.

Figure 3.1.1: Japanese trade flows (1995 – 2012, bn USD)



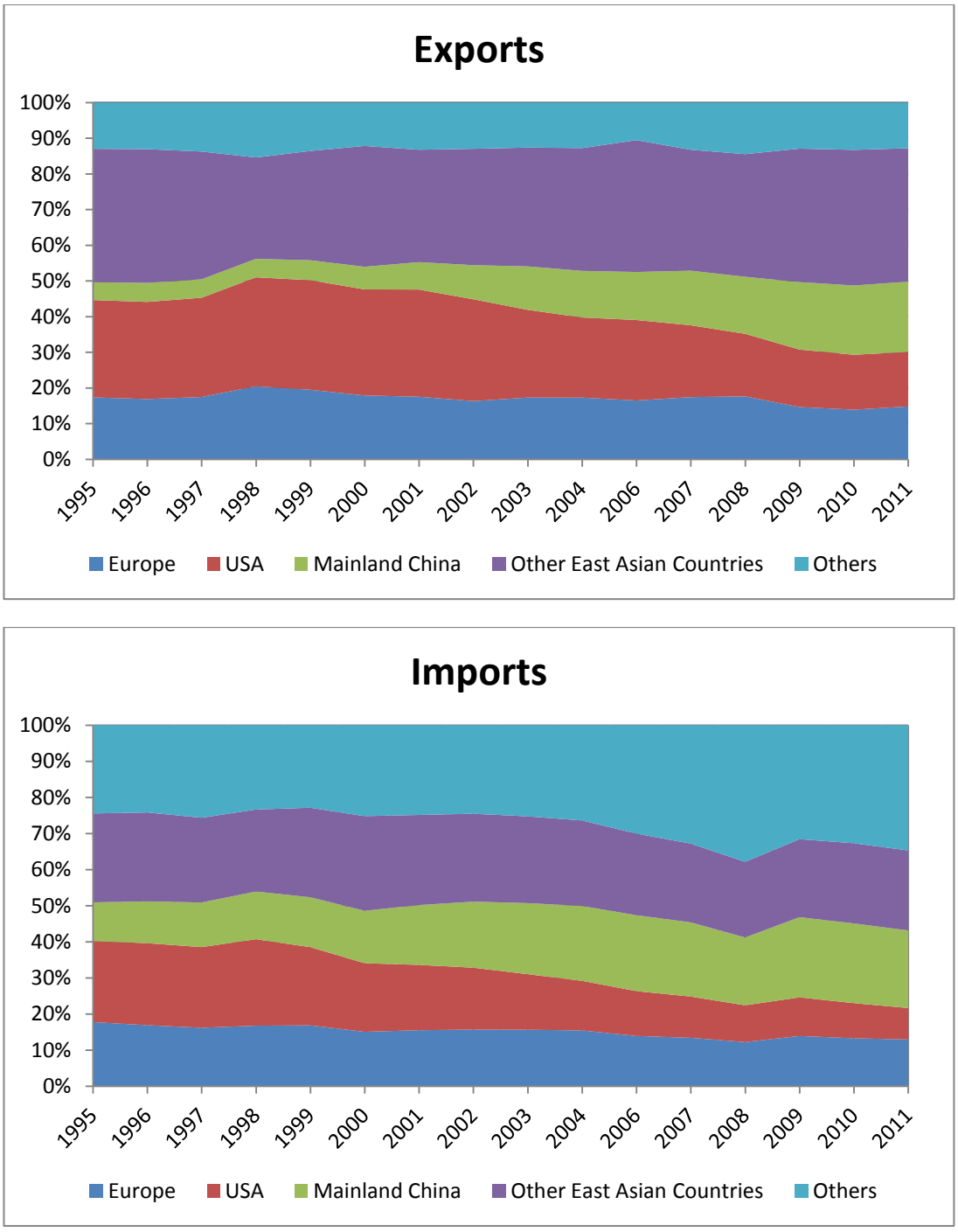
Source: WTO (http://stat.wto.org)

Because this work deals with financial linkages of Japan and countries of different regions of the world, it might be helpful to look at the developments in regional structure of Japanese trade flows represented by the Figure 3.1.2 as well. For Japanese exports we can observe that the share belonging to the Other East Asian countries[10] together with Mainland China increased from around 42% in 1995 to almost 60% in 2011 and on the other hand the share of US dropped from 27% to 15%. This might indicate that there is an increased potential of East Asian markets to influence Japanese stock markets. In this context however, it is necessary to point out the vertical structure of East Asian trade. As opposed to the horizontal trade structure, where the whole production takes place in the exporting country, in the case of vertical integration the production is geographically fragmented and the trade volumes might be misleading when we want to assess the interdependence of different markets. In the case of East Asian exports, the typical trade structure is such that Japan uses East Asian countries as production hubs for its exports that eventually head to the western markets (Europe and US). Just to illustrate this phenomenon, from around USD 800 bn of imports to Mainland China in 2006, more than 55% were again re-exported (He, Cheung, & Chang, 2007, p. 27). The dependence of Japanese exports on the western economies therefore might not have decreased as opposed to what the trade flow data indicate. Consequently, it is questionable if we could expect relative increase in potential of East Asian countries and China to influence Japanese stock markets via trade flows. As for the imports, Japan is one of the world's leading importers of raw materials, which explains high proportions of imports from Middle Eastern countries[11] and East Asian countries. Concerning the changes in proportions, apart from decrease in US share from 23% to 9%, the growth of China imports that increased from 11% to 22% is also a substantial change. Whether this could mean that Japanese market becomes more important for the Chinese stock market and less for the US stock market is questionable, all the more so that the importance of Japan as an importing country decreased as we have seen previously.

[10] ASEAN + Taiwan, Hong Kong, South Korea

[11] In the Figure 3.3.2 contained in Others.

Figure 3.1.2: Regional Structure of Japanese trade flows (1995 – 2012, %)



Source: Statistical Bureau of Japan(http://www.stat.go.jp)

3.2 Japanese Financial Markets

3.2.1 Deregulation of the financial markets

Even though the foreign countries pressured Japan to deregulate already since the 1980's, it was first during the late 1990's, when the government took the deregulation agenda seriously. As commented on by Ujiie (2002, p. 19) the change in government stance was given by various environmental factors that emerged as consequences of the burst of economic bubble in 1990. Among others it was the non-performing loan crisis caused by the decline in stock prices and real estate and the deterioration of competitiveness of Japanese financial markets that manifested itself for example by decreasing number of foreign companies listed on Japanese stock market (see the next subchapter). As an answer to these issues that were beginning to threaten the overall health of economy, Japanese government was forced to switch from the gradualist approach towards reforms to implementation of wide-range, comprehensive changes. The goal of the reforms was twofold, firstly it was to maintain the stability of the existing financial system and secondly then to *"foster the development of financial industry and to develop a financial system infrastructure on a par with that in the leading global financial market"* (Ujiie, 2002)

To respond to the first goal, wide measures to liquidate Japanese banks and other financial service institutions took part throughout the 1990's (for details see Ujiie, 2002, pp. 20-26). What is however more important when examining the Japanese financial linkage, a reform package to achieve the second goal - to transform Japanese financial market into a global one - was announced by Hashimoto legislation in 1996. The reform package, sometimes called the Japanese Big Bang with a reference to the 1986 deregulation of the London Stock Exchange, aimed at stock and all other financial markets and its implementation took place from 1997 to 2001. The most important single measure was probably the liberalization of capital transactions between domestic and overseas entities (effective from April 1998). Ujiie (2002, pp. 27 - 31) states a detailed list of measures introduced and divides them into main groups: a) measures supporting new asset management alternatives (investment trusts, derivative instruments), b) measures facilitating companies raising capital from capital markets, c) measures increasing the efficiency of Japan's capital market, d) measures to ensure the fairness of transactions. Rather than going through

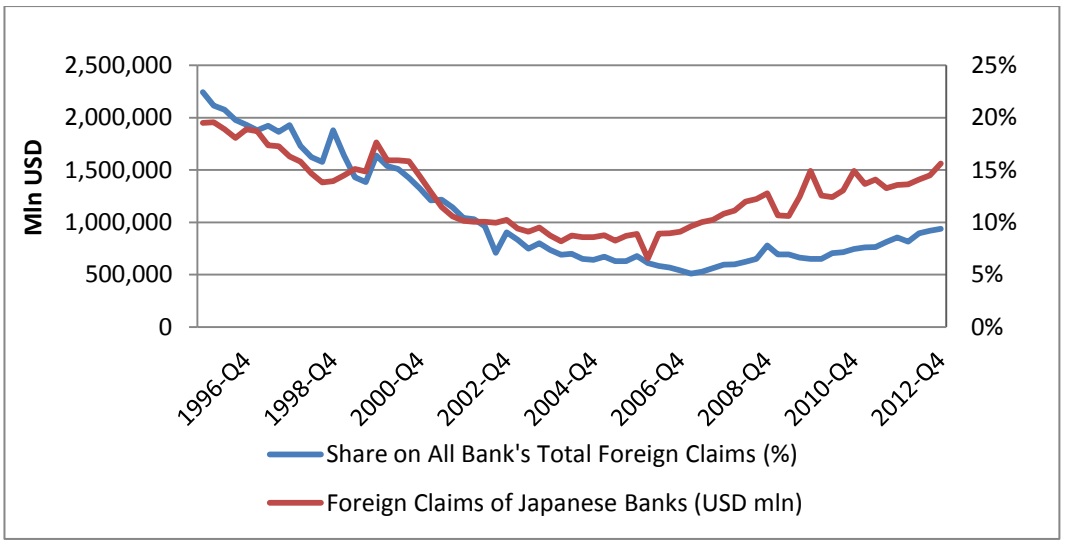
each of them individually, for our purpose it is enough to say that the measures aimed at making the Japanese financial markets more attractive to both domestic and foreign investors.

In the context of capital flows liberalization it is interesting to look at the developments of foreign claims of Japanese banks and on the other hand claims of foreign banks in Japan. As we stated in the Chapter 2.2, these developments are in relation to financial linkages. From the Figures 3.2.1 and 3.2.2, we can observe that the foreign claims of Japanese banks decreased significantly from 1995 up until 2007 in both absolute value and as a percentage of the all bank's total foreign claims. Whereas the foreign claims of Japanese banks reached up to 23 % of the total banking foreign claims in 1995, they bottomed at the levels around 5% in 2007. This shows that as for the banking sector, the reforms took place during a long period of time, as the influence of bad-loans crisis extended well to the first decade of the new millennium – the amounts of non-performing loans peaked in 2002 and reached a stable level first in 2006 (Hoshi, 2011, p. 2). Since 2007 however both the share, which reached almost 10% at the end of 2012, and the absolute level of foreign claims of Japanese banks have been growing. As commented on by the Wall Street Journal (Dvorak & Fukase, 2009), this might be given by the fact that *"many European and US lenders are squeezed by write-offs from recent financial crises and a crunch on capital."* The same source states that in some areas the increase in presence of Japanese banks is even larger – the Japanese banks had provided more than 14% of the world's syndicated loans versus about 6% in 2007. This growing trend could have influence on Japanese financial linkage, as the foreign loans heighten the susceptibility of the Japanese financial sector towards economic conditions overseas. Moreover, even though the detailed statistics of the regional structure of claims of Japanese banks are not available[12], taking in consideration Park and Bae (2002, p. 71), it seems that the shares of claims on East Asian countries strongly diminished in favor of the claims towards developed economies in reaction to the Asian Financial Crisis. This signifies that the western developed countries

[12] Japanese banks do not report the foreign claims to BIS according to the countries they flow into.

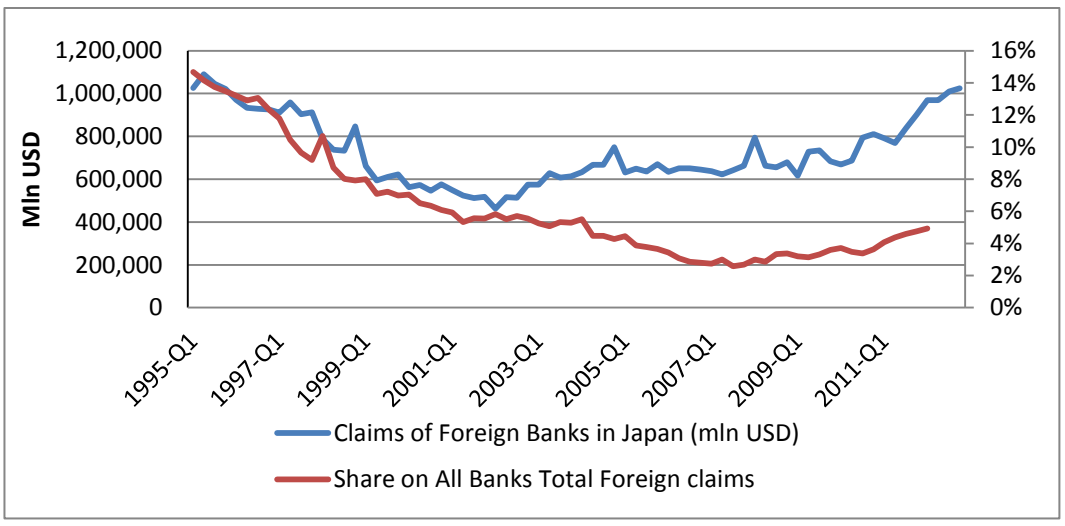
could have increased its potential to influence Japanese stock markets via banking industry.

Figure 3.2.1: Foreign claims of Japanese Banks (1996 – 2012, mln USD)



Source: Bank of International Settlements (http://stats.bis.org)

Figure 3.2.2: Claims of Foreign Banks in Japan (1995 – 2012,mln USD)



Source: Bank of International Settlements (http://stats.bis.org)

Claims of foreign banks in Japan then halved from around 1 trillion USD in 1995 to 500 billion USD in 2002 and since then started to grow back to reach the 1 trillion volume in 2012 again. However as for the share on all bank's foreign claims, it sharply decreased from 14% to 5%. The development therefore seems to support weaker dependence of foreign banking on Japan and therefore lower potential of Japan to influence foreign markets via this channel.

3.2.2 Stock Market Historical Developments

Let us now concentrate on the developments of the Japanese stock market itself. We will pay attention particularly to the factors that could influence the financial linkage such as the presence of foreign capital. Generally, the Japanese stock market has belonged among the largest in the world. The trading occurs on two main whole country level exchanges, the Tokyo Stock Exchange (TSE) and the Osaka Securities Exchange (OSE), which are complemented by regional exchanges that trade mainly in local stocks. The TSE dominates the Japanese market and accounts for the majority of all stock trading in Japan[13]. We will therefore take it as a representative stock exchange for Japan.

The TSE is divided between three sections that differ according to the listing criteria. The ***First Section*** that has constantly accounted for more than 95% of the capitalization contains the stock for the large corporations, the ***Second Section*** contains medium-sized companies and the ***Mothers market*** is the market for high growth and emerging stocks (including foreign stocks) that was newly established in 1999 as a part of the Big Bang reforms. Concerning the total number of listed companies, it has grown from 1791 in 1995 to 2292 in 2010, but he share of foreign stock listed has decreased tenfold from 5% in 1995 to 0,5% in 2012 (see the Table 3.2.1).

[13] Long term around 90% of the Japanese stock trading volume has been occurring on the TSE. (TSE Factbooks 1995 – 2012, www.tse.or.jp/english).

As the Figures 3.2.3 and 3.2.4 show, the total capitalization of the exchange in the period 1995 – 2012 peaked at around 5 trillion USD in the late 1990's and is currently (2012) around 3,5 trillion, which is roughly the same as in 1995. The share of the TSE capitalization on the total world's stock capitalization has however decreased from 9% to 6% in the same period. On the other hand, when we look at the structure of the share ownership (Figure 3.2.5), we can see that while it has been dominated by financial institutions, their share has decreased from 43% in 1995 to about 30% in 2012 and this decrease has happened mostly in favor of the foreign investors[14]. They as a group increased their share from 12% in 1995 to almost 27% in 2011. We can also see that even though there has been a decline in their share related to the global financial crisis after the year 2007, their position bottomed in 2009 and started to recover since then. It therefore seems that while the Big Bang reforms might not have been that successful in increasing the capitalization of TSE and the number of foreign stock traded, they have had effect on attracting the foreign capital into the country.

Table 3.2.1: Tokyo Stock Exchange listed companies (1995 – 2010, pcs.)

	TSE listed companies	
	Domestic	Foreign
1995	1714	77
2000	2055	38
2005	2323	28
2010	2280	12

Source: TSE Factbooks (1995 – 2012), www.tse.or.jp/english

For the purpose of this work it is also interesting to look at the development of the cross border capital flows (Figure 3.2.6). Both inbound and outbound[15] securities investments have increased significantly since 1995, which was most likely a consequence of the liberalization of foreign transactions in 1998. The inbound ones

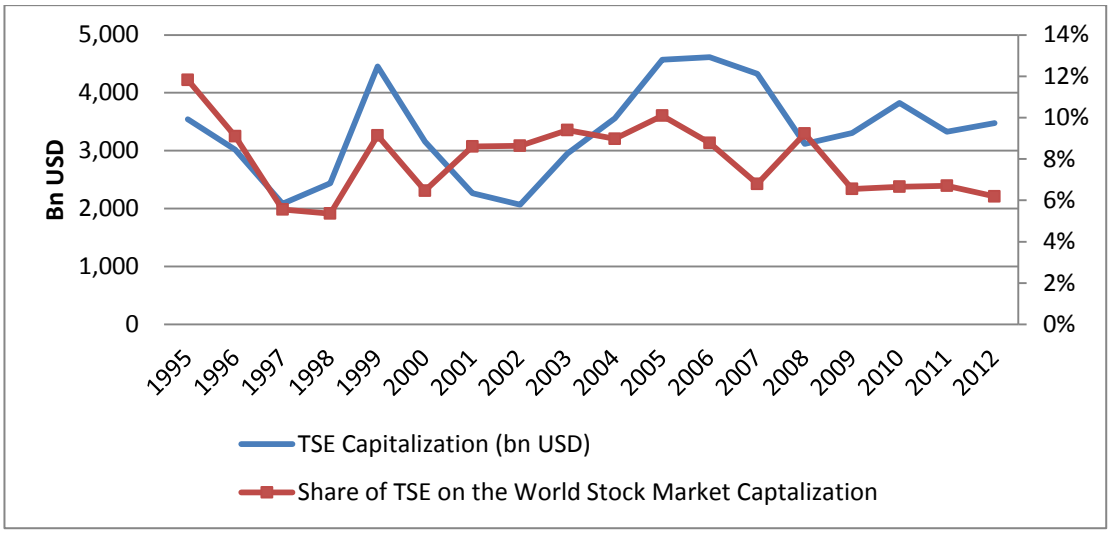
[14] The term „foreigners" indicates foreign individuals and foreign corporations.

[15] Inbound investments are sale and purchases of non-residents of Japan. Outbound are sale and purchases of Japanese residents.

Figure 3.2.3: Tokyo Stock Exchange Capitalization (1995 – 2012, bn USD, monthly)

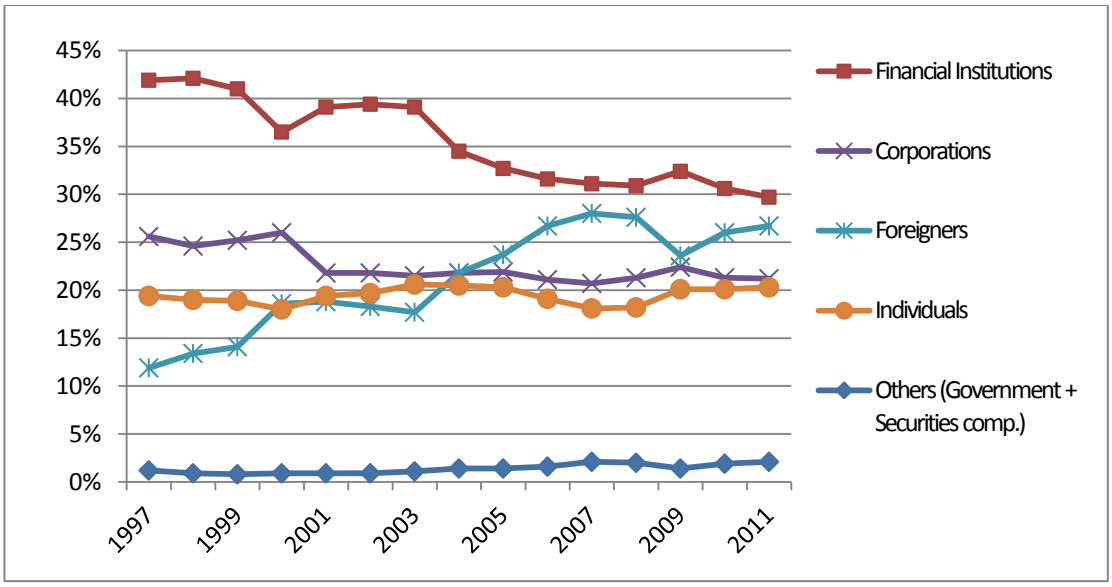
Source: TSE Factbooks (1995 – 2012), www.tse.or.jp/english

Figure 3.2.4: Tokyo Stock Exchange Capitalization (bn USD, yearly)



Source: World Federation of Exchanges, http://www.world-exchanges.org/statistics/annual-query-tool

Figure 3.2.5: Tokyo Stock Exchange Share ownership by type of investor (%)



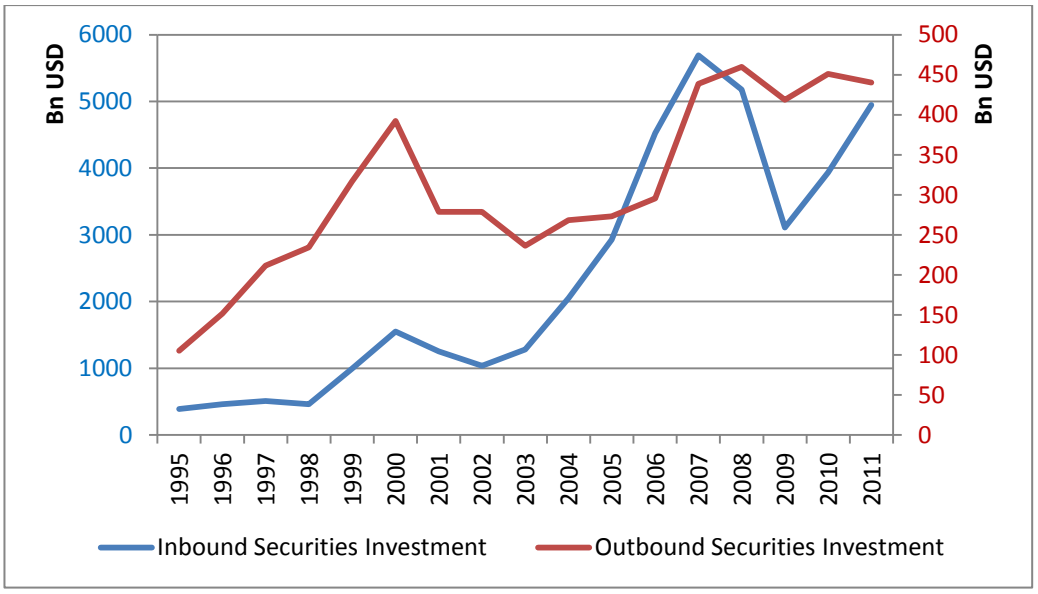
Source: TSE Factbooks (1995 – 2012), www.tse.or.jp/english

then grew at a faster pace (in 1995 outbound investments amounted to almost 27% of the inbound, in 2011 it has only been 8%). Their volumes rose from USD 370 bn in 1995 to almost USD 6000 bn in 2007. There was a sharp fall following the financial crisis in 2007, but the inbound investments revived quickly and were again reaching to USD 5000 bn in 2011. As for the outbound investments their reaction to the world financial crisis was not that prolific, on the other hand there was a significant decline after the year 2000. The reason of this decrease might possibly be connected to the stock market downturn in the world markets that followed the long term bullish market. Consequently the Japanese investors shifted to domestic shares and also foreign bonds – domestic bonds were not a suitable option given the new wave of quantitative easing of the Bank of Japan that drove the interest rates down. The decrease was again reverted in 2007, when the outbound securities investments increased to about USD 450 bn. Nevertheless it seems that the increase in cross border capital flows could have an impact on the Japanese financial linkage.

As for the regional structure of the cross boarder capital flows, the majority of both inbound and outbound security investments consists of the capital flows with the US and the EU, who together stood for more than 80%. The data of Japanese Ministry of Finance are limited, but it seems that while the proportion of the inbound share investment from the US had decreased in the period before the financial crisis of 2007, the opposite held for the EU, who therefore might be influenced by the

developments on the Japanese stock market more strongly. Also the inbound share investment from the ASEAN countries strengthened relatively to the other regions. This is not the case of outbound investment, ASEAN countries stayed out of the central attention of the Japanese equity investors in the period mentioned. The attention belonged mainly to the bullish US stock market that alone accounted for about 60% of the total outbound investments.

Figure 3.2.6: Japanese inbound and outbound securities investments (1995 – 2012, bn USD)



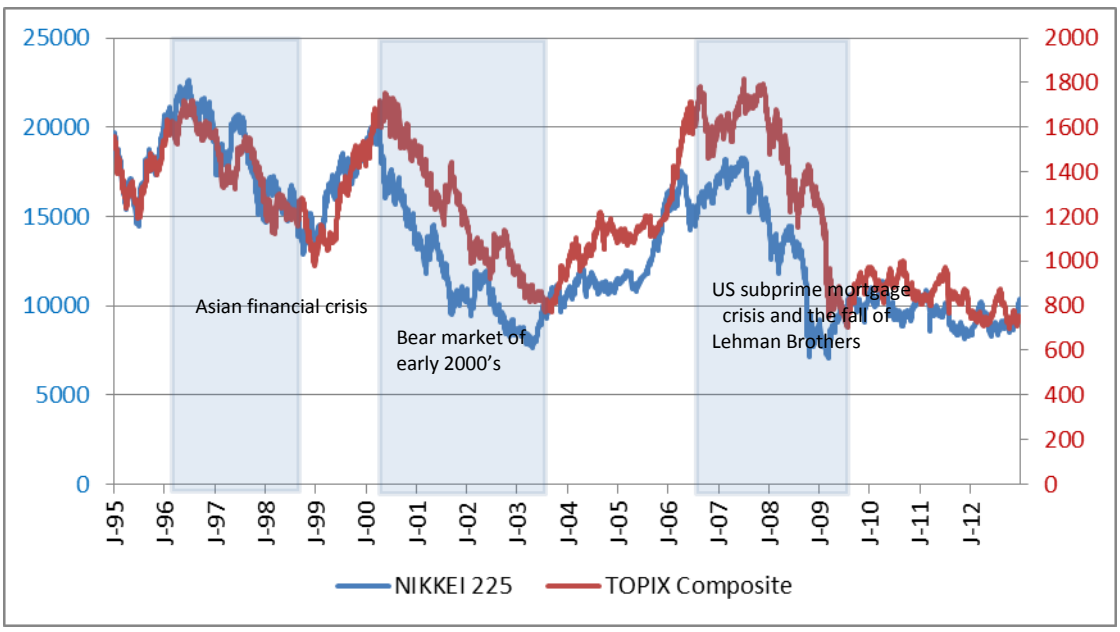
Source: MOF Statistics - "Securities at Home and Abroad" and "International Transactions in Securities", www.mof.go.jp/english

The main Japanese stock market indices are the Nikkei indices (sometimes also called the "Japanese Dow"). They are published by Nihon Keizai Shimbun, a leading Japanese business newspaper[16]. The family of Nikkei indices comprises several kinds, but it is the Nikkei 225 that is regarded as a benchmark stock index for the Japanese Market. Nikkei 225 is a price weighted index that has been calculated continuously since September 7th 1950, consisting of 225 components that belong

[16] 'Nikkei' is an abbreviation of 'nihon keizai'. 'Nihon' is Japanese for 'Japan', while 'keizai' means 'business, finance, economy' and so on.

among the most actively traded issues of the First Section of the Tokyo Stock Exchange (therefore, the Nikkei 225 only includes domestic shares). Index components are reselected each year by ranking stocks based on trading volume, trading value and market capitalization. Widely used are also TOPIX indices published by the TSE. As opposed to Nikkei, they are market capital weighted and since June 2006 also free float weighted[17]. The main index from the TOPIX family is the TOPIX Composite, which is a composite index of all the stock listed in the First Section of TSE (again only domestic stocks are included). Figure 3.2.7 shows the historical development of both indices. They unanimously show the main developments in the Japanese stock markets. There were three major downturns in the period between 1995 and 2012: the Asian financial crisis in 1997, Bear market of the early 2000's and the global financial crisis in 2007.

Figure 3.2.7: Historical developments of the main TSE indices (1995 – 2012)



Source: www.stooq.pl

[17] Free float refers to the percentage of a company's shares that is freely available for purchase; it therefore excludes shareholdings by the likes of controlling or strategic shareholders, governments and government agencies, which can account for a significant proportion of the equity in some companies.

3.3 East Asian Financial Integration

In respect to the financial integration, there are two spheres that are of interest. First of all it is the common monetary and fiscal policies, second of all it is the liberalization of individual markets. Regarding the common monetary and financial policies in the East Asian region that potentially aim at deepening the economic integration, Sally (2010) provides a description of the few initiatives that took place, but as he states they *"are all "soft" or "middle-strength" ideas, not "hard" proposals for exchange-rate and monetary coordination or harmonization of financial regulations. One harder proposal – for an Asian Monetary Fund – was tabled by the Japanese government in response to the Asian financial crisis in 1997/8. It was promptly shot down by the US administration as an unwelcome rival to the IMF."* (Sally, 2010, p. 11)

One of the few measures that have been at least partly implemented is the Chiang Mai Initiative (CMI), a network of currency-swap arrangements among ASEAN+3[18] countries, which was proposed in 2000 as a direct response to the Asian financial crisis. The main cause of the crisis were slumping currencies that caused stock devaluations among the countries in the region. Consequently, the CMI is *"intended as a precautionary crisis-preventing measure by increasing the availability of liquidity* (to fight currency speculations) *and instilling market confidence"* (Sally, 2010, p. 11). Because it is a precautionary measure, we cannot say that it should have a direct influence on the financial integration or the financial linkage, all the more so that its applicability is limited – it has not been used during the global financial crisis of 2007. Furthermore, there is the Asian Bond Fund, whose aim is to foster the often underdeveloped regional bond markets and to diversify the reliance on bank lending. Its size is however very limited and the Asian Bond Initiative, which proposed more concrete measures how to deal with the problematic, has not been quite successful in implementation (Sally, 2010, p. 12). Other measures such as the establishment of an Asian Currency Unit, modeled on the ECU, which

[18] ASEAN + China, Japan, South Korea

would help to reduce the dependence on the US dollar, or the establishment of an Asian Financial Stability Dialogue, which should serve as a forum for policy dialogue on financial regulation, are however still in the form of proposals and their implementation in the near future is not very likely.

While it is not the common monetary and financial policies that act as a strong means of financial integration in the East Asian region, it might be the liberalization of financial markets of individual countries that could have direct influence on the financial linkages in the region. Park and Bae (2002, p. 5) state that the term financial liberalization most often refers to the removal of restrictions on capital account transactions that will increase mobility of capital between countries. In the next two paragraphs, we will therefore present a basic overview of capital restrictions policies in the East Asian Countries.

The main trigger of capital movement liberalization were the requirements of IMF that were conditioning the rescue measures following the Asian financial crisis in 1997. South Korea that historically belonged among the most protectionist markets announced the liberalization plan in 1998. Its implementation took place throughout the early 2000's and included capital account controls removal and partial deregulation of both overseas investments for domestic investors and inland investments for foreign investors (for details see e.g. Choi, 2009). Indonesian liberalization concentrated mainly on FDI deregulation to encourage inflows of foreign capital. Main measures were introduced already in 1998. Similarly Thailand government has not taken any steps towards portfolio capital flows deregulation and its liberalization efforts focused on encouraging FDI only. On the other hand Malaysian government decided rather than following the IMF liberalization policies to impose more stringent capital control measures in 1998. Park and Bae also estimate the degree of capital control in the year 1999 for mentioned countries (Park & Bae, 2002, p. 54), which reflects the scope of liberalization measures undertaken in individual markets. The estimate for Malaysia was the highest (0.72) followed by Thailand (0.70). On the other hand capital control was substantially lower for South Korea (0.42) and Indonesia (0.49). Park and Bae (2002, p. 55) further report the degree of capital control in the same period for other markets – Japan (0.23), Hong Kong (0.23), Singapore (0.31) and Phillipines (0.85). In spite of the liberalization tendencies however, most of the East Asian countries have not been able to borrow from international capital markets in their own currencies, which still puts them in danger of currency mismatch problems (Park & Bae, 2002, p. 38). Furthermore, to

compare with the openness of developed markets, the average degree of capital control in East Asian countries on the verge of new millennium was much lower (0.55) than in developed economies (0.27) (Park & Bae, 2002, p. 54). According to the Table 3.3.1 , which summarizes the presence of capital transactions controls in East Asian markets, the degree of capital control seems to have stayed quite high throughout the whole period up until 2012. For most of the countries, the only deregulation that was completely implemented is related to the FDI support. The exception being South Korea, Singapore and Japan, countries that belong among the more liberalized. Despite its economic importance, the Chinese financial market stays under tight control of the government. Capital account has not been liberalized mainly because of the regulated exchange and interest rates (all forms of capital transaction controls were present as of 2012). However in the recent years, some steps that suggest China might be preparing to float its currency (e.g. widening of the RMB floating band) have appeared. It therefore seems that the capital transaction controls could present a barrier that hinders East Asian stock markets to become more important players.

Table 3.3.1: Capital Transaction Controls Presence in the East Asian markets (2012)

	China	Indonesia	Japan	Malaysia	Phillipines	Singapore	South Korea	Thailand
Capital market securities	●	●	●	●	●		●	●
Money market instruments	●	●	●	●	●			●
Collective investment securities	●	●	●	●	●			●
Derivatives and other instruments	●	●	●	●	●			●
Commercial credits	●	●		●	●			●
Financial credits	●	●	●	●	●	●		●
Guarantees and financial backup facilities	●	●		●	●			●
Direct investments	●	●	●	●	●		●	●
Liquidation of direct investments	●							
Real estate transactions	●	●	●	●	●	●		●
Personal capital transactions	●	●		●	●			●
Comercial banks and other credit institutions provisions	●	●		●	●	●	●	●
Institutional investors provisions	●	●	●		●	●	●	●

Source: IMF Annual Report of Exchange Arrangements and Exchange Restrictions

To conclude the three previous subchapters, it is a fact that Japanese economy has become more open towards international influences through both trade and financial flows. As for the foreign trade the opening seems to be driven by trade flows with East Asian countries. The financial flows exchange on the other hand happens mainly with the western countries and this is despite the liberalization tendencies that took place in East Asia as a consequence of the Asian crisis.

3.4 Empirical Literature Survey

3.1.1 Early studies

As Japan has belonged to the most important world economies already since the 1970's, its financial markets are included in many early studies dealing with the international financial linkage that were written during that time. However those studies usually emphasize pair wise analysis with other in those days already developed economies such as US or UK and do not take into consideration other Asian countries. The interest in studies involving Asian developing countries begun in early 1990's and most often tried to assess the influence of developed economies (typically Japan and US). Because the volume of these works is quite substantial, we will only mention the most important examples.

Among the first belong Cheung and Mak (1992). In their work, they use the stock returns of developed countries as explanatory variable of movements in developing Asian markets and assess their significance via ARIMA model. If the explanatory variables are significant, the authors then consider it as a causal relationship between the stock markets. They examine the weekly stock from 1977 to 1988 and conclude that the US is the driving force behind the movements on the emerging Asian markets, while the influence of Japan is only limited. However their methodology has a drawback of being strictly pairwise as each of the ARIMA processes explaining stock market returns in Asian developing countries only uses one of the developed countries as an explanatory variable at a time. Possible interactions between the developed countries as well as among the developing countries are therefore not accounted for.

On the other hand, Chan, Gup and Pan (1992) already test the interrelationships among the movements of the Asian and US stock returns on collective basis. They apply the cointegration method on the financial data from years 1983 to 1987. Their findings, unlike to Cheung and Mak (1992), show that there is no cointegration among the stock prices in the examined markets. The authors interpret the lack of cointegration as a sign that there is no significant linkage to speak of and that the markets are weakly efficient[19]. They also comment on weak correlation between the stock indices of the countries, especially those of Japan and the rest of Asia, which is in accord with the absence of linkages. The application of the cointegration method on a return series is however questionable, as the cointegration relations might well be gotten rid of by the transformation.

Some studies from the early era already use the VAR and Variance Decomposition. Park and Fatemi (1993) analyze the data range from 1983 to 1990. The methodology allows them to examine the system on collective basis, while being able to account for individual effects of countries. They however find only a weak linkage of Asian countries to developed economies (US, UK, Japan) and explain it by limited accessibility of the local Asian stock markets.

3.1.2 Recent studies

The outbreak of Asian financial crisis in 1997 caused a newly renewed interest in researching Asian financial linkage. Gosh, Saidi and Johnson (1999) use the stock market daily data from the short period between March and December of 1997. Their methodology builds once again on the cointegration principle and is strictly pair wise. The evidence on cointegration is however mixed. The authors explain the difference in cointegration by heightened presence of large US

[19] If the markets are weakly efficient, it means that the future prices cannot be explained by analyzing the prices from the past. However, whether the absence of cointegration really implies weak efficiency as the authors presume is disputable (DeFusco, Geppert, & Tsetsekos, 1992, p. 344).

corporations in some of the markets in one side and strong economic relationships of some countries with Japan on the other. The credibility of the study is however hindered by the pair wise setting. Moreover as the cointegration accounts for common stochastic trend, i.e. a long-term relationship between the time series, it is questionable if this method can be applied on a dataset of such a short term nature representing atypical period of financial turmoil.

Cha and Oh (Cha & Oh, 2000) use the VAR methodology with correction for heteroscedasticity by ARCH errors in period 1980 to 1998. They divide the dataset in several sub-periods and find already evidence of increasing financial linkage with respect to the Asian financial crisis especially by Japanese stock markets. Similar conclusions are brought by Yang et al. (2003), who work with multivariate cointegration method (VECM) and a data range 1995 to 2001. On the other hand Worthington et al. (2003) use similar methodology and come up with opposite results, i.e. that the interdependence of Asian markets decreased after the financial crisis. This is most probably caused by variable omission bias, as they do not include the effect of US stock markets into their model.

Darrat and Zhong (2002) use the cointegration method on a longer sample of daily data between 1987 and 1999. They however do not concentrate on the effects of Asian financial crisis. More likely they decompose the effects into transitory and permanent components, which allows them to conclude that whereas the influence of US permanent, Japan's influence is only transitory.

Kim (2005) concentrates only on the advanced countries in the region during the 1990's and works with returns but also with volatilities and trading volumes dividing the period into multiple sub-periods to be able to account for the crisis. Using the EGARCH models, he distinguishes between contemporaneous and dynamic spillovers. The results suggest that while the Asian financial crisis has increased contemporaneous linkages, it was not the case with the dynamic linkage. Also in terms of dynamic linkage, US (and not Japan) is the regional leader.

Awokuse, Chopra and Bessler (2009) deal with the effects of market liberalization and Asian financial crisis on the financial linkage between Asian developing economies and three major global partners, US, Japan and UK, while paying attention to possible time variation in stock market linkages. To do so they use the multivariate rolling cointegration method which basically reestimates the parameters in a 2 year fixed rolling window and is therefore a more sophisticated

variant to dividing datasets into sub-samples as the previous studies did. Moreover to assess the causality between variables they replace the methods based on Granger causality by inductive causative methods (DAG – Directed Acyclic Figure). Their results suggest that there is a time-varying cointegration relationship between the stock markets: they claim that the wave of financial liberalization policies in the 1990's and the 1997 Asian financial crisis led to a significant increase in market linkages. The data also indicates that Japan and the US have the greatest influence on the emerging markets, while the influence of Japan is equally strong as the influence of US. On the other hand the innovations in Japanese stock markets are not well explained by other Asian countries.

Debold and Yilmaz (2010) also come up with the rolling window method, they however use the VAR forecast error variance decomposition to compose a spillover index. Examining the period between 1992 and 2009 the authors compare the effects of two crises, they provide a comprehensive study of financial linkages in the region – interestingly are they the first to include China in the data sample. However their study is strictly collective, therefore it does not mention any conclusions valid for Japan as an individual country. Fujiwara and Takahashi (2011) use the same methodology, they are however using the spillover index to show changing influence of leading regional countries on Asian economies as a group. They show that the main driver is still the US, there are no signs of Japan or China stepping up. It is this methodological direction that we will reexamine in the empirical part of this work.

We can summarize the subchapter by stating that even though the subjects and methodologies of the empirical studies are various, it seems that they in general indicate that there have been integrating tendencies in East Asian stock markets. The role of Japan within the region then seems to be important, nevertheless the US is the main driving force. Moreover there is no study that would the authors know about, which concentrates especially on Japanese financial linkages - it is the East Asia in general that stands in the center of attention. This fact only underlines the contribution of this work that aims at examining the Japanese financial linkages.

4. Empirical study of Japanese financial linkages

In the empirical part of this work, we will extend the studies by Diebold and Yilmaz (2009) and Fujiwara and Takahashi (2011). Similar to them, we will use the Spillover Index as a tool to assess intertemporal development of financial linkage among East Asian stock markets. Moreover, we will also have a detailed look at the developments of financial linkages of Japanese stock market. To run the data analysis statistical environment R with package vars has been used.

4.1 Data Specification

The dataset comprises of 16 stock indices representing development on stock markets of 16 respective countries. We have chosen predominantly the Asian countries as one of the purposes of this study is to assess the influence of Japanese stock market in Asia. However major world stock markets are included as well in order to give an insight into which of them have had major influences on the Japanese stock markets. The observed period is 1995 to 2012 with total 4695 observations per one index[20]. All the indices used are summarized in the Table 4.1.1.

Table 4.1.1: Data Sample - Stock Indices

Country	Indice	Country	Indice
Australia	All Ordinaries Index	Japan	NIKKEI 225
Canada	TSX Composite	Malaysia	KLCI
China	SSE Composite	Philippines	PSE Index

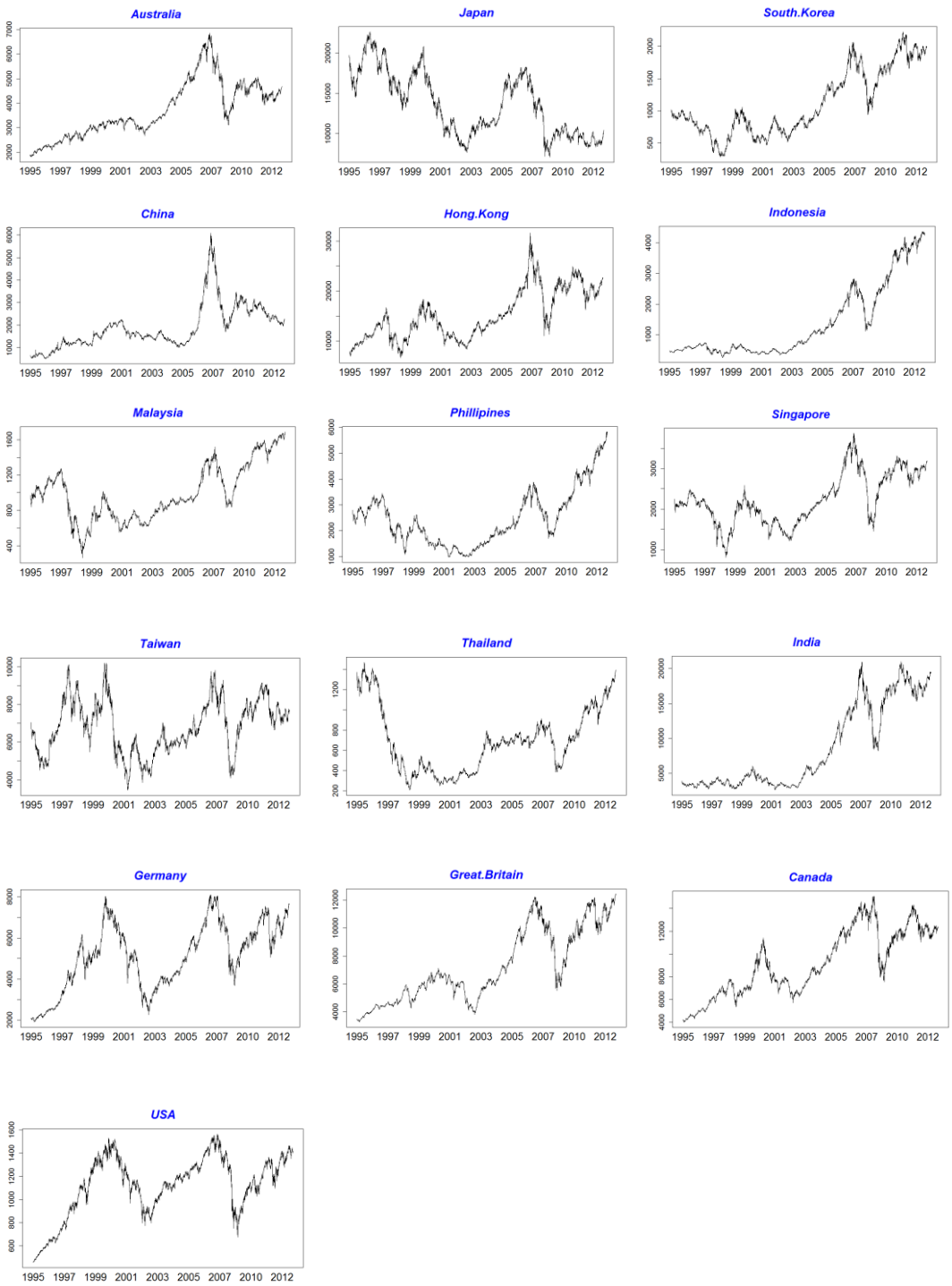
[20] If an observation is missing due to the stock exchange being closed (e.g. national holiday), the value of previous day is used once more.

Great Britain	FTSE 250	Singapore	STI
Germany	DAX	South Korea	KOSPI
Hong Kong	HSI	Taiwan	TAIEX
India	SENSEX 30	Thailand	SET
Indonesia	JCI	USA	SP 500

As the dataset comprises stock price indices of markets from different time zones, there is a need to deal with the influence of possible time differences on the model. Literature deals with this problem in two ways, firstly it is working with weekly prices instead of daily (Yilmaz, 2010) and secondly using two days price average (Forbes and Rigobon, 2002). We however find both methods are not optimal. In the first case, much of the information given by the data on the daily basis is lost. In the second case, averaging the values introduces autocorrelation into the data. We have therefore chosen a different approach. For the markets eastern to UTC + 6, we will use the market index closing price. For the markets in between UTC + 6 and UTC +1 we will use the average daily price and for the markets western to UTC +1, we will use the opening price (corresponding time zones of the countries can be found in the Appendix Table A.1). We believe that this approach will help to minimize the effect of time differences on the financial linkage measurement and still preserve the information contained in the dataset.

The time development of the stock price indices levels contained in the dataset are presented in the Figure 4.1.1. It can be seen that all of the indices except for the Japanese one are subjected to more or less growing trend. This might among others be given by the fact that Japan is one of the few countries with long-term deflation. Preliminary analysis of the stock price level shows us that there is very high probability, all of the time series have a unit root. Using Dickey Fuller Augmented Test (ADF), the null hypothesis of a unit root could not have been rejected in all the time series on significance levels up to 10%. Detailed results of the ADF test can be found in the Appendix (Table A.3). The data are therefore not *I(0)* and the usage of VAR levels model would be inappropriate.

Figure 4.1.1: Data Sample - Stock Indices Price Levels



Source: stooq.pl

The non-stationarity is very typical for financial time series and as explained in Chapter 2.4.1, one possibility how to deal with it is to transform the data into continuously compounded returns. Transformed data are depicted in Figure 4.1.2.

Running the ADF test on the adjusted data shows us that by turning the stock prices levels into log returns, we have successfully dealt with non-stationarity and all the time series are *I(0)*.

Figure 4.1.2: Data Sample - Stock Indices Log Returns

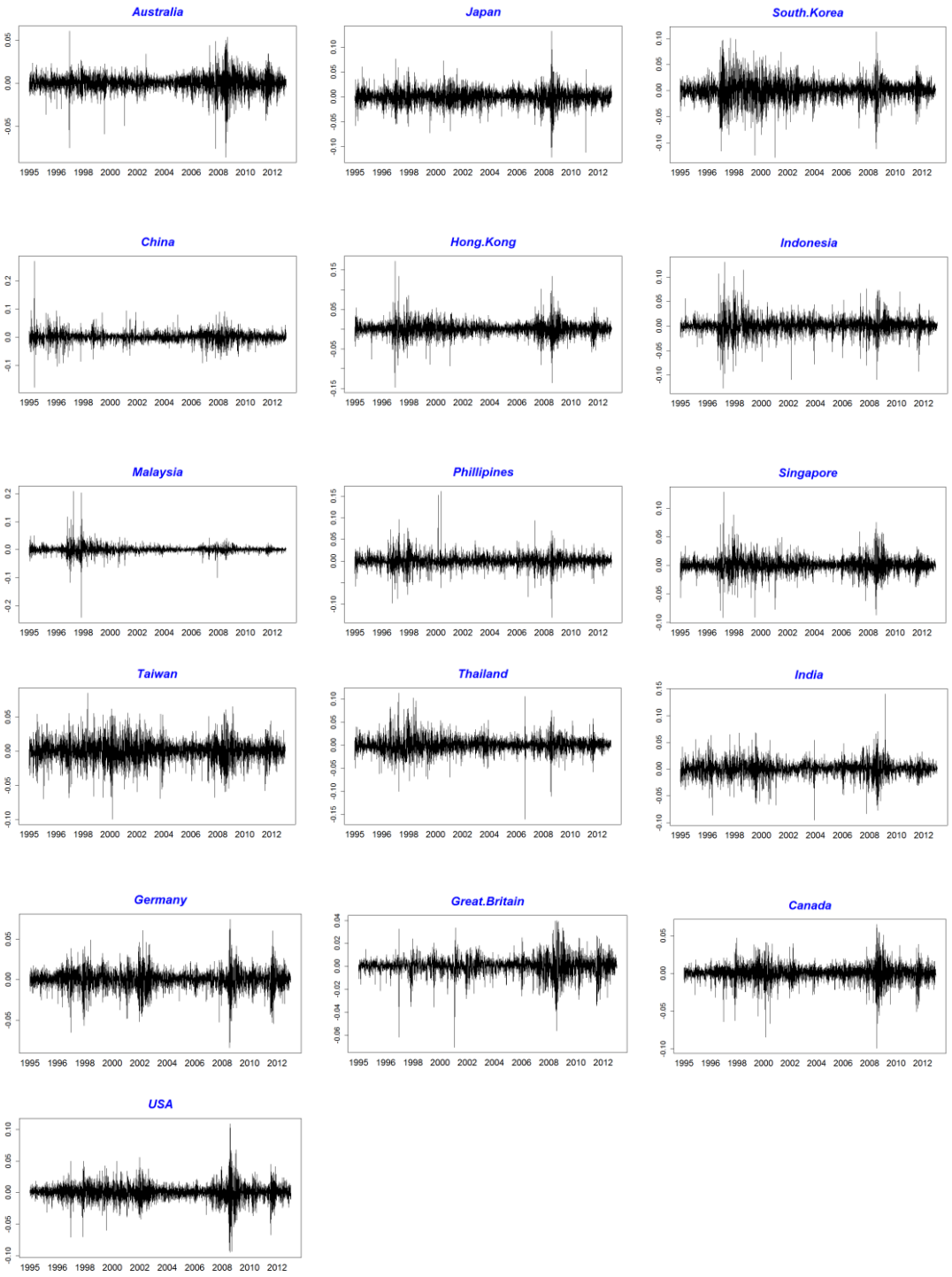


Table 4.1.2: Unit Root Testing – logarithmic returns

Augmented Dickey Fuller Test, lags according to AIC (max set to 5 lags)

	Critical values		
	1%	5%	10%
no constant	-2.58	-1.95	-1.62

Country	Deterministics terms	Lags	Test Value	Unit root
Australia	None	2	-40.549	Most unlikely
Japan	None	1	-51.165	Most unlikely
South Korea	None	4	-32.549	Most unlikely
China	None	1	-48.462	Most unlikely
Hong Kong	None	5	-29.281	Most unlikely
Indonesia	None	5	-28.961	Most unlikely
Malaysia	None	5	-28.694	Most unlikely
Phillipines	None	4	-31.194	Most unlikely
Singapore	None	1	-45.759	Most unlikely
Taiwan	None	5	-28.903	Most unlikely
Thailand	None	1	-43.969	Most unlikely
India	None	5	-28.368	Most unlikely
Germany	None	4	-30.787	Most unlikely
Great Britain	None	5	-30.413	Most unlikely
Canada	None	1	-29.627	Most unlikely
USA	None	3	-52.760	Most unlikely

The simplest form of the ADF test without deterministic terms has been used for the log returns (we suppose that the deterministic terms were removed by the differencing).

4.2 Model

Looking at the logarithmic returns of the stock prices depicted in the Figure 4.1.2 , it seems plausible that the data set could be a stochastic process with zero mean represented by a VAR process (2.2) as mentioned in Chapter 2.4.1. We will first try to search for an appropriate model specification of the true data generating process (DGP) for the whole data set. The Table 4.2.1 presents the appropriate lag selection given the information criteria for different maximum lags. In accordance with the theory, the equality (2.5) holds. However the lag estimated by different

criteria is not identical. We will therefore try to choose the most appropriate model by running residual assumption testing.

Table 4.2.1: Lag Selection by information criteria

Maximum lag	AIC lag	HQ lag	SC lag
2	2	2	1
3	3	2	1
4	4	2	1
5	5	2	1
6	5	2	1
7 to 20	5	2	1

In the VAR levels model as presented by (2.2), the residuals are assumed to be a zero mean white noise as stated in the Chapter 4.2.1. The testing for this assumption can be done via testing for residual autocorrelation, residual normality and conditional heteroscedasticity. Table 4.2.2 summarizes the results of Breusch-Pagan (BP) test for residual autocorrelation.

Table 4.2.2: Residual Autocorrelation Test

Breusch-Pagan test

	p=1	**p=2**	**p=5**
h	p-value	p-value	p-value
1	≤2.20E-16	≤2.20E-16	0.000001152
2	≤2.20E-16	≤2.20E-16	5.129E-11
3	≤2.20E-16	≤2.20E-16	≤2.20E-16
4	≤2.20E-16	≤2.20E-16	≤2.20E-16
5	≤2.20E-16	≤2.20E-16	≤2.20E-16

H_0: Residuals are not autocorrelated.

To test for normality, we have used the Jarque-Bera multivariate test that uses the standardized residuals by Cholesky decomposition as described in the Chapter (2.4.3). For conditional heteroscedasticity then the multivariate ARCH-LM test.

Table 4.2.3: Residual Normality and Conditional Heteroscedasticity Tests

Jarque-Bera multivariate test

	p=1	p=2	p=5
p-value	<2.20E-16	<2.20E-16	<2.20E-16

H_0: Residuals are normally distributed.

ARCH-LM multivariate test

	p=1	p=2	p=5
p-value	<2.20E-16	<2.20E-16	<2.20E-16

H_0: No arch effect present.

The results of the tests suggest that while the *VAR(5)* has slightly better properties, none of the considered model specifications is good enough to represent true DGP with white noise residuals for the whole dataset. This is not that surprising considering the complexity of the dataset (N=16, t=4694) and its nature – financial data time series are very often subjected to ARCH effects. As the aim of this empirical study is not to find the true DGP for the dataset, but to work with forecasting on a rolling-window basis, we believe that the problematic assumptions will not prevent us from applying the Spillover Index. Lütkepohl (2005, p. 157) for example argues that if the forecasting is the main objective, the residuals properties must not be of a central interest as long as the quality of forecasting is suitable. Nevertheless we have to bear this problem in mind.

Because we were not able to find the true DGP for the whole data sample, we will be re-estimating the VAR for each of the rolling windows of the length t = 260 (representing the approximate number of working days in a year, which we set as a reasonable period to run the VAR), which as can be seen from the Appendix (Table A.5) will partly improve the quality of the model as the VAR tends to represent the DGP better in a shorter term view. This improvement concerns mainly the residual autocorrelation and partly also the ARCH effects. Normality of residuals still remains an issue.

As further mentioned in the Chapter 2.4.3 the ordering of the variables in the vector x_t is of the central interest for the forecast error variance and the Spillover Index. We have chosen to order the countries according to the stock market size represented by average yearly trading volume in years 1995 to 2012 as stated in the Table 4.2.4. We are very well aware of the fact that the criteria stated by Lütkepohl

(2005, p. 59) - that the ordering should be such that the first variable is the only one with potential immediate impact on all other variables, the second variable may have an immediate impact on the last *N-2* components of x_t but not on x_{1t} and so on - might be impossible to achieve in the context of stock markets. Nevertheless, we believe that the ordering according to the stock market size could correspond to the criteria the most.

Table 4.2.4: Stock markets ordering in the model

According to average yearly trading volume of stocks in between (1995 – 2012)

n	Country	Trading volume (mil. USD)
1	**USA**	26,961,500
2	**Japan**	3,024,894
3	**Great Britain**	2,651,646
4	**China**	2,441,935
5	**India**	1,880,217
6	**Germany**	1,600,466
7	**South Korea**	949,875
8	**Canada**	899,690
9	**Taiwan**	785,982
10	**Hong Kong**	742,938
11	**Australia**	629,972
12	**Singapore**	210,675
13	**Thailand**	92,058
14	**Malaysia**	71,417
15	**Indonesia**	46,828
16	**Phillipines**	12,991

Stock exchanges that are reflected in stock market indices in the dataset are used.

Both domestic and foreign trading volume is reflected.

Source: World Federation of Exchanges, http://www.world-exchanges.org/statistics/annual-query-tool

Furthermore, for each of the data windows the Spillover Indices as explained in Chapter 2.4.2 will be calculated from the forecast error variance decomposition of the forecast. The sequence of calculated indices will give us a representation of financial linkage development among and between observed countries. We will calculate the Global Index (given by 2.9) as well as Individual Indices (given by

2.10) for the whole sample of all 16 countries, i.e *n,m ={All the Countries}*. We will also look at the indices for East Asian region[21]only. Global Index and Individual Indices for East Asia will be calculated according to the formulas, but they will include the forecast error variances for the countries within the region only[22], i.e. *n,m ={East Asian Countries}*. Additionally, we will compute the Individual and Group Contribution Indices of Non-East Asian Countries[23] to East Asian Countries forecast error variance. The Contribution Indices follow the Spillover Index formulas as well, with the distinction that *n* and *m* are different sets, here *n ={East Asian Countries}* and *m ={Non-East Asian Countries}*. Finally we will explore the development of Individual Contribution Indices of different countries to Japanese forecast variances, where *n ={Japan}* and *m ={All the Countries}* and the other way around Japanese contributions to different countries forecast variances, where *n ={All the Countries}* and *m ={Japan}.*

4.3 Results and Interpretation

Following calculations are based on the data set consisting of 16 countries, and 4694 observations (1995 to 2012). The forecast error variances are estimated for the 10 step ahead forecast and the time development is observed with help of running window estimation of length t=260.

[21] Japan, China, South Korea, Taiwan, Hong Kong, Singapore, Thailand, Malaysia, Indonesia, Philippines

[22] The forecast variances will however be given by the whole VAR model for all 16 countries.

[23] USA, Great Britain, India, Germany, Canada, Australia

Global Spillover Index

The total Global Spillover Index for the whole data set and the whole period is equal to **0.329**. Table 4.3.1 further summarizes the individual spillover indices. These can be perceived as individual contributions of countries to the total spillover index and their size should therefore reflect the ability of each of the countries to influence other stock markets on the international level. Not surprisingly, the most influential countries seem to be the US, Great Britain, Japan, which is by far the most influential of the Asian countries, and Germany. Hong Kong, South Korea and Singapore then seem to belong to the more influential Asian countries as well.

Table 4.3.1: Individual Spillover Indices

	Country	Individual Spillover Index
1	**USA**	0.0957
2	**Great Britain**	0.0701
3	**Japan**	0.0467
4	**Germany**	0.035
5	**Hong Kong**	0.0188
6	**South Korea**	0.0122
7	**Singapore**	0.0098
8	**India**	0.0097
9	**China**	0.0058
10	**Thailand**	0.0055
11	**Taiwan**	0.0049
12	**Canada**	0.0047
13	**Australia**	0.0037
14	**Indonesia**	0.0035
15	**Malaysia**	0.002
16	**Phillipines**	0.0012

Estimating the Global Spillover Index on a rolling window, we get the Figure 4.3.1, which represents the time development of the Global Spillover Index in the observed period. Clearly it can be seen that the financial linkage among the countries increased substantially. The biggest increases happened during the Asian Financial Crisis in 1997 and in relation to the bear market preceding the Global Financial Crisis. It is however interesting that the increase in both cases does not seem only transitory. In the first case, this could be given by the wave of financial liberalization that followed the Asian Financial Crisis.

Figure 4.3.1: Full sample spillover index development in time

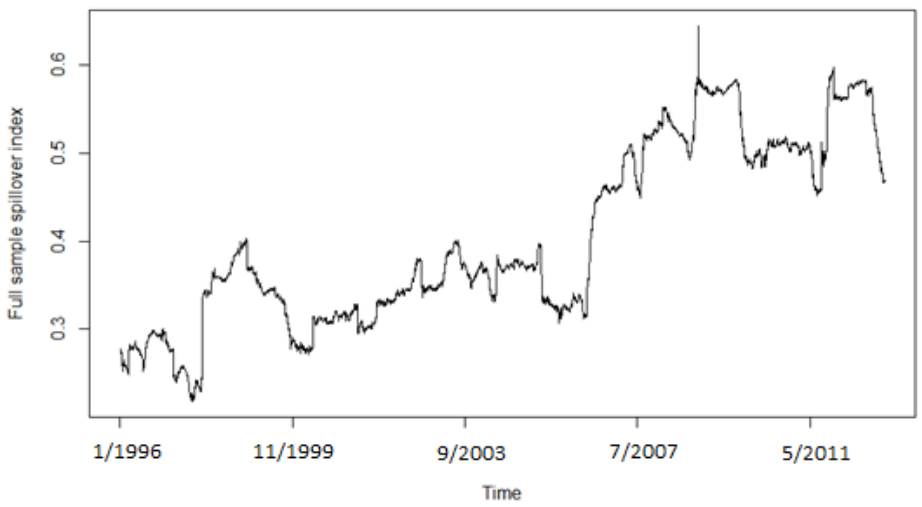
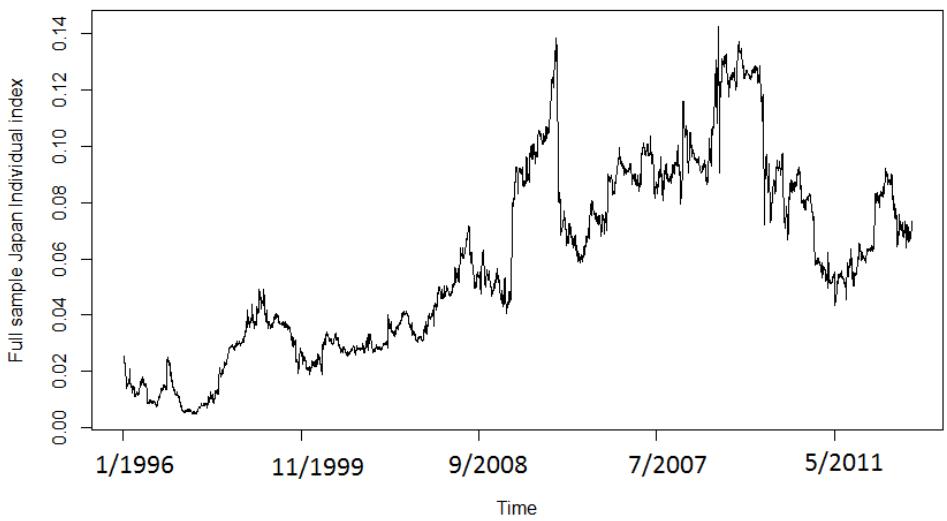


Figure 4.3.2: Individual Spillover Index for Japan development in time



Calculating the Individual Spillover Index for Japan on the rolling window, we get the Figure 4.3.2. Again, this can be understood as a contribution of Japan to the Spillover Index of the whole group. It seems that the contribution has been increasing throughout the period, which could signify that Japanese stock markets became globally more influential. The increase is however not relative towards other countries, so it could be given by the increasing global financial linkage that was shown in the Figure 4.3.1.

East Asian Spillover Index

Given the whole sample VAR and forecast error variance calculation, it is possible to calculate sub-sample Spillover Index by including only a East Asian countries. The value of such Spillover Index is **0.135.** Furthermore, the values of Individual Spillover Indices within the East Asia sub-sample are represented in Table 4.3.2 and the values of Contribution of NEAC (Non East Asian Countries) to the EAC (East Asian Countries) in Table 4.3.3.

Table 4.3.2: Individual Spillover Indices of EAC

	Country	Individual Spillover Index
1	**Japan**	0.0495
2	**Hong Kong**	0.0265
3	**South Korea**	0.017
4	**Singapore**	0.0145
5	**Thailand**	0.0077
6	**Taiwan**	0.0063
7	**China**	0.006
8	**Indonesia**	0.0039
9	**Malaysia**	0.0024
10	**Phillipines**	0.0014

Table 4.3.3: Individual Contribution Indices of NEAC to EAC

	Country	Individual Contribution Index
1	**USA**	0.0685
2	**Great Britain**	0.047
3	**Germany**	0.0248
4	**India**	0.0129
5	**Canada**	0.0052
6	**Australia**	0.0043

It is obvious that the countries that seem to exercise the biggest influence on the East Asian Countries are USA, Great Britain and Japan. The influence of China is given its economic size insignificant, which is not surprising considering the time frame and the closed nature of Chinese financial markets.

Estimating the East Asian Spillover Index on a rolling window, we get the Figure 4.3.3. The Index represents cross variance contributions of EAC to other EAC. We observe that the Index grew during the whole period and that the peaks, corresponding to periods of financial unrest, were less prominent than in the case of the Global Index for the whole group. The development could mean that there are processes of increasing financial linkage in the region of East Asia.

Figure 4.3.3: East Asian Spillover Index development in time

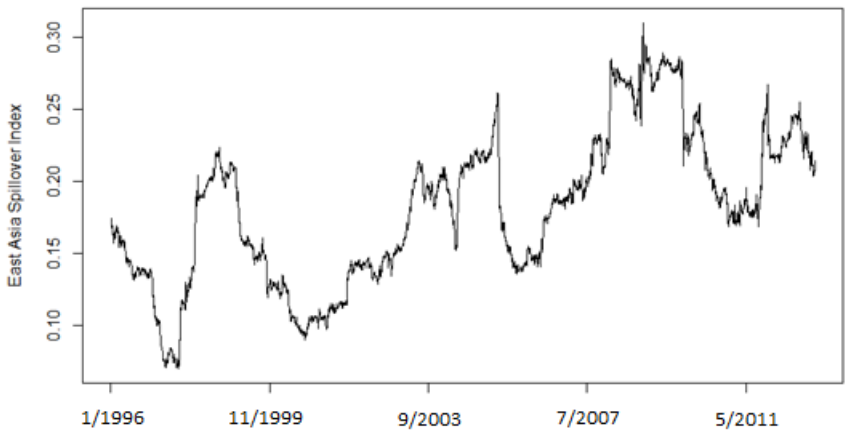
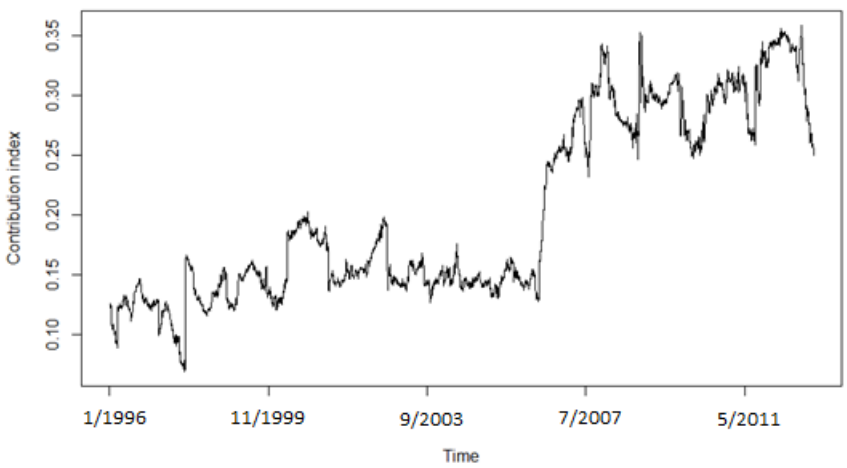


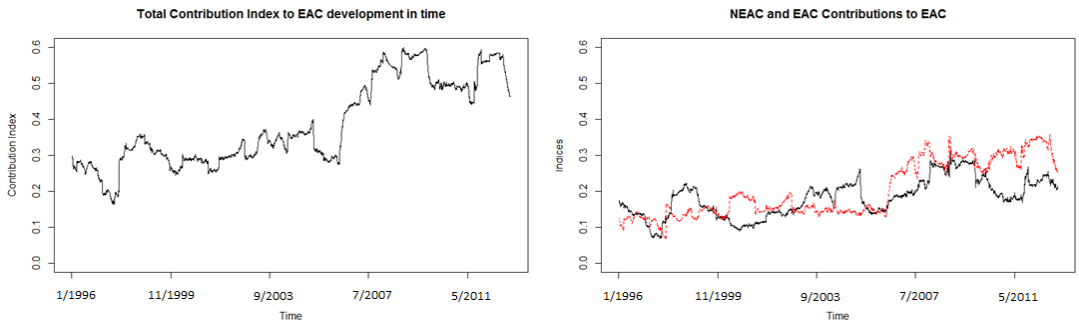
Figure 4.3.4: NEAC Contribution to EAC Index development in time



Also, calculating NEAC contribution to EA countries is possible. The rolling window estimation of such index is depicted in the Figure 4.3.4. The most striking result is the increase in NEAC contribution before the global financial crisis and the fact that this increase does not seem to be fading yet. Finally, the sum of East Asian Spillover Index and NEAC Contribution Index represents the Total Cross Variance Contribution Index of EAC as depicted in the left part of the Figure 4.3.5. The right

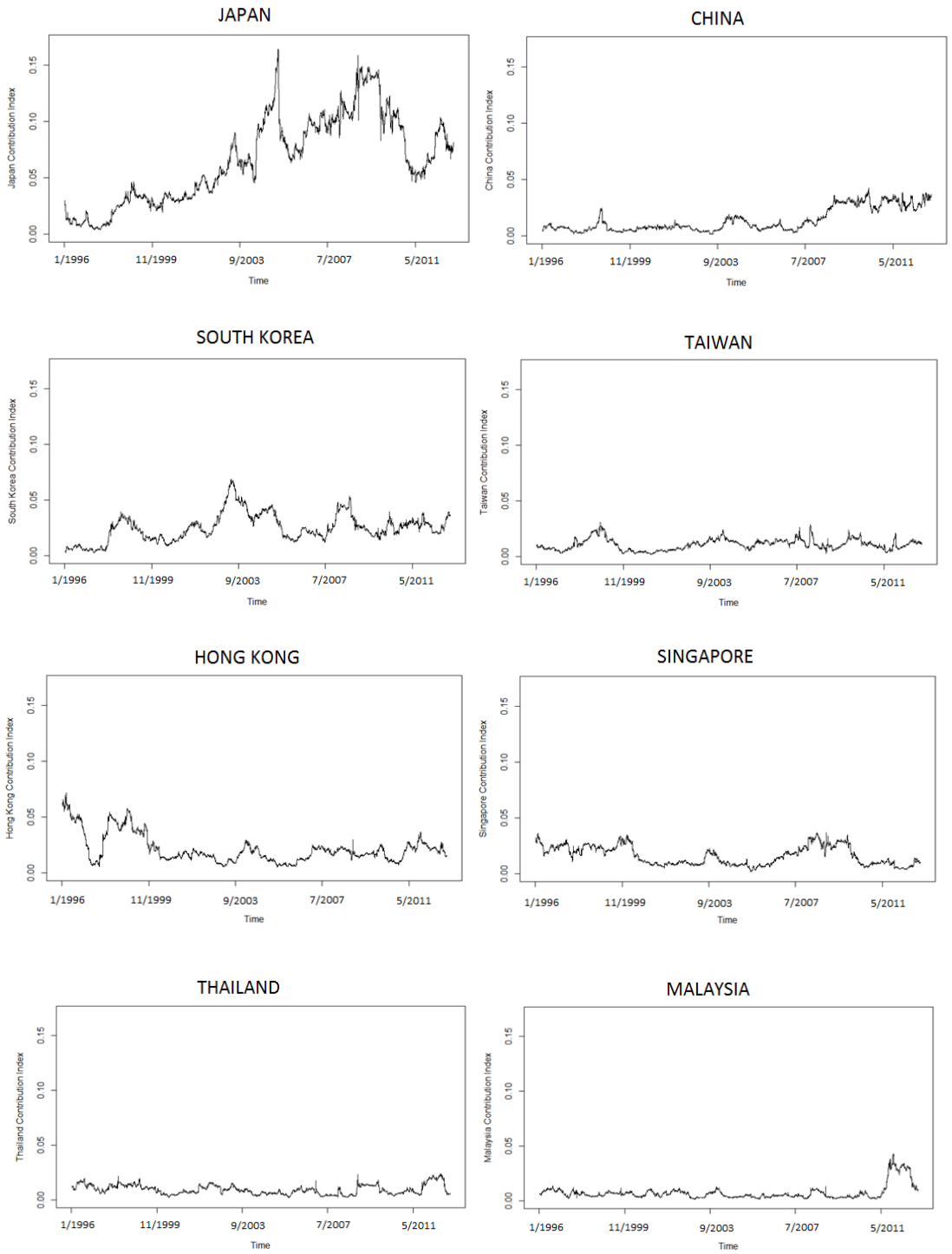
part of the Figure 4.3.5 then represents the comparison of the East Asian Spillover Index and the NEAC Contribution index, which shows how much of the cross variance share belongs to the EAC and how much to the NEAC. It implies that both EAC and NEAC contributions are similarly important for developments of EAC stock markets. Whereas the increasing cross variance contributions among the East Asian countries were more of a continuous process that took place throughout the whole period, the contribution of NEAC increased on an impulse basis.

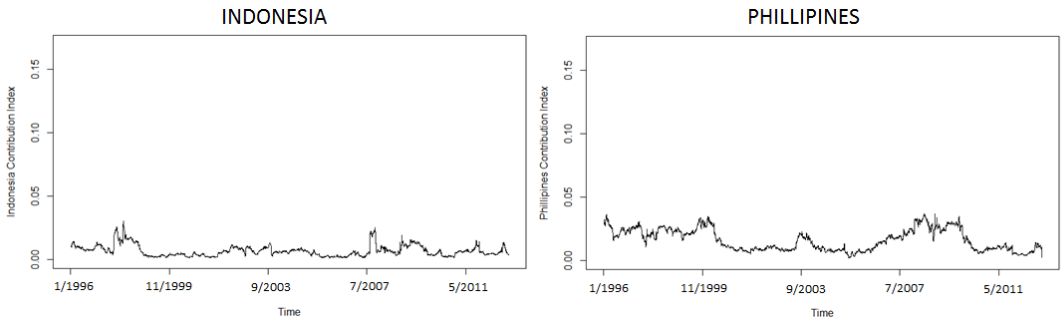
Figure 4.3.5: NEAC Contribution to EAC Index development in time



Calculating the Individual Spillover Indices on a rolling window basis for EAC, we get the time development of the contribution of each EAC country to the EAC Spillover index as pictured in the Figure 4.3.6. The influence of Japan increased substantially during the period, which might mean that the liberalization reforms that took place in 1990's increased East Asian linkage to Japan. Interestingly also the influence of China seemed to have increased towards the end of the period. If this is a consequence of the Global Financial Crisis spillover or of the signs of some very limited deregulation is, considering the scale of increase, not possible to determine. The fact that the remaining East Asian Countries did not undergo any significant increase in their influence could however signify that the Chinese stock market could be becoming more important.

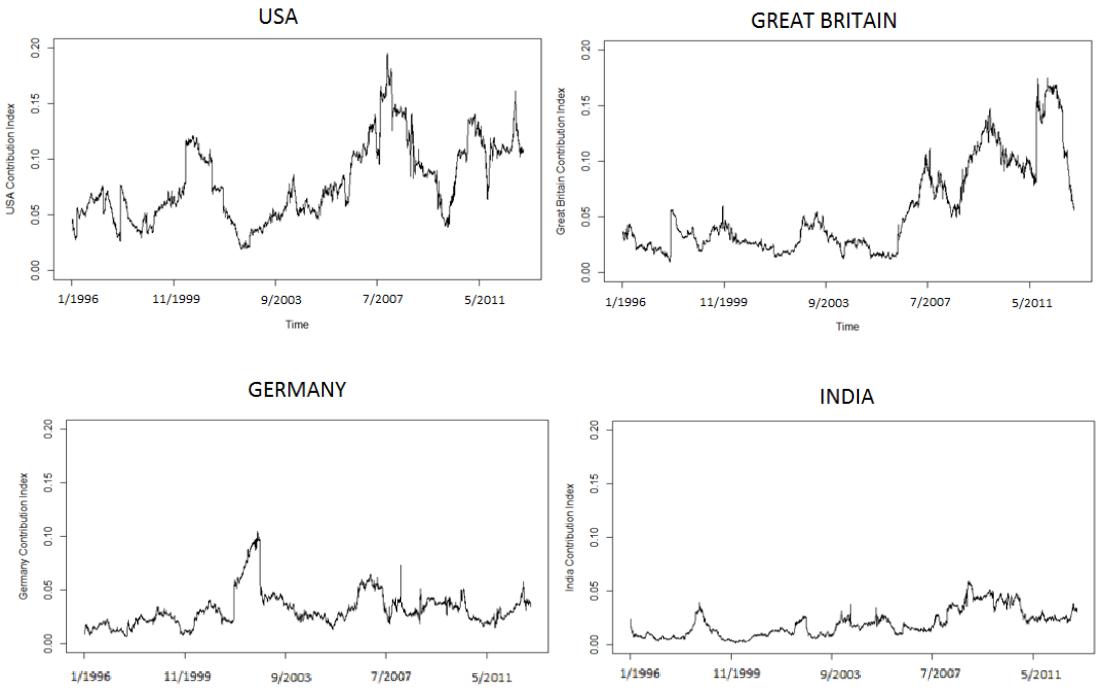
Figure 4.3.6: Individual Spillover Indices for EAC development in time

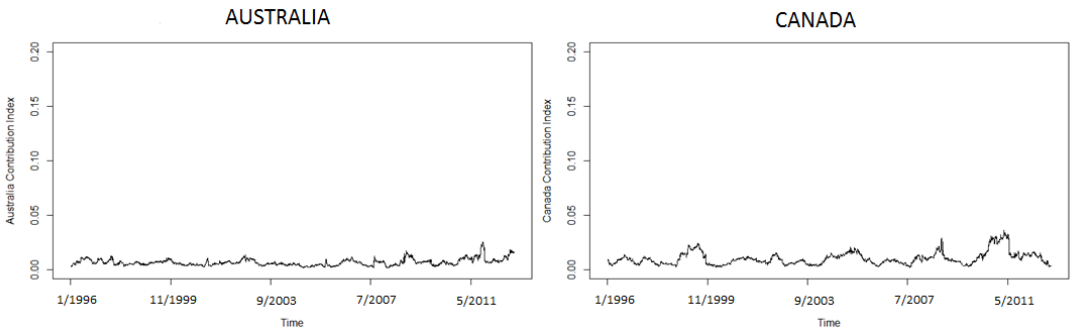




Furthermore, we can also trace the time development of Individual NEAC Contribution index across time as shows the Figure 4.3.7. While Australia and Canada are quite unimportant partners for developments of East Asian stock markets, Germany and Indian influence is a bit more pronounced. There is still no comparison to the US and Great Britain. The Contribution Indices of these two countries however seem to have quite a huge variance, which might signify that rather than by some pronounced long term relations, the influence of these countries is mainly driven by tome sort of contagion effect. Especially strong is the increase in the cross variances of Great Britain.

Figure 4.3.7: Individual NEAC Contribution Indices to EAC development in time

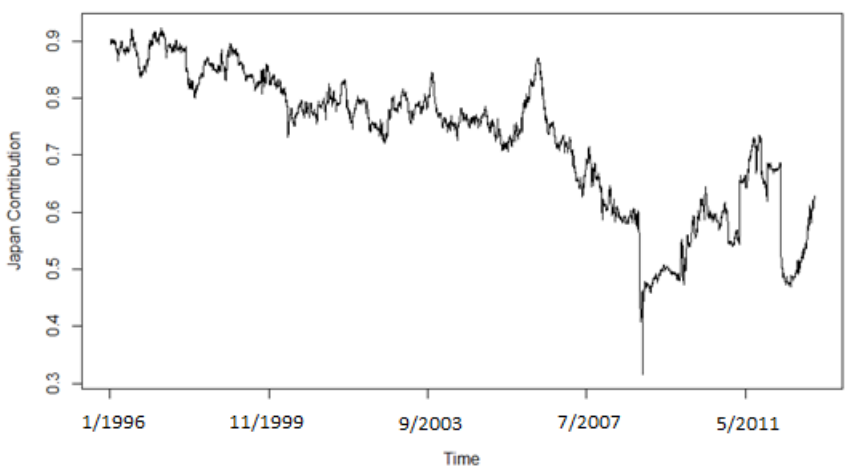




Japanese Contribution Indices

Regarding the individual contribution indices to and from Japan, first of all, we can calculate the Own Variance Share of Japan, which has been estimated to **0.751** for the whole period. The time development throughout the period is summarized in the Figure 4.3.8. The Japanese stock market seems to have been very secluded in the beginning of the period, but its linkages to international markers clearly increased throughout the last years. Some of the increase seems to be given by the deregulation and internalization of the stock market as it begins after 1998, which was the period when the Big Bang reforms took place. Some of it on the other hand relates to the global financial crisis - we can see a pronounced effect of the Lehman Brothers fall that caused a huge sock to the Japanese stocks. Nevertheless, it is not clear whether the tendency will be permanent or transitory as recently the own variance share of Japanese stock has been on rise again.

Figure 4.3.8: Own variance share of Japan development in time



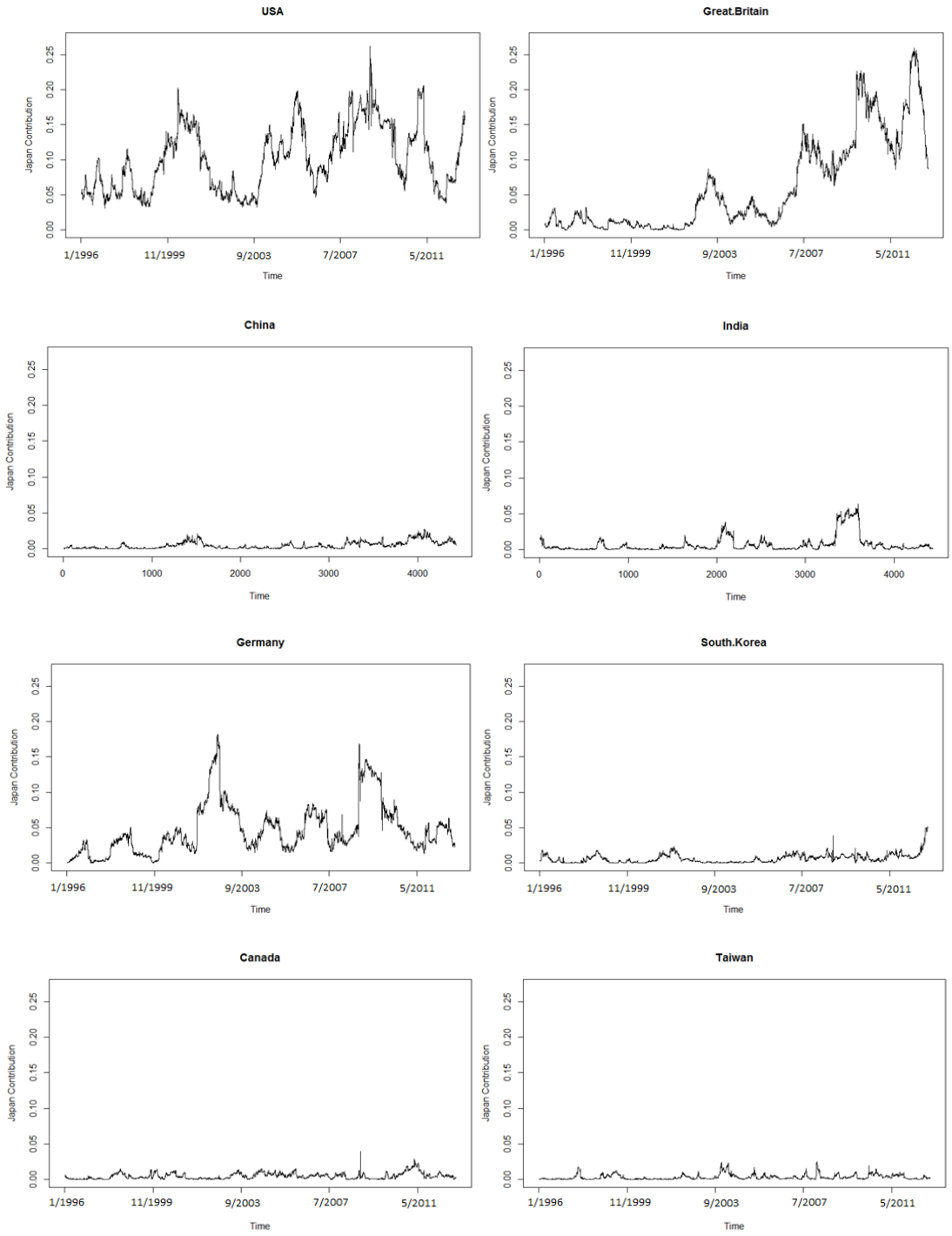
The contributions of all the countries to the Japanese variance are summarized in the Table 4.3.4 and in Figure 4.3.9. The results show that Japan is much more dependent on the western countries than the countries from region. USA is the most important one, followed by Great Britain and Germany. Among the East Asian countries it is then Singapore, but also China that seems to be relatively important. The values for all other than the first three named countries are nevertheless insignificant.

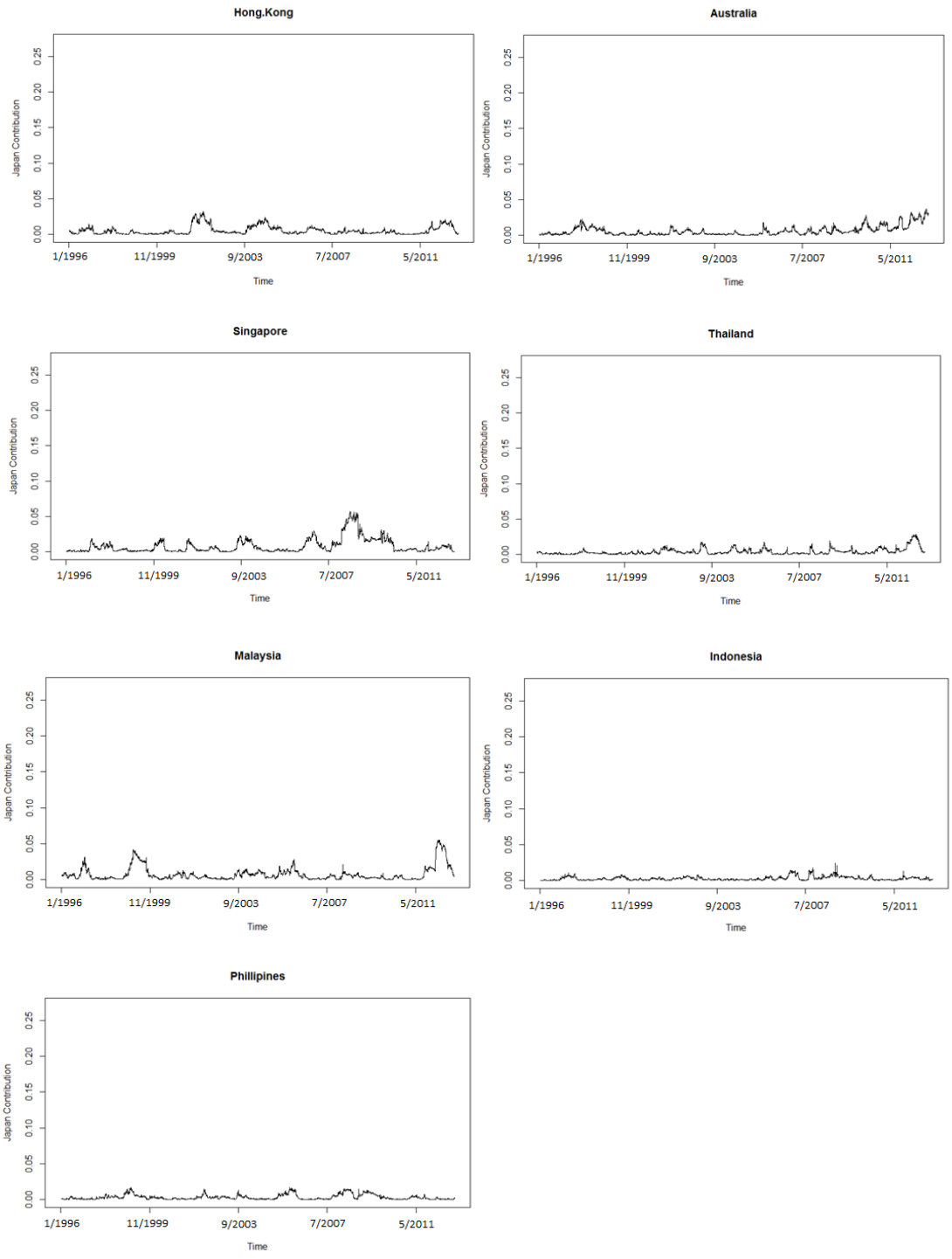
Table 4.3.4: Contribution of sample countries to Japanese FEV

	Country	Contribution to Japanese FEV
1	**Japan**	0.7506
2	**USA**	0.115
3	**Great Britain**	0.0631
4	**Germany**	0.0402
5	**Canada**	0.006
6	**Singapore**	0.0045
7	**Australia**	0.0038
8	**China**	0.003
9	**India**	0.0026
10	**South Korea**	0.0023
11	**Hong Kong**	0.0022
12	**Indonesia**	0.0019
13	**Thailand**	0.0016
14	**Phillipines**	0.0012
15	**Malaysia**	0.001
16	**Taiwan**	0.0009

Looking at the time developments (Figure 4.11) we can see that whereas the influence of the US seems to be constantly high with high variance throughout the period, the influence of Great Britain was quite small in the beginning of the period and increased quite substantially since 2006. As for the Germany, its influence seems to be similar to the US, but of a lower extent – no clear developments are visible but the variance is quite high. As for the influences of all other countries, they are constantly very low and no clear pattern of development is visible from the figures.

Figure 4.3.9: Contribution of sample countries to Japanese FEV development in time





Finally, the individual contribution of Japan to forecast error variances of the rest of the countries in the sample is presented in Table 4.3.5 and its time development then in the Figure 4.3.10. Japan as an individual country seems to influence the East Asian countries more than it influences the western countries. The strongest linkage seems to be towards Hong Kong, South Korea and Singapore, on the other hand the influence on China is small. As for the NEAC, the strongest

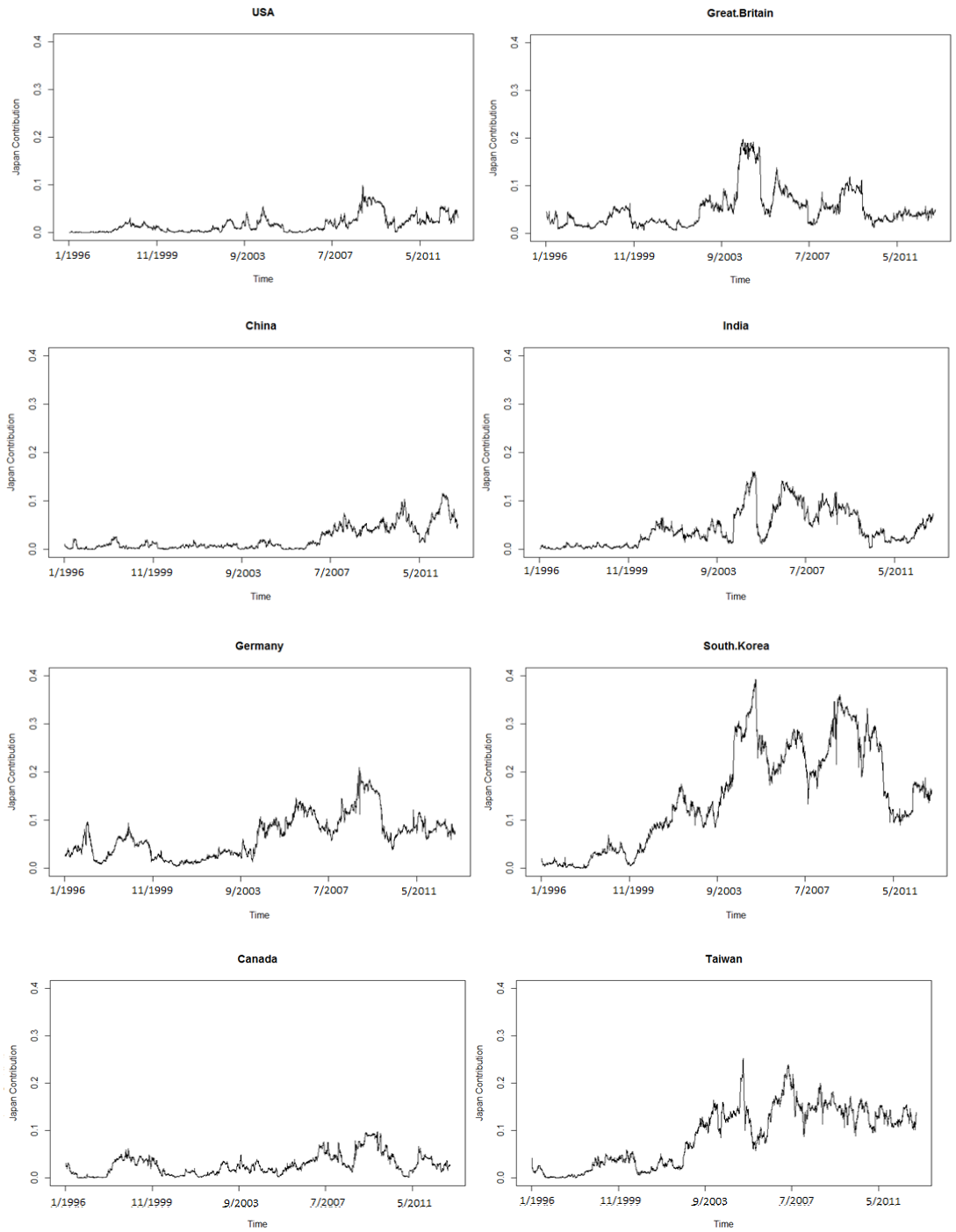
linkage is then towards Australia, Germany and Great Britain. The influence on US is quite negligible.

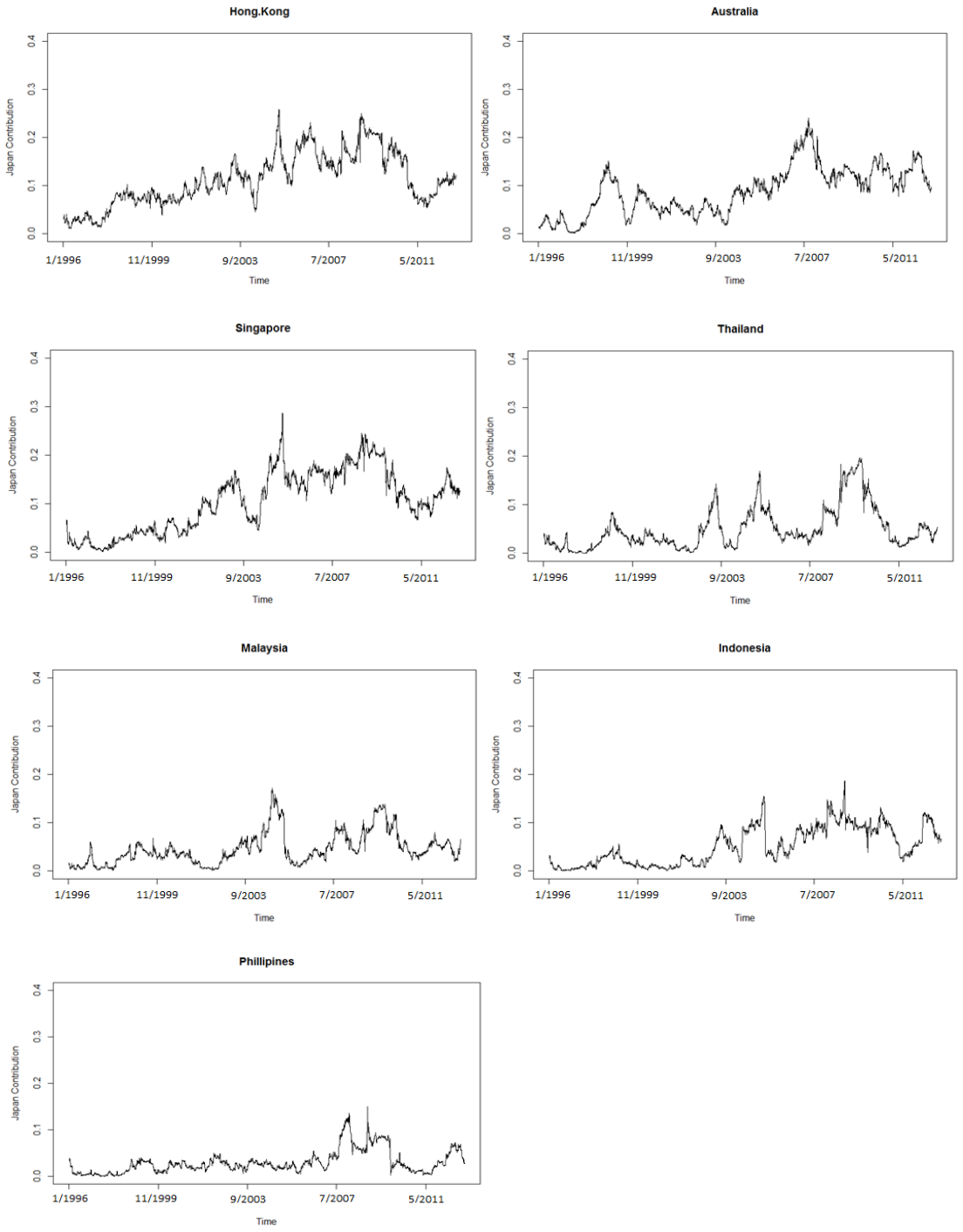
Table 4.3.5: Contribution of Japan to sample countries FEV

	Country	Japan's contribution to FEV
1	**Japan**	0.7506
2	**Hong Kong**	0.1121
3	**South Korea**	0.0903
4	**Singapore**	0.0866
5	**Australia**	0.0854
6	**Taiwan**	0.0613
7	**Germany**	0.0555
8	**Great Britain**	0.0425
9	**Indonesia**	0.041
10	**Thailand**	0.0403
11	**India**	0.0304
12	**Philippines**	0.0267
13	**Malaysia**	0.0243
14	**USA**	0.0202
15	**Canada**	0.0181
16	**China**	0.0124

When we look at the time developments, we see that the Japanese influence on both the US and Great Britain was quite low throughout the period. Whereas in the case of US there were no significant hikes, there was a hike around the year 2004 in the Case of the Great Britain. After that period however, the Japanese influence again lowered. Looking further at other countries, we can see several cases when the influence of Japan seems to have increased substantially. These are above all South Korea, Hong Kong, Taiwan and Singapore. Moreover this increase seems to really have been gradual. Japanese influence seems to have increased even in the cases of other countries, such as Australia, Germany, Indonesia or even China. In the case of China the increase took place later in the observed period, since 2007, which might be supported both by the Global Financial Crisis and the signs of RMB liberalization. The influence on the rest of the countries (Canada, Thailand, Philippines) did demonstrate some hikes, but no clear developmental pattern.

Figure 4.3.10: Contribution of Japan to sample countries FEV development in time





To sum the chapter up, the empirical study signifies several facts. First of all, the global financial linkage seems to have increased substantially in the observed period. The increase also seems to be triggered by financial crises, whose effect is likely to be more permanent than transitory. The US is then being the main driver of these developments, closely followed by Great Britain and also Japan. Second of all, for the East Asian linkage, the increase was much less prominent and also quite continuous compared to the global one. While its impact has been growing, Japan is

clearly the most influential country in the region, followed by Hong Kong, South Korea and Singapore. On the other hand the importance of China is negligible, even though it started slight growth recently. As for the contributions of Non East Asian countries towards East Asian region, not surprisingly US is the most important driver, though its contribution is not that much higher as that of Japan. Also the importance of Great Britain for East Asian Countries increased substantially with the global financial crisis and has not decreased yet. Third of all, the fact that Japanese stock market has been opening towards foreign influences is obvious. Its main foreign drivers are then clearly the western countries, among which Great Britain demonstrated the biggest growth. The influence of East Asian countries is low with no signs of any development. Ability of Japan to influence other markets has been growing as well and it is higher for East Asian Countries than for the rest of the sample. Most of all it is for Hong Kong, South Korea and Singapore. The intensity in which Japan influences Australia is also relatively strong. On the other hand Japan does not have very much influence on US but neither on China so far, even though in case of China there are signs that this could change.

5. Conclusions

Even though the empirical literature dealing with international financial interdependence is rich, its results are inconclusive. This fact might be given by various issues that make the application of theoretical approaches more difficult. It is above all the complexity and the time-varying nature of international financial markets. Among the most suitable methods to analyze these relations belong the multivariate models based on VAR. With their help, not only contemporaneous linkages but also dynamic causal relationships between individual markets can be researched. The Spillover Index is one of such methods that builds on VAR Forecast Error Variance and is particularly convenient for analyzing the financial linkages. It is because using this method, one is able to quantify both group and individual relationships of researched countries, which is very useful while assessing the intertemporal developments of financial linkages. In this work, it is this theoretical approach that we have used to research the Japanese stock market linkages between years 1995 and 2012.

The main factor that affects country's financial linkages is the openness of its economy towards international influences given mainly by the setting of its trade and capital markets. Last 20 years was a period during which Japanese economy underwent significant changes in this respect. Japanese government, which had been quite protectionist throughout the whole post-war era, was forced by unfavorable economic conditions to proceed with financial liberalization in order to fight decreasing competitiveness of Japanese financial markets. Moreover the period was also marked by a distinctive growth in foreign trade flows. The contribution of this work is the fact that it offers a comprehensive review of the developments of Japanese financial linkages throughout this for the economy unprecedented era.

Our empirical study presents several conclusions. First of all, we have found that even though the US have been the main driving force behind both global and East Asian stock market developments, Japan is the clear regional leader. Contrary to what one might have expected given the decreasing relative economic importance of

the country, the impact of Japanese stock markets has been increasing, above all in the East Asian region. The second conclusion is that there has been a continuous increase in intraregional linkages. This however touches only some countries, most of all Japan, South Korea, Hong Kong and Singapore, whose markets underwent substantial liberalization during the period. The rest of the East Asian countries including Mainland China stays quite closed and insignificant to international financial markets. Therefore, for the time being, the hypothesis about Chinese growing importance relative to Japan is not confirmed. Third of all, even though the integration of East Asian stock markets seems to have increased, there are no signs of region's dependence on the western developed economies weakening. On the contrary, beginning in the period before the global financial crisis, especially the influence of Great Britain increased significantly. The results of our work therefore refute the theory about East Asian countries decoupling from economic influence of the western developed economies, at least in the context of financial markets. Last but not least, our study has provided detailed analysis of Japanese linkages with other stock markets. We have confirmed that Japanese stock markets opened significantly towards external influence, which is almost uniquely transmitted from the western developed economies. On the other hand, we have also found that Japan exercises growing influence on East Asian countries - most of all Hong Kong, South Korea and Singapore but also Australia. This further confirms Japanese position of regional financial leader.

To sum the subject of this work up, in accordance with the majority of empirical literature, we have demonstrated that the global financial linkages have been showing an upward trend and that Japan plays an important role in these globalization tendencies. However because the nature of the international financial markets relations is dynamic, further research of the developments of Japanese stock market linkages stays in the center of attention. The chance to expand the topic lies in the author's view mainly in two aspects. Firstly in order to grasp the complexity of the financial markets, it is the improvement of methodology – e.g. extension to GARCH forecast error variance is an option. Secondly then, a detailed analysis of the impact of global financial crisis on the East Asian financial linkages is an area worth

examining as it has not been evident so far, whether it is of transitory or permanent nature.

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Data Sources

Stock price indices – http://stooq.pl

World Trade Organization – http://stat.wto.org

Statistical Bureau of Japan – http:// stat.go.jp

Bank of International Settlements – http://stats.bis.org

Tokyo Stock Exchange Factbooks – http://tse.or.jp/english

World Federation of Exchanges – http://www.world-exchanges.org/statistics/annual-query-tool

Japanese Ministry of Finance – http://mof.go.jp/english

Appendix

Dataset

Table A.1: Table of time zones

Country	Time Zone	Price used
Australia (Sindney)	UTC + 10	Closing
South Korea	UTC + 9	Closing
Japan	UTC + 9	Closing
Taiwan	UTC + 8	Closing
Singapore	UTC + 8	Closing
Philippines	UTC + 8	Closing
Malaysia	UTC + 8	Closing
Hong Kong	UTC + 8	Closing
China	UTC + 8	Closing
Thailand	UTC + 7	Closing
Indonesia (Jakarta)	UTC + 7	Closing
India	UTC + 5:30	Average
Germany	UTC + 1	Average
Great Britain	UTC	Average
USA (New York)	UTC - 5	Opening
Canada (Toronto)	UTC - 5	Opening

Preliminary Data Analysis

a) Stock Prices Levels

Table A.2: Data Summary (Stock Price Levels)

```
   Australia         Japan        South.Korea         China          Hong.Kong      Indonesia         Malaysia
Min.   :1823   Min.   : 7055   Min.   : 280.0   Min.   : 516.5   Min.   : 6660   Min.   : 256.8   Min.   : 262.7
1st Qu.:2915   1st Qu.:10087   1st Qu.: 718.1   1st Qu.:1239.5   1st Qu.:11136   1st Qu.: 490.8   1st Qu.: 744.0
Median :3363   Median :13159   Median : 923.5   Median :1627.1   Median :14106   Median : 716.2   Median : 927.7
Mean   :3723   Mean   :13579   Mean   :1110.4   Mean   :1892.7   Mean   :15279   Mean   :1387.1   Mean   : 996.4
3rd Qu.:4562   3rd Qu.:16813   3rd Qu.:1579.0   3rd Qu.:2364.1   3rd Qu.:19581   3rd Qu.:2167.8   3rd Qu.:1237.5
Max.   :6854   Max.   :22667   Max.   :2229.0   Max.   :6092.1   Max.   :31638   Max.   :4375.2   Max.   :1689.0
 Phillipines      Singapore        Taiwan          Thailand          India          Germany      Great.Britain
Min.   : 979.3   Min.   : 805   Min.   : 3446   Min.   : 207.3   Min.   : 2640   Min.   :1908   Min.   : 3302
1st Qu.:1612.5   1st Qu.:1770   1st Qu.: 5798   1st Qu.: 406.0   1st Qu.: 3493   1st Qu.:3946   1st Qu.: 4996
Median :2252.2   Median :2140   Median : 6847   Median : 679.1   Median : 5205   Median :5221   Median : 6364
Mean   :2495.5   Mean   :2237   Mean   : 6821   Mean   : 695.7   Mean   : 8608   Mean   :5100   Mean   : 7248
3rd Qu.:3112.0   3rd Qu.:2758   3rd Qu.: 7884   3rd Qu.: 862.1   3rd Qu.:14767   3rd Qu.:6359   3rd Qu.: 9732
Max.   :5832.8   Max.   :3876   Max.   :10202   Max.   :1472.0   Max.   :20995   Max.   :8104   Max.   :12413
    Canada           USA
Min.   : 3991   Min.   : 459.1
1st Qu.: 6812   1st Qu.: 952.6
Median : 8777   Median :1158.4
Mean   : 9205   Mean   :1119.7
3rd Qu.:11854   3rd Qu.:1317.9
Max.   :15070   Max.   :1565.2
```

Table A.3: ADF Unit root test (Stock Price Levels, whole sample)

Augmented Dickey Fuller Test, lags according to AIC (max set to 5 lags)

	Critical values		
	1%	5%	10%
constant	-3.43	-2.86	-2.57
constant, trend	-3.96	-3.41	-3.12

Country	Deterministics terms	Lags	Test Value	Unit root
Australia	constant	1	-1.614	Most likely
	constant, trend	1	-1.893	Most likely
Japan	constant	2	-1.861	Most likely
	constant, trend	2	-2.219	Most likely
South Korea	constant	5	-0.540	Most likely
	constant, trend	5	-2.633	Most likely
China	constant	5	-1.738	Most likely
	constant, trend	5	-1.845	Most likely
Hong Kong	constant	1	-1.815	Most likely
	constant, trend	1	-2.777	Most likely
Indonesia	constant	4	1.342	Most likely
	constant, trend	4	-1.009	Most likely
Malaysia	constant	5	-0.388	Most likely
	constant, trend	5	-1.564	Most likely
Phillipines	constant	5	0.885	Most likely
	constant, trend	5	-0.434	Most likely

Singapore	constant	1	-1.255	Most likely
	constant, trend	1	-2.192	Most likely
Taiwan	constant	4	-2.444	Most likely
	constant, trend	4	-2.551	Most likely
Thailand	constant	2	-1.078	Most likely
	constant, trend	2	-1.648	Most likely
India	constant	5	-0.181	Most likely
	constant, trend	5	-2.181	Most likely
Germany	constant	5	-1.723	Most likely
	constant, trend	5	-2.052	Most likely
Great Britain	constant	4	-0.737	Most likely
	constant, trend	4	-2.196	Most likely
Canada	constant	5	-1.603	Most likely
	constant, trend	5	-2.345	Most likely
USA	constant	3	-2.446	Most likely
	constant, trend	3	-2.398	Most likely

b) Stock Prices Log Returns

Table A.4: Data Summary (Log Returns)

```
   Australia            Japan            South.Korea            China            Hong.Kong
Min.   :-0.0855360   Min.   :-0.1211100   Min.   :-0.1280470   Min.   :-0.1790510   Min.   :-0.147346
1st Qu.:-0.0042852   1st Qu.:-0.0076450   1st Qu.:-0.0077538   1st Qu.:-0.0071347   1st Qu.:-0.006859
Median : 0.0001895   Median : 0.0000000   Median : 0.0000000   Median : 0.0000000   Median : 0.000000
Mean   : 0.0001908   Mean   :-0.0001364   Mean   : 0.0001445   Mean   : 0.0002697   Mean   : 0.000226
3rd Qu.: 0.0051268   3rd Qu.: 0.0076768   3rd Qu.: 0.0086905   3rd Qu.: 0.0080915   3rd Qu.: 0.008071
Max.   : 0.0606660   Max.   : 0.1323460   Max.   : 0.1128440   Max.   : 0.2699280   Max.   : 0.172470
   Indonesia            Malaysia           Phillipines            Singapore            Taiwan
Min.   :-0.1273180   Min.   :-0.2415340   Min.   :-0.1308870   Min.   :-9.154e-02   Min.   :-9.936e-02
1st Qu.:-0.0059985   1st Qu.:-0.0044995   1st Qu.:-0.0065010   1st Qu.:-6.046e-03   1st Qu.:-6.966e-03
Median : 0.0000670   Median : 0.0000000   Median : 0.0000000   Median : 0.000e+00   Median : 0.000e+00
Mean   : 0.0004713   Mean   : 0.0001182   Mean   : 0.0001552   Mean   : 7.318e-05   Mean   : 1.873e-05
3rd Qu.: 0.0075000   3rd Qu.: 0.0048175   3rd Qu.: 0.0071902   3rd Qu.: 6.332e-03   3rd Qu.: 7.587e-03
Max.   : 0.1312780   Max.   : 0.2081740   Max.   : 0.1617760   Max.   : 1.287e-01   Max.   : 8.520e-02
    Thailand             India              Germany          Great.Britain            Canada
Min.   :-1.606e-01   Min.   :-0.0953630   Min.   :-0.0842250   Min.   :-0.0706230   Min.   :-0.0992160
1st Qu.:-7.763e-03   1st Qu.:-0.0061703   1st Qu.:-0.0054307   1st Qu.:-0.0027403   1st Qu.:-0.0045225
Median : 0.000e+00   Median : 0.0000000   Median : 0.0006895   Median : 0.0005985   Median : 0.0004605
Mean   : 5.880e-06   Mean   : 0.0003412   Mean   : 0.0002774   Mean   : 0.0002691   Mean   : 0.0002282
3rd Qu.: 7.549e-03   3rd Qu.: 0.0074850   3rd Qu.: 0.0064522   3rd Qu.: 0.0039178   3rd Qu.: 0.0055465
Max.   : 1.135e-01   Max.   : 0.1405970   Max.   : 0.0749960   Max.   : 0.0399470   Max.   : 0.0652350
      USA
Min.   :-0.0946950
1st Qu.:-0.0050583
Median : 0.0003320
Mean   : 0.0002379
3rd Qu.: 0.0058712
Max.   : 0.1095720
```

Subsample testing

Table A.5: Residual assumptions tests (subsamples of log returns)

		BP test p-value		JB test	LM test
Subsample (t)	Lag (AIC)	h=1	h=2	p-value	p-value
(1;261)	1	0.0012	0.0009	< 2.2e-16	0.002853
(261;521)	1	0.0574	0.0008	< 2.2e-16	3.33E-16
(521;781)	1	4.08E-05	0.0004	< 2.2e-16	< 2.2e-16
(781;1041)	1	0.5611	0.2511	< 2.2e-16	1.90E-01
(1041;1301)	1	0.0022	0.0219	< 2.2e-16	1.02E-10
(1301;1561)	1	6.78E-06	3.17E-09	< 2.2e-16	7.95E-10
(1561;1821)	1	0.0001	3.09E-06	< 2.2e-16	0.057510
(1821;2081)	1	0.0235	0.0442	< 2.2e-16	0.000643
(2081;2341)	1	0.0009	0.0005	4.44E-15	0.006156
(2341;2601)	1	0.0017	0.0010	< 2.2e-16	0.000941
(2601;2861)	1	7.71E-05	1.56E-06	< 2.2e-16	0.254800
(2861;3121)	1	0.0916	0.0008	< 2.2e-16	0.033880
(3121;3381)	1	0.0002	6.44E-07	< 2.2e-16	2.11E-15
(3381;3641)	1	1.16E-07	1.21E-12	< 2.2e-16	< 2.2e-16
(3641;3901)	1	0.0011	5.31E-05	< 2.2e-16	< 2.2e-16
(3901;4161)	1	8.73E-06	2.06E-07	< 2.2e-16	< 2.2e-16
(4161;4421)	1	2.17E-10	1.12E-09	< 2.2e-16	< 2.2e-16
(4421;4694)	1	8.85E-06	5.92E-04	< 2.2e-16	7.69E-08

Spillover Index Calculation Algorithm

The following R code excerpt is presented in order to describe the intuition behind the Spillover Index calculation. The output of the cited code is the Table 4.3.1 and the Figures 4.3.1 and 4.3.2. Because of the fact that for the rest of the results, similar logic of the computation is used, we do not state the complete code.

```
# Simple Spillover index for the whole sample
################################################

#Model
Model <- VAR(Data, type = "none",lag.max = 5,ic = "AIC")
Model

# fevd
krok <- 10 # step for the forecast
Model.fevd <- fevd(Model, n.ahead = krok)
Model.fevd

# Construction of the spillover matrix, contributions to/from others and the spillover index
Model.spilloverMatrix <- rbind(Model.fevd$USA[krok,],Model.fevd$Japan[krok,],Model.fevd$Great.Britain[krok,],
Model.fevd$China[krok,],Model.fevd$India[krok,],Model.fevd$Germany[krok,],Model.fevd$South.Korea[krok,],Model.fevd$Canada[krok,],
Model.fevd$Taiwan[krok,],Model.fevd$Hong.Kong[krok,],Model.fevd$Australia[krok,],Model.fevd$Singapore[krok,],Model.fevd$Thailand[krok,],
Model.fevd$Malaysia[krok,],Model.fevd$Indonesia[krok,],Model.fevd$Phillipines[krok,])
Model.spilloverMatrix
Model.spilloverMatrix.ContribToOthers <- colSums(Model.spilloverMatrix)-diag(Model.spilloverMatrix) # contribution to others
Model.spilloverMatrix.ContribToOthers
Model.spilloverMatrix.ContribToOthersInclOwn <- colSums(Model.spilloverMatrix) # contribution incl. own
Model.spilloverMatrix.ContribToOthersInclOwn
Model.spilloverMatrix.ContribFromOthers <- rowSums(Model.spilloverMatrix)-diag(Model.spilloverMatrix) # contribution from others
Model.spilloverMatrix.ContribFromOthers
Model.spilloverMatrix.FullSampleIndex <- sum(Model.spilloverMatrix.ContribToOthers)/ncol(Model.spilloverMatrix) # full sample spillover index
Model.spilloverMatrix.IndividualIndices <- Model.spilloverMatrix.ContribToOthers/16 # divided by number of countries
Model.spilloverMatrix.FullSampleIndex
Model.spilloverMatrix.IndividualIndices


#Rolling window - total spillover index #
#################################
okno = 260 # rolling window lag
krok = 10 # forecast step
i = 1 # initialization

SpilloverIndex <- rbind(c(0),c(0))

for (i in 1:(nrow(Data)+1-okno)) {Subset <- (Data[i:(i+okno-1),])
                                  Model <- VAR(Subset,type = "none",lag.max = 5, ic = "AIC")
                                  Model.fevd <- fevd(Model, n.ahead = krok)
                                  Model.spilloverMatrix <- rbind(Model.fevd$USA[krok,],Model.fevd$Japan[krok,],Model.fevd$Great.Britain[krok,],
                                Model.fevd$China[krok,],Model.fevd$India[krok,],Model.fevd$Germany[krok,],Model.fevd$South.Korea[krok,],
                                Model.fevd$Canada[krok,],Model.fevd$Taiwan[krok,],Model.fevd$Hong.Kong[krok,],Model.fevd$Australia[krok,],
                                Model.fevd$Singapore[krok,],Model.fevd$Thailand[krok,],Model.fevd$Malaysia[krok,],Model.fevd$Indonesia[krok,],
                                Model.fevd$Phillipines[krok,])
                                  Model.spilloverMatrix.ContribToOthers <- colSums(Model.spilloverMatrix)-diag(Model.spilloverMatrix)
                                  Model.spilloverMatrix.FullSampleIndex <- sum(Model.spilloverMatrix.ContribToOthers)/ncol(Model.spilloverMatrix)
                                  SpilloverIndex <- cbind(SpilloverIndex,c(i,Model.spilloverMatrix.FullSampleIndex))}

SpilloverIndex <- SpilloverIndex[,2:ncol(SpilloverIndex)] # make rid of the free 0 observation
TotalSpilloverIndex <- SpilloverIndex


#Rolling window - Japanese individual spillover index #
#######################################################
okno = 260 # rolling window lag
krok = 10 # forecast step
i = 1 # initialization

JapanIndividualIndex <- rbind(c(0),c(0))

for (i in 1:(nrow(Data)+1-okno)) {Subset <- (Data[i:(i+okno-1),])
                                  Model <- VAR(Subset,type = "none",lag.max = 5, ic = "AIC")
                                  Model.fevd <- fevd(Model, n.ahead = krok)
                                  Model.spilloverMatrix <- rbind(Model.fevd$USA[krok,],Model.fevd$Japan[krok,],Model.fevd$Great.Britain[krok,],
                                Model.fevd$China[krok,],Model.fevd$India[krok,],Model.fevd$Germany[krok,],Model.fevd$South.Korea[krok,],
                                Model.fevd$Canada[krok,],Model.fevd$Taiwan[krok,],Model.fevd$Hong.Kong[krok,],Model.fevd$Australia[krok,],
                                Model.fevd$Singapore[krok,],Model.fevd$Thailand[krok,],Model.fevd$Malaysia[krok,],Model.fevd$Indonesia[krok,],
                                Model.fevd$Phillipines[krok,])
                                  Model.spilloverMatrix.ContribToOthers <- colSums(Model.spilloverMatrix)-diag(Model.spilloverMatrix)
                                  Model.JapanIndividualIndex <- Model.spilloverMatrix.ContribToOthers[["Japan"]]/16
                                  JapanIndividualIndex <- cbind(JapanIndividualIndex,c(i,Model.JapanIndividualIndex))}

JapanIndividualIndex <- JapanIndividualIndex[,2:ncol(JapanIndividualIndex)] # make rid of the free 0 observation
JapanIndividualIndex
plot(JapanIndividualIndex[1,],JapanIndividualIndex[2,], type = "l",xlab="Time",ylab="Full sample Japan Individual index")
```