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Faculty of Social Sciences
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MASTER'S THESIS

Interconnectedness of capital markets during the financial crisis

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Declaration of Authorship

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Abstract

We study the interconnectedness between the United States and thirty three international stock markets during the period of January 2003 to December 2012, with an emphasis on the global financial crisis of autumn 2008. By applying the DCC-GARCH model, our results show evidence of the increase in correlation during the period of crisis. The largest increase was reported for Argentina and India. The average increase was 0.164. Within the sample period, the US stock market was found to be the most correlated with markets of Brazil, Canada, France, Germany, Euro Area and Mexico and the least correlated with markets of China, Malaysia and New Zealand. In the second part of the thesis we study the relationship between the four selected markets (China, Euro Area, Japan and United States) and macroeconomic variables (exchange rate, total trade, industrial production and interest rates). The markets show positive relationship with the exchange rate, trade and the industrial production. The interest rate does not reveal any specific, negative nor positive, relationship. We conclude that more indices respond to a shock in one index in a very similar way.

JEL Classification	C12, C22, C32, G01, G15
Keywords	stock markets, financial crisis, GARCH

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Abstrakt

Študujeme prepojenosť tridsiatich troch medzinárodných akciových trhov so Spojenými štátmi v období od januára 2003 do decembra 2012, s dôrazom na globálnu finančnú krízu v roku 2008. Pomocou modelu DCC-GARCH, naše výsledky ukazujú dôrazné zvýšenie korelácie v priebehu krízy. Najväčší nárast bol zaznamenaný v Argentíne a Indii. Priemerný nárast korelácie predstavoval 0.164. Zistili sme, že počas celého obdobia americký trh najviac koreluje s trhmi v Brazílii, Kanade, Francúzsku, Nemecku, eurozóne a Mexiku a najmenej s trhmi v Číne, Malajzii a na Novom Zélande. V druhej časti práce študujeme vzťah medzi štyrmi vybranými trhmi (Čína, eurozóna, Japonsko a Spojené štáty) a makroekonomickými premennými (menový kurz, celkový obchod, priemyselná výroba a úrokové sadzby). Trhy vykazujú pozitívny vzťah ku kurzu, obchodu a priemyselnej výrobe. Úroková sadzba neodhalí žiadny konkrétny, negatívny ani pozitívny vzťah. Došli sme k záveru, že viacero indexov reaguje na šok v jednom indexe veľmi podobným spôsobom.

Klasifikace JEL C12, C22, C32, G01, G15
Klíčová slova akciové trhy, finančná kríza, GARCH

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Acronyms

ADF Augmented Dickey-Fuller

DCC Dynamic Conditional Correlation

GARCH Generalized Autoregressive Conditional Heteroskedasticity

IRF Impulse Response Function

VECM Vector Error Correction Model

Master's Thesis Proposal

Author	Bc. Soňa Kocholová
Supervisor	PhDr. Petr Gapko
Proposed topic	Interconnectedness of capital markets during the financial crisis

Motivation Global economic growth is encouraged by an increasing share of global economic activity taking place across borders. This causes the financial linkage between countries to increase exponentially. Different countries are becoming complexly interconnected.

Interconnectedness (of countries) refers to the phenomenon in which the failure of, or large losses borne by, one country precipitates the failure of, or large losses borne by, a second country because the second has an exposure to the first failed institution that exceeds its capital. Through such interconnectedness, an event, taking place in one country can transmit economic shocks across the globe.

Understanding of financial interconnectedness is becoming increasingly important. The financial crisis of 2007-09 originated in the sub-prime market in the United States in the housing finances system, but had soon turned the spotlight on shadow banking not only in the US, but also globally.

Hypotheses

Hypothesis #1: Degree of interconnectedness differs across countries' stock markets.

Hypothesis #2: The interconnectedness of markets increased during the period of crisis.

Hypothesis #3: There is a relationship between the interconnected markets and macroeconomic variables.

Methodology By appying the Dynamic Conditional Correlation multivariate GARCH model (DCC-GARCH) we will measure the degree of time-varying correlation between markets. Our aim is to estimate how does the interconnectedness within markets differ and whether it increases during the period of crisis. The data will include daily stock market returns of a large sample of major stock markets of countries from across the world. We will examine their correlation with the US stock market.

In the second part of the thesis we will employ the Vector Error Correction model to examine the long run relationship between selected countries' stock markets and their macroeconomic variables. By modelling the Impulse Response Functions, we will study the responses of individual markets to one standard deviation positive shock given to one stock market.

Expected Contribution Our biggest contribution to the literature is taking into account large sample number of international capital markets. The model will not be limited to just one area of the world, for example Europe, Asia or Latin America. Instead we use international stock markets form the entire world. Also the time horizon will be extended, to the previous papers, to improve our results. The aim is to show whether the correlation differs across countries and how is it effected by the crisis. We further investigate the markets, by testing for their long run relationship with selected macroeconomic variables.

Outline

1. Introduction: We will introduce our main idea, motivation, aim, results and structure of the thesis.

2. Background information: We will introduce the topic and give the reader the main idea behind this area of research.

3. Literature Review: We will review previous literature on selected topic.

4. Data: We will explain the reason for choosing our data and its descriptive statistics.

5. Methodology: We will explain in detail the models, which will be used in this paper.

6. Empirical results: We will examine, analyse and discuss results.

7. Conclusion: We will summarize the problem, our work, results, main contribution and ideas for future research.

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Chapter 1

Introduction

The question of market interconnectedness has become increasingly important in the field of research economics in recent years. The continuously higher globalization of the world leads to larger correlation within markets, making them more vulnerable to the effects of the crisis. The main interest of academic researchers is to investigate whether the global financial crisis affects the already correlated markets and to what extent.

Mighri & Mansouri (2013) study time-varying conditional correlations in order to capture potential contagion effects between US and major developed and emerging stock markets during the 2007-2010 global financial crisis. Their result contrasts with one of the biggest contribution to the current literature, Forbes & Rigobon (2002) and 'no contagion' conclusion, as they show empirical evidence of significant increase in conditional correlation or contagion. The topic of market correlation has been already broadly examined (see, for example, Theodossiou & Lee (1993), Longin & Solnik (1995), Worthington & Higgs (2004), Horvath & Poldauf (2012), Arouri *et al.* (2013), Mollah *et al.* (2014), among many others).

The aim of our thesis is to study the conditional correlation between the US and international stock markets, with the emphasis on the period of recent global financial crisis of autumn 2008. Similarly to Horvath & Poldauf (2012), we test for the conditional correlation by employing a multivariate GARCH model. Our intention is to extend the sample of data in terms of number of countries and time. Most of the current literature usually concentrates on a specific region, for example Latin America in case of Johnson & Soenen (2003), Benelli & Ganguly (2007) and Arouri *et al.* (2013) or Asia in case of Worthington & Higgs (2004). We use daily stock market returns from total of thirty three international stock markets, based on the world market capitalization. Also we believe, that most of the previous studies do not cover long enough period after the crisis began. We take the period from January 2003 to December 2012, covering substantial period after and before the beginning of the crisis. Another contribution to the current literature is that we examine September 2008 as the begging of the crisis, by testing for structural breaks by applying the Chow test. We reject the null hypothesis of stability for most of the countries, at 95% level of confidence. As we prove the presence of structural break in September 2008, we define the beginning of the crisis as the day, when Lehman Brothers filed for bankruptcy, September 15^{th} 2008. By determining this exact day, we investigate the change in correlation over time with respect to the crisis. In order to differentiate our thesis from the previous literature, we take our analysis further. We study the long term relationship between four selected markets (China, Euro Area, Japan and the United States) and their macroeconomic variables (exchange rate, total trade, industrial production and interest rates) by employing the Vector Error Correction Model. Using the Impulse Response Functions we also examine the reaction of markets to one standard deviation of positive shock given to one market.

Our results from the GARCH model suggest that the US market is least correlated with stock markets of New Zealand, China and Malaysia, and most correlated with markets of Canada, Mexico, Brazil, Germany, Euro Area and France. The largest difference in the correlation between the before crisis period and the period of one year after the crisis began, was reported for Argentina and India. By studying the results graphically, we distinguish between five main trends of correlation progress over time within markets.

By employing the VECM we find evidence of positive relationship between the stock markets with the exchange rate, total trade and industrial production. The results for the interest rate do not support any certain relationship, as there is evidence of both positive and negative relationships. We model the Impulse Response Functions between two stock markets. We find that if one standard deviation positive shock is given to one stock market, both of the markets show evidence of the same response.

The thesis is organized as follows: Chapter 2 gives brief summary of the background information and Chapter 3 gives review of the previous literature on the selected topic. Chapter 4 describes the data. Chapter 5 reviews the methodology. Chapter 6 presents the results. Chapter 7 summarizes our conclusion. Appendix with additional results.

Chapter 2

Background Information

Lehman Brothers

Lehman Brothers Holdings Inc. (LBHI), the fourth largest investment bank in the US at the time of its collapse, filed for bankruptcy on September 15, 2008. Dealing with the largest bankruptcy filling in the US history, Lehman Brothers declared 639 billion US dollars in assets and 613 billion US dollars in debt in its audited financial report on May 31, 2008.[1]

History of Lehman Brothers traces back to 1844, with Henry Lehman, German immigrant, opening a small general store in Montgomery, Alabama. In 1850, Henry Lehman and his brothers founded Lehman Brothers. Lehman became a prosperous firm, able to survive many disasters over the years.

Lehman's acquisitions started taking place after the US housing boom in 2003 and 2004. Lehman acquired five mortgage lenders. Its revenues suddenly increased by 56% from 2004 to 2006. Lehman reported record profit every year from 2005 to 2007.

However in the first quarter of 2007 the US housing market began to show its defaults, as on March 13, 2007 the stock reported its biggest one-day drop over the past five years.[2] Lehman's management and then chief financial officer (CFO) did not believe that rising defaults would have an impact on Lehman's profitability. They did not expect the problems spreading through out the whole housing market, affecting not only the US economy, but also the rest of the world.

[1] Wiggins *et al.* (2014)

[2] Wiggins *et al.* (2014)

Credit crisis broke out by august 2007 and Lehman's stock fell rapidly. The company closed down offices and whole units, hundreds of mortgage-related jobs were eliminated. When looking back at the events, the last and, what seemed to be, the only chance for the company not to fail was to reduce its enormous mortgage backed portfolio.

Lehman's leverage ratio, the ratio of total assets to shareholders equity, was reported to be thirty to one in year 2007.[3] The firm's portfolio was entirely based on mortgage securities, which made it increasingly exposed to worsening market conditions. On March 17, 2008 Lehman's shares fell by 48%. Lehman's hedge fund clients began withdrawing, while its short-term creditors cut credit lines. Lehman Brothers was completely dependent on short-term funding, especially on repos, the repurchase operations. As this short-term funding became unavailable, Lehman Brothers suffered enormous liquidity crisis.

Over the summer the firm's management made some bad decisions, which only proved to be extremely costly and left Lehman Brothers an undesirable acquisition target.[4] In the first week of September 2008 the stock crashed by another 77%. An unsuccessful attempt of a takeover of Lehman took place over the weekend of September 13, 2008. Its stock fell by 93% after its last repost on the weekend of September 12. On Monday September 15, Lehman announced bankruptcy.

The collapse of the US housing market eventually brought Lehman Brothers to their own collapse, which had significant effects, as it was this crisis that spread rapidly across institutions and markets.

[3] Scott (2010)
[4] Scott (2012)

Interconnectedness

Systemic risk was a major contributor to a crisis of 2007-2008. The possibility for systemic risk arises, for example, due to potential build-up of leverage and liquidity mismatches at the same time or due to exposures to common networks of intermediaries. It involves the so-called "three Cs": *connectedness* (asset and liability interconnectedness), *contagion* and *correlation*.[5]

Interconnectedness can relate to assets or liabilities, and generally refers to the phenomenon in which the failure of, or large losses borne by, one firm precipitates the failure of, or large losses borne by, a second firm because the second has an exposure to the first failed institution that exceeds its capital.[6]

Asset interconnectedness refers to the failure of one financial institution will directly cause the collapse of other financial institutions that have direct credit exposures to the first failed institution. *Liability interconnectedness* is the concept of one institution that is a source of short-term funding to other institutions will stop funding those institutions, causing the failure of the other institutions. *Contagion* is when funding is withdrawn from banks and other financial institutions as a result of a fear of general upcoming failure.[7]

Systemic risk concerns can be directly linked to the failure of Lehman Brothers. Asset interconnectedness and liability interconnectedness were not the main features of the systemic risk concerns during the financial crisis. As Lehman was not a significant source of short-term funding, the loss of Lehman as a creditor did not directly result in failures of other financial institutions. It was the contagion, which was the main determinant of causing the spread of default of major financial markets.

[5] Scott (2011)
[6] Scott (2012)
[7] Scott (2012)

Chapter 3

Related Literature

3.1 Markets interconnectedness

In the following section we review the selected literature, related with measuring the cross-market conditional correlation using specifically the multivariate GARCH models.

King & Wadhwani (1990) investigated the uniformity with which the world stock markets fell during the US stock market crash in October 1987. By examining a rational expectation price equilibrium, they model contagion between markets as a result of rational investors using imperfect information. Based on hourly data from London, New York and Tokyo stock exchanges over the period of July 1987 to February 1988, they were able to prove empirically how failure in the market mechanism in one market could transmit to other markets. Their main conclusion is that an increase in volatility leads to the increase in contagion effects.

Similarly to the previous paper, Hamao *et al.* (1990) studied the correlation and volatility of the daily opening and closing prices between the three major international stock market indices of London, New York and Tokyo from April 1985 to March 1988. By employing the GARCH model, they found statistically significant volatility spillover effects from the US and the UK stock markets to Japan and much weaker effect from Japanese market to the other two markets.

Theodossiou & Lee (1993) assessed the nature and degree of correlation of stock markets of the United States, Japan, the United Kingdom, Canada and Germany by applying multivariate GARCH model between years 1980 and 1991. They found that the stock market volatility is most persistent in Canada and Germany and least persistent in the UK Statistically significant volatility spillovers are present from the US market to all four stock markets, the strongest to the UK, Canada and then Japan. The weakest spillovers from the US are to Germany, from the UK to Canada and from Germany to Japan. Lastly the German market was found to be the least integrated of all five markets.

Karolyi (1995) studied the short-run dynamics of returns and volatility of US and Canadian stock markets, together with their cross-market dynamics, by applying multivariate GARCH models during years 1981 to 1989. The author noted that many of the Canadian stocks are also listed on the US exchange and therefore in his study divided these stocks into *interlisted* (dually listed) and *noninterlisted*. Karolyi (1995) firstly reported that the degree of the effects of shocks from the US stock market on the returns and volatility of the Canadian stock market is decreasing over time. Secondly, there is a difference in the magnitude and intensity of the effects of the US shocks between the interlisted and noninterlisted Canadian stocks. Specifically, the US shocks have a greater impact on the interlisted Canadian stocks.

Longin & Solnik (1995) examined the long-term conditional correlation of monthly excess returns for seven major stock markets (the United States, Canada, the United Klinkageingdom, Germany, France, Switzerland and Japan) over the period 1960-90. Using a multivariate GARCH model they reported that the international conditional correlation increases over the period of thirty years and in periods of turmoil. They estimated that the highest unconditional correlations among the stock markets over the sample period is present in Canada and the US and the lowest in Germany and Japan. The results are almost identical to those of Theodossiou & Lee (1993). Lastly they revealed that higher dividend yields and interest rates may lead to higher correlations.

Berben & Jansen (2005) studied the changes in the pattern of correlations among international stock market weekly returns of Germany, Japan, the United Kingdom and the United States over the period of 1980 to 2000. The authors introduced a novel bivariate GARCH model with smoothly time-varying correlation and then derived a Lagrange Multiplier statistic to test for constant correlation. The results of the paper are the following. The correlation between the German, the UK and the US stock markets have more than doubled over the period of twenty years, as compared to the correlation with the Japanese stock market, which remained at the same level. However, there is evidence of a great diversity in timing and speed of these correlation shifts. When focusing on the correlation of the equity returns at the industry level, it was found to be identical to the correlation at the aggregate level.

Forbes & Rigobon (2002) is considered to be one of the most important contribution to the literature. They proved that the test for contagion using the correlation coefficient is biased due to heteroskedasticity. If the correlation coefficients are corrected for heteroskedasticity, there is no evidence of a significant increase in cross-market correlation coefficient, therefore there is no evidence of contagion during the 1997 East Asian crisis, 1994 Mexican peso devaluation, and 1987 US stock market crash.

Johnson & Soenen (2003) explored the degree of integration of the eight equity markets of the Americas (Argentina, Brazil, Chile, Mexico, Canada, Colombia, Peru and Venezuela) with the United States stock market, using daily returns from year 1988 to 1999. There is a statistically significant evidence of correlation between the returns of the US stock market and the eight equity markets of the Americas, mostly in Canada and Mexico. The highest degree of the integration was reported in the middle of the 1990s. Johnson & Soenen (2003) also examined which of the macroeconomic variables are associated with the correlation of the markets as its driving factors. They presented that a high share of trade with the US has a positive effect, while increased exchange rate volatility and a higher stock market capitalization relative to that of the US has a negative effect on stock market comovements.

Worthington & Higgs (2004) investigated the diversity of equity returns and volatility of Asian developed (Hong Kong, Japan and Singapore) and emerging (Indonesia, Korea, Malaysia, the Philippines, Taiwan and Thailand) stock markets during the years 1988 to 2000. The estimated coefficient of the multivariate GARCH model proved that all Asian equity markets are highly correlated. They noted that the changes in volatility in emerging markets are more effected by their domestic conditions than by the developed markets.

Following Johnson & Soenen (2003), Benelli & Ganguly (2007) reviewed the linkage between the United States and the seven largest Latin American economies (Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela) for the stock, currency and bond markets from year 1997 to 2006. They conclude that the linkage from the US stock market to Latin American stock markets increase over time.

Sun & Zhang (2009) assessed the spillovers from the United States on the stock markets in China and Hong Kong during the recent financial crisis using both univariate and multivariate GARCH models with the daily data from January 2005 to October 2008. The return and volatility spillovers from the

US were reported to be stronger and more persistent for Hong Kong than those for China. The conditional correlation between Hong Kong and China themselves was higher than their conditional correlation with the US.

Horvath & Poldauf (2012) explored the stock market comovements, both at the market and sectorial level between Australia, Brazil, Canada, China, Germany, Hong Kong, Japan, Russia, South Africa, the United Kingdom, and the United States between years 2000 and 2010. By employing multivariate GARCH model, they showed that the conditional correlation among the stock market returns increased during the period of the financial crisis (2008). Brazil, Canada and the UK were found to be the most correlated, while China, Australia and Japan the least correlated stock markets with the US The sectorial returns were less correlated than the market returns, although they share a similar character, as they both increase during the period of crisis.

Arouri *et al.* (2013) reviewed the comovements and contagion effects between four emerging Latin American markets (Argentina, Brazil, Chile, and Mexico) and the United States stock market using the DCC and the BEKK GARCH models over the period from February 1988 to April 2009. Firstly, the DCC-GARCH model provided better in-sample estimates than the BEKK-GARCH model. Secondly, there was a significant time-varying market correlation between the Latin American and the US stock markets, with an increase in periods of turmoil.

Mighri & Mansouri (2013) used the DCC multivariate GARCH model to study the time-varying conditional correlation of the daily stock index returns during year 2007 to 2010. Their empirical results based on correlation coefficients, both adjusted and unadjusted for heteroskedasticity showed significant evidence of an increase in conditional correlation or contagion during the crisis period, which contradicts the 'no contagion' results presented by Forbes and Rigobon (2002).

Mollah *et al.* (2014) studied financial market contagion during the recent financial crisis using the United States dollar-denominated MSCI daily indices for the period of 2006 to 2010 by applying multi-approach econometric techniques, the Dynamic Conditional Correlation-Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH), principal component analysis (PCA) and the vector error correction model (VECM) approach to test Granger causality and the impulse response function (IRF). The results of the DCC approach, together with the PCA framework, proved the contagion for all the countries in the study. The Granger causality test and the IRF within the VECM framework supported these results with an exception of Sweden, which seems to be not effected by the global crisis.

3.2 Cointegration and macroeconomic variables

In the following part we review the literature related to testing the cointegration between the stock markets and their relationship with macroeconomic variables. We categorize this literature review according to the variables.

The first commonly investigated variable is the exchange rate. The results of the studies vary. For example, Karolyi & Stulz (1996) do not find evidence that exchange shocks have an effect on return correlations between US and Japanese market returns. However, most of the results indicate a strong positive relationship between the exchange rates and the stock markets.

One of the biggest contribution to the current literature was done by Granger *et al.* (2000). The study is based on the contrasting theories of the "traditional" approach, i.e. currencies lead stocks, and the "portfolio" approach, i.e. stocks lead currencies negatively correlated. Using daily data between years 1986 and 1998, the support for the traditional approach is found in South Korea and the portfolio approach in Hong Kong.

Also, Hatemi-J & Irandoust (2002) examine the exchange rates and stock prices of Sweden, using a new Granger non-causality testing procedure developed by Toda & Yamamoto (1995). The results show evidence of an increase in Swedish stock prices which is associated with an appreciation of the Swedish krona.

The results of Hochstotter & Weskamp (2012) indicate that the correlations between equity market and exchange rate returns have an impact on the risk foreign investors are exposed to. Also, the relationship over a time period is definitely not stable.

Bello (2013) found evidence of the significantly negative correlation between the Japanese yen and the US stock market, while the euro, the pound and the Chinese yuan correlated positively.

Most of the evidence shows a strong relationship between stock markets of two countries and their exchange rates. As there is a relationship between the exchange rate and international trade, there must be a relationship between stock markets and international trade.

Ma & Kao (1990) investigated the relationship between two financial market variables in import and export dominated countries. Their results show that a currency appreciation has a negative effect on the domestic stock price movements of export dominated economies, while having a positive effect on stock prices of import dominated countries.

Interest rate is the second most important, hence most investigated, factor, after the exchange rate, showing a significant relationship with the stock market.

Alam & Uddin (2009) uses the monthly data from January 1988 to March 2003 to investigate the relationship between stock index and interest rate for fifteen developed and developing countries. The authors give empirical evidence that interest rate has significant negative relationship with stock price and for six countries, the interest rate change has significant negative relationship with changes of stock price.

Fama (1990) found that the growth rate of industrial production had a strong contemporaneous relation with stock returns.

Chen *et al.* (1986) gave evidence based on a US stock market portfolio, that future growth in industrial production is a significant factor in modeling stock returns.

Tainer (1993) supports the idea that the industrial production index is pro-cyclical, therefore it rises during economic expansion and falls during a recession.

Ali *et al.* (2010) studied causal relationship of industrial production with stock returns and results showed cointegration between the two variables.

Quadir (2012) investigated the effect of macroeconomic variables on the stock returns on Dhaka Stock Exchange, by applying *Autoregressive Integrated Moving Average, ARIMA*, model using monthly data for the period between January 2000 and February 2007. The coefficients estimating the positive relationship between industrial production and market stock returns were reported to be statistically insignificant.

Chapter 4

Data

4.1 Markets interconnectedness

In the first part of the thesis, we use the daily data from international stock market indices to study the interconnectedness between countries with reference to the period of crisis, by applying *the Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroscedasticity model, DCC-GARCH*. The data cover the period from January 1^{th}, 2003 until December 31^{th}, 2012. Our aim is to distinguish between the period of turmoil caused by the world financial crisis of autumn 2008. The period which the crisis covers is further discussed in more detail in the descriptive statistics paragraph.

Overall, we selected the leading stock market indices for 33 countries, apart from the United States. The motivation behind the choice of these particular countries is to cover the stock markets with the world's largest market capitalization. The data contain the adjusted prices for dividends and splits, listed in the US dollars. We compare the daily prices of indices of each country together with the US stock market index, to obtain the missing values. Some data are not be available due to differences in the national holidays, bank holidays, or for any other reason. After the evaluation we remove the days on which the data are non-available.

In the following paragraph we briefly describe the international indices selected for each country. The United States is represented by the *S&P 500 index*, which includes 500 main companies and captures approximately 80% coverage of available market capitalization. Argentina is presented by the most widely known index on its local market, *the MerVal Index*. *The ASX 200 Index* is used for Australia, as it is its leading share market index containing the top 200 companies listed on the Australian Securities Exchange, accounting for 70% of its equity market. *The ATX Index* is the Austria's largest index traded on the Vienna Stock Exchange, comprising of 20 companies. *The BEL 20 Index* is the most widely used indicator of the Belgian stock market, consisting of the 20 largest shares listed on the Euronext Brussels. Brazil is represented by *the Bovespa Index*, the main index of the Sao Paolo Exchange, one of the largest exchanges across the world by market capitalization. *The S&P TSX Composite Index* represents Canada, covering approximately 95% of its equity market. Chile is presented by *the Selective Stock Price Index*, made of the top 40 most liquid companies, which account for about 71% of the overall market capitalization of all the companies listed on the Santiago Exchange. *The SSE Composite Index* traded on the Shanghai Stock Exchange is used to describe China. The most important stock market index for Denmark is *the OMX Copenhagen 20 Index* that belongs to the NASDAQ OMX Group, traded on the Copenhagen Stock Exchange. *The EURO STOXX 50 Index* is a stock index of Eurozone stocks of 50 large, blue-chip European companies that reflect the performance of the Euro Area. It is traded on the Frankfurt Stock Exchange. France is represented by *the CAC 40 Index* including the 40 largest and most actively traded shares listed on Euronext Paris, accounting for around 65% of market capitalization. Germany is presented by *the DAX 30 Index* consisting of the 30 largest companies listed on the Frankfurt Stock Exchange. *The Athex Composite Share Price Index* is used to characterize Greece. Representing Hong Kong is *the Hang Seng Index*, the most widely quoted indicator of the performance of the Hong Kong stock market. *The S&P BSE SENSEX Index* is used for measuring the performance of India and its 30 largest, most liquid and financially sound companies listed in the Bombay Stock Exchange. Indonesia is defined by *the Jakarta Composite Index*, an index including all stocks listed on the Indonesia Stock Exchange. *The ISEQ 20 Index* comprising of the 20 most liquid and largest capped companies listed on the Irish Stock Exchange reflects the performance of Ireland. *The TA 100 Index* represents Israel, being one of its leading indices it covers 100 shares with the highest market capitalization in the Tel Aviv Stock Exchange. Italy is represented by the *The FTSE MIB Index*, the primary benchmark index conceived to measure the performance of the 40 Italian equity markets listed on the Borsa Italiana, accounting for approximately 80% of the home market capitalization. Japan is represented by *the Nikkei Stock Average* comprised of 225 stocks traded on the Tokyo Stock

Exchange, capturing about 60% of market capitalization. *The Kuala Lumpur Composite Index* is the leading index of the FTSE Bursa Malaysia Index Series. It presents the top 30 companies by market capitalization on the Bursa Malaysia Main Market. *Mexico IPC Index* is the main benchmark stock index for the Mexican Stock Exchange. Accounting for Netherlands is *the AEX Index*, the most widely used indicator in the Dutch stock market. It describes the performance of the 25 largest and most actively traded shares listed on Euronext Amsterdam. New Zealand is represented by *the S&P/NZX 50 Index* covering approximately 95% of New Zealand equity market capitalization, expressing the performance of the 50 largest stocks listed on the New Zealand Stock Market. *The RTS Index* is covering the 50 most liquid Russian stocks on the Moscow Stock Exchange. Singapore is represented by *The Straits Times Index*, the headline index of the FTSE ST Index Series that reflects the performance of the top 20 companies listed on the Singapore Exchange. *The Korea Composite Stock Index* is the main stock composite price index listed on the Korea Exchange used for South Korea. Spain is represented by *the IBEX 35 Index* that is composed of the 35 most liquid securities traded on the Madrid Stock Exchange. *The OMX Stockholm 30 Index*, made of the 30 most traded stocks on the Stockholm Stock Exchange is used to present Sweden. *The SMI, Swiss Market Index,* traded on the Swiss Exchange accounts for Switzerland. *Taiwan Capitalization Weighted Stock Index* is the most widely quoted stock on the Taiwan Stock Exchange. The most commonly traded stock on the Borsa Istanbul, *the BIST 100 Index*, is used to describe Turkey. And finally, the United Kingdom is represented by *the FTSE 100 Index*.

In order to proceed in our analysis, we calculate the daily stock index returns as logarithmic differences of stock price indices using the equation:

$$r_{i,t} = ln\left(\frac{p_{i,t}}{p_{i,t-1}}\right) \times 100 \quad t = 1, 2, ..., T \tag{4.1}$$

where $r_{i,t}$ is the return specified for a country i at time t, T is the total number of observations, p denotes the current stock price index (t) and the lagged day's stock price index $(t-1)$.

The plots of daily returns of all the stock market indices are available in Figure A.1 in the Appendix. Most of the countries share similar characteristics, when looking at the plot of their returns. The countries that stand out are Greece and Malaysia. Volatility of Greece remains high even after year 2009 and Malaysia reports large mostly negative returns in 2008 and two dramatic jumps around year 2010. Also, for each country we can notice a change in the volatility of the returns around year 2008.

4.1.1 Descriptive Statistics

Table A.1 in the Appendix reports the summary statistics of each of the market series for the entire sample period, from January 2003 until December 2012. Standard deviation expresses the volatility of the series. Russia's returns show the highest volatility, with its standard deviation of 2.2458. Other countries with relatively high volatile returns, above 1.7, are Argentina, Brazil, Greece and Turkey. The lowest volatility is reported in New Zealand, 0.7236 and Malaysia, 0.9878.

More detailed description of the standard deviation is presented in Table A.2 in the Appendix, where the sample period is divided into *the pre-crisis*, *the crisis* and *the post-crisis* period.

The crisis covers the period since September 2008 until the end of our sample. We determine the beginning of the crisis by conducting the Chow test to study for structural breaks in our series. With 95% level of confidence, we reject the null hypothesis of stability for September 2008 for most of the countries. Therefore, there is evidence of structural break caused by the crisis. We decided to specify the date of the beginning of the crisis by the day when the Lehman Brothers filed for bankruptcy, September 15^{th} 2008. Our sample period ends in December 2012, by then the end of the crisis was nowhere close to be seen.

Therefore, the pre-crisis period represents the time from the January 1^{st} 2003 until the September 15^{th} 2008 and the crisis period is afterwards, from the September 16^{th} 2008 until the 31^{st} of December 2012. The post-crisis period covers one year after the crisis began, from the September 15^{th} 2008 until the September 14^{st} 2009. We decided to name the period as the post-crisis period, because it describes the period after the crisis began. In this table we can review the difference in the volatility of the returns between the three periods.

Reviewing the post-crisis period, we report the highest degree of volatility in

Russia, 4.6701, and above 3 volatility in Austria, Brazil, Argentina, Hong Kong and Japan. These are also the countries, which experience the highest change in the volatility between the pre-crisis period and the year after the beginning of the crisis, therefore most effected by the shocks from the crisis. The largest volatility during the whole crisis period, above 2, is found for Russia, Argentina, Austria, Brazil, Greece and Italy. The largest increase in the volatility from the pre-crisis to the crisis period is reported for Greece, 1.1767, and Italy with 1.0874. These were the only two countries with change in the volatility of their returns being higher than one. This is mainly the result of the returns of the market in Greece and Italy remaining highly volatile until the end of the period, year 2012.

Furthermore, the least change in the volatility during the post-crisis and crisis period is found in Malaysia, China, Turkey and New Zealand. The standard deviation of the returns of the stock market in Malaysia the year after the beginning of the crisis is recorded to be only 1.115. The difference in the volatility of the returns in Chinese and Turkish stock index markets between the pre-crisis and the crisis period is even negative.

Skewness is used to describe the asymmetry of a data distribution about its mean. Only 11 out of the sample of 34 countries show positive skewness. Most of the countries have a negative skewness of their stock market index returns. The negative skewness indicates that negative stock returns are more common than positive returns.

Kurtosis describes the trend of a data distribution about its mean. A flatter, more concentrated toward the mean distribution with thin tails has a negative kurtosis, while more peaked distribution with fat tails has a positive kurtosis. All the countries display positive kurtosis. The only country standing out from the sample is Malaysia, with its unusually high kurtosis of 85.5737.

Jarque-Bera statistics indicate that the assumption of normality is rejected for all stock return series. Normal distribution has a skewness coefficient of zero, and a kurtosis coefficient of three (zero excess kurtosis). The p-value is used to test the null hypotheses that the returns have approximately a standard normal distribution. All the p-values are equal to zero at four decimal places, therefore we reject the null hypothesis that daily returns of the stock markets are normally distributed.

4.2 Cointegration and macroeconomic variables

In the second part of the thesis, we test for the cointegration of two series and their relationship with selected exogenous variables by applying *the Vector Error Correction model, VECM.*

The two series are represented by two international stock market indices from the previous section. We decided to use the stock markets of four countries. The first combination is the US stock index market and the market of the Euro Area, the second is the Euro Area stock market and the Chinese market and the last is the stock market of Japan and China.

We chose five macroeconomic variables, exchange rate, international trade, the long and the short term interest rate and the industrial production, to investigate the existence and the nature of their relationship with stock markets. More detailed description of each individual variable, together with the reasons for our choice is explained in the next part.

4.2.1 Exchange Rate

The main idea is that a depreciation of a currency of one country will lead to an increase in demand for that country's exports and therefore increasing the cash flows to the country. In contrary, if a country's currency is expected to appreciate, this will attract foreign investments. This rise in demand will lead to an increase in the stock market level, showing evidence that the stock market market returns are positively correlated with the changes in the exchange rate.

However, the impact of the exchange rate changes on the economy depends strongly on the level of the international trade and the trade balance of a country. This brings us to the second chosen variable, the international trade.

4.2.2 International Trade

In case of a foreign trade, an extended trade deficit may have a negative impact on the stock market. If a country keeps on importing more goods than it can export for a significant period of time, it will eventually go into debt. The availability of the imported goods at a cheap rate will increase, affecting domestic producers and their stock prices. Investors will be less willing to invest into the domestic produced goods and more in the foreign stock markets, causing foreign stock prices to rise and domestic stock prices to fall.

4.2.3 Interest Rate

Most companies obtain their capital through borrowing. Lower interest rate reduces the cost of borrowing and therefore encourages expansion. This has a positive impact on future expected returns of the firm, making investors more willing to pay higher price for the stock, in the believe of higher future dividend payments. Therefore, lower interest rates increase the stock prices. In contrary, large amount of stocks is purchased with borrowed money. With the interest rates increase, the transaction costs rise as the borrowing is now costlier. Investors will not be willing to invest. This will reduce demand and lead to a decrease of stock market prices. Also the changes in the domestic interest rate might be useful to predict the future stock price movement.

4.2.4 Industrial Production

Based on the previous studies, the index of industrial production is believed to be strongly positively related to the stock market prices. The increase in industrial production leads to an increase in the prices of the stock market index.

4.2.5 Descriptive Statistics

The data were obtained from the OECD database, with the exception of the long term interest rate for China, which is obtained from the Central Bank of the Republic of China and the index of industrial production for the Euro Area obtained from the Statistical Data Warehouse of the European Central Bank. We use monthly data from December 2002 until December 2012. Summary statistics is reported in Table A.3 in Appendix. We present the variables in their absolute values and their differences. The plots of the variables are shown in Figures A.2 to A.6.

We decide to use the current exchange rates, that is the monthly averages of one country's national currency expressed in the US Dollars, as most of the trading in China and Japan are done in the US dollars. Euro Area uses Euro, EUR, as a currency, Japan Japanese Yen, JPY, and China Chinese Yuan, NCY. To give the idea of the values of the currencies, today as of 4^{th} May 2016, 1 Euro is equal to 1.15 US Dollars, 122,89 Japanese Yens and 7,47 Chinese Yuans. For the comparison of the US and Euro Area, we also included the exchange rate of US Dollar expressed in Euro, in order to have two variables that represent the exchange rate.

Volatility of the series, expressed by the standard deviation shows that the Japanese Yen is the most volatile out of the three currencies. This is the case of the absolute values of the currency and also of it differences.

The skewness indicates, that the Japanese Yen, the Chinese Yuan and the US Dollar experience more of the negative changes in the value of their currencies, indicating the depreciation, while Euro demonstrates more of the positive changes, the appreciation of the currency. This trend can be seen in the plots of the exchange rates, where the Japanese Yen and the Chinese Yuan clearly show a downward trend.The highest kurtosis is reported for Chinese Yuan, which is noticeable from the plot of the exchange rate differences.

For the international trade data, we combine total exports and imports, which are in the absolute monthly US-converted value, in billions of USD. The difference between the total exports and imports is *the balance of trade*. When a country's imports exceed exports we get negative balance of trade, the so called *trade deficit*, while if a country exports more than it imports, there is a positive balance of trade, a *trade surplus*.

The balance of trade of the USA noted negative values over the entire sample period, demonstrating prolonged trade deficit. This is also marked in the unusually low mean of its absolute values. However, even though the values have negative values, the USA experienced more positive, rather than negative changes in its balance of trade. This is illustrated by its positive skewness in both cases, the absolute values and their differences. Note that USA is the only country with positive skewness in the trade differences.

The balance of trade of all the countries have rather fluctuating trend, with China being a country with the most volatile values of trade. China differs in its significantly higher standard deviation and kurtosis, and the lowest negative skewness.

For studying industrial production we use *the Index of Industrial Production* defined as following.

> Definition: *Industrial production refers to the output of industrial establishments and covers sectors such as mining, manufacturing and public utilities (electricity, gas and water). This indicator is measured in an index based on a reference period that expresses change in the volume of production output.*[1]

The plots of the index of industrial production show almost identical pattern for USA, Euro Area and Japan. The index is showing upward trend until about the begging of the crisis, September 2008, when it experiences a huge decline in its value, reaching its lowest point around the begging of year 2009. After the fall, the index begins to slowly increase, returning back to its original level.

The substantial fall in year 2008 is also present in China, yet, there are few differences. China appears to have two large additional shocks to its index of industrial production around the begging of year 2004 and 2005. Also, after 2010 the index starts to decline again. In Japan, we notice another rapid fall in the index in the first half of year 2011.

Due to the large drop in the index value, Euro Area, Japan and the USA show evidence of more negative changes in industrial production, marked by negative skewness, while the variation of the index in China notes more of the large positive than negative changes.
For the interest rates, we use short term and long term interest rates, which are defined as following

> Definition: *Short-term interest rates are the rates at which short-term borrowings are effected between financial institutions or the rate at which short-term government paper is issued or traded in the market. Short-term interest rates are generally averages of daily rates, measured as a percentage. Short-term interest rates are based on three-month money market rates where available. Typical standardised names are "money market rate" and "treasury bill rate".*[2]
> *Long-term interest rates refer to government bonds maturing in ten years. Rates are mainly determined by the price charged by the lender, the risk from the borrower and the fall in the capital value. Long-term interest rates are generally averages of daily*

[1] OECD. (2014a)
[2] OECD. (2014c)

> *rates, measured as a percentage. These interest rates are implied by the prices at which the government bonds are traded on financial markets, not the interest rates at which the loans were issued. In all cases, they refer to bonds whose capital repayment is guaranteed by governments. Long-term interest rates are one of the determinants of business investment. Low long-term interest rates encourage investment in new equipment and high interest rates discourage it. Investment is, in turn, a major source of economic growth.*[3]

When examining the differences of the short and long term interest rates, we conclude that the interest rates of Japan share very similar trend to those of the United States and Euro Area. The patterns of the interest rates of China are completely different. For the short interest rate, China shows the most volatile results, as can be also seen in its fluctuating plot. USA and Euro Area present negative skewness, which is probably caused by the evident decline. It is clear from the graph that their short term interest rates experienced higher negative than positive changes. The USA notes the first decline of the short term interest rate at the end of year 2007, besides all four countries showing the highest fall right at the end of the year 2008.

For the long term interest rate, Japan is again more close to the United States and Euro Area, rather than China. In its differences, USA shows the highest volatility and it also reports negative skewness, indicating presence of more falls than rises. In the absolute values, Euro Area, Japan and USA are found to have negative skewness. In the graph we can notice their overall downward trend.

Our hypothesis is that there exists a positive relationship between the stock market prices and the exchange rates, the balance of trade and the industrial production index; and a negative relationship between the stock market prices and interest rates.

[3] OECD. (2014b)

Chapter 5

Methodology

5.1 Markets interconnectedness

The Autoregressive Conditional Heteroskedasticity ARCH model was first proposed by Engle (1982). It has been then generalised by Bollerslev (1986) to the Generalised Autoregressive Conditional Heteroskedasticity GARCH model. A new class of multivariate GARCH models, the Dynamic Conditional Correlation GARCH model, was later developed by Engle (2002). The DCC-GARCH model improves the Constant Conditional Correlation CCC-GARCH model of Bollerslev (1990) by allowing for time-varying correlations.

In this paper we apply the DCC-GARCH model to assess the interconnectedness among the world stock market indices.

Suppose that stock market returns from n series are multivariate normally distributed with zero mean and conditional variance-covariance matrixes H_t.

The DCC-GARCH model is defined as:

$$\begin{cases} r_t = \mu_t + \varepsilon_t, \varepsilon_t \mid I_{t-1} \rightarrow N(0, H_t) \\ \varepsilon_t = H_t^{\frac{1}{2}} z_t \\ H_t \equiv D_t R_t D_t \end{cases} \tag{5.1}$$

where r_t is a $n \times 1$ vector of log stock market returns of n series at time t and ε_t a $n \times 1$ vector of mean-corrected returns (conditional standard deviation) of n series at time t. I_t is the information set up to and including time $t-1$.

We assume that international stock market rate of returns are generated by the following autoregressive process:

μ_t for the individual stock market i

$$\mu_{i,t} = \delta_{i0} + \delta_{i1} r_{i,t-1} + \delta_{i2} r_{i,t-1} \tag{5.2}$$

μ_t for the US stock market

$$\mu_{us,t} = \delta_{us0} + \delta_{us1} r_{us,t-1} \tag{5.3}$$

μ_t is a $n \times 1$ vector of the expected value of the conditional r_t. Let r_i, t be the rate of return of individual world stock market indices and r_w, t the rate of return of the US stock market index.

D_t refers to a $n \times n$ diagonal matrix of conditional standard deviations of ε_t at time t

$$D_t = \begin{bmatrix} \sqrt{h_{1t}} & 0 & \dots & 0 \\ 0 & \sqrt{h_{2t}} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & \sqrt{h_{nt}} \end{bmatrix} \tag{5.4}$$

The elements at the diagonal in matrix D_t are standard deviations following the univariate GARCH model:

$$h_{it} = \alpha_{i0} + \sum_{q=1}^{Q_i} \alpha_{iq} \alpha_{i,t-q}^2 + \sum_{p=1}^{P_i} \beta_{ip} h_{i,t-p} \tag{5.5}$$

where $\alpha_{i0} > 0$; $\alpha_{iq} \geq 0$; $\beta_{ip} \geq 0$ and $\sum_{q=1}^{Q_i} \alpha_{iq} + \sum_{p=1}^{P_i} \beta_{ip} < 1$

The elements of $H_t = D_t R_t D_t$ are:

$$[h_t]_{ij} = \sqrt{h_{it} hjt} \rho_{ij,t} \tag{5.6}$$

H_t is a $n \times n$ matrix of conditional variance-covariance of ε_t at time t.

DCC-GARCH model allows for a two-stage estimation of the conditional covariance matrix H_t in order to assess the correlation parameters. In the first stage, estimates of $\sqrt{h_{i,t}}$ are obtained by fitting the univariate GARCH(1,1) volatility models for each of the stock return residuals. In the second stage, these stock return residuals are converted into their standardised residue z_{it} by their estimated standard deviations from the first stage.

$$z_{ij} = \varepsilon_{it}/\sqrt{h_{i,t}} \tag{5.7}$$

z_t is a $n \times 1$ vector of i.i.d. (independent and identically distributed) errors.

Q_t is a $n \times n$ time-varying covariance matrix of z_t modelling the dynamics of the correlation:

$$Q_t = (1 - a - b)\bar{Q} + az_{t-1}z'_{t-1} + bQ_{t-1} \tag{5.8}$$

where $a \geq 0$, $b \geq 0$ and $a + b < 1$

$\bar{Q}$ is a $n \times n$ unconditional covariance matrix of z_t.

$$\bar{Q} = Cov(z_t z'_t) = E[z_t z'_t] \tag{5.9}$$

In a bivariate case, the conditional covariance is expressed as follow:

$$q_{ij,t} = (1 - a_{ij} - b_{ij})\bar{q_{ij}} + a_{ij}z_{i,t-1}z_{j,t-1} + b_{ij}q_{ij,t-1} \tag{5.10}$$

R_t is a $n \times n$ conditional correlation matrix. Two conditions need to be satisfied in the DCC-GARCH model to determine the structure of R_t:

- The conditional covariance matrix H_t has to be positive definite. To ensure this, Q_0, the first value of Q_t, should be positive definite;
- All the elements in the conditional correlation matrix R_t have to be equal to or less than one.

In order to satisfy these two requirements, R_t is specified as follows:

$$R_t = Q_t^{*-1/2} Q_t Q_t^{*-1/2} \tag{5.11}$$

where Q_t^* is a symmetric positive definite matrix defining the structure of the dynamics with the square root of elements of Q_t at its diagonal. $Q_t^{*-1/2}$

adjusts the elements of Q_t to ensure that the conditional correlation estimator is lower than or equal to unity.

$$Q_t^* = diag(Q_t) = \begin{bmatrix} \sqrt{q_{11,t}} & 0 & \dots & 0 \\ 0 & \sqrt{q_{22,t}} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & \sqrt{q_{nn,t}} \end{bmatrix} \tag{5.12}$$

Thus a correlation matrix R_t is given as a matrix with ones on the diagonal and off-diagonal elements being less than one in absolute value.

$$R_t = \begin{bmatrix} 1 & \rho_{12,t} & \dots & \rho_{1n,t} \\ \rho_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & \rho_{n-1,n,t} \\ \rho_{n1,t} & \dots & \rho_{n,n-1,t} & 1 \end{bmatrix} \tag{5.13}$$

where

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}q_{jj,t}}} \quad \forall\, i,j = 1,2,...,n;\; i \neq j;\; |\rho_{ij,t}| \leq 1 \tag{5.14}$$

In a bivariate setting, the conditional correlation coefficient ρ_{ij} between two markets i and j can be expressed as follows:

$$\rho_{ij,t} = \frac{(1-a-b)\bar{q_{ij}} + az_{i,t-1}z_{j,t-1} + bq_{ij,t-1}}{\sqrt{(1-a-b)\bar{q_{ii}} + az_{i,t-1}^2 + bq_{ii,t-1}}\sqrt{(1-a-b)\bar{q_{jj}} + az_{j,t-1}^2 + bq_{jj,t-1}}} \tag{5.15}$$

To estimate the parameters, we maximise the log-likelihood function, which is given by:

$$L_t = -\frac{1}{2}\sum_{t=1}^{T}(nlog(2\pi) + 2log|D_t| + \varepsilon_t' D_t^{-1} D_t^{-1}\varepsilon_t - z_t' z_t + log|R_t| + z_t' R_t^{-1} z_t \tag{5.16}$$

The log-likelihood function can be split into two components, the volatility and the correlation part.

The volatility component:

$$L_{V,t} = -\frac{1}{2}\sum_{t=1}^{T}(nlog(2\pi) + 2log|D_t| + \varepsilon_t' D_t^{-1} D_t^{-1} \varepsilon_t) \tag{5.17}$$

The correlation component:

$$L_{C,t} = -\frac{1}{2}\sum_{t=1}^{T}(log|R_t| + z_t' R_t^{-1} z_t - z_t' z_t) \tag{5.18}$$

5.2 Cointegration and macroeconomic variables

In the second part of the thesis we use a *Vector Error Correction Model, VECM*, approach to analyze the relationship between stock market indices and selected macroeconomic variables. We believe that the series are cointegrated and share a long-term relationship. To examine whether this relationship exists, we first test for the stationarity of our series, using the Augmented Dickey-Fuller unit root test. If the series confirm the non-stationarity in their levels and stationarity in their first differences, we proceed to the Johansen cointegration test. After determining the cointegration rank, we estimate our VECM model using the two cointegrated series as dependent variables, in order to test their relationship with the exogenous variables. Lastly, by modelling the Impulse Response Functions, IRFs, we review the reaction of individual endogenous variables after one standard deviation of positive shock is given to another endogenous variable.

5.2.1 Stationarity test

First step is to test for the stationarity of the series, with the so called unit root test. The stationarity is a statistical property of a series, similar to its mean or variance. If both series are constant over time, then the series are said to be a stationary non random process, with no unit root. Contrarily, if the series is a non-stationary random process, it contains a unit root. Series can be made stationary by differencing. When the series becomes stationary after d times differencing, it is integrated by order d, noted as *I(d)*. For example, if a series is stationary without any differencing it is said to be integrated of order 0, *I(0)*. If a series is stationary in its first differences, it is integrated of order one 1, *I(1)*.

We test for the stationarity of our series by using *the Augmented Dickey-Fuller, ADF,* unit root test proposed by Dickey & Fuller (1981). We assume, from the terminology of Engle and Granger, that x_t and $x_t - 1$ are two unit root series that are cointegrated of order one. If these two series are non-stationary random processes, then modelling their relationship as a simple OLS relationship would only generate a spurious regression.

$$x_t = \alpha + \rho x_{t-1} + \varepsilon_t \tag{5.19}$$

where $\mu = 0$ we have a random walk and $\mu \neq 0$ we have a no random walk process. ε_t is a vector error correction term.

Then by subtracting x_t from both sides we get

$$\triangle x_t = \alpha + \delta x_{t-1} + \varepsilon_t \tag{5.20}$$

where $\delta = (1 - \rho)$. The significance of δ is tested as a one-sided "t- test".

In case of autocorrelation in the observed series, the Dickey-Fuller "t-statistics" for the significance of ρ including lags is based on the estimated model

$$\triangle x_t = \alpha + \beta t + \delta x_{t-1} + \sum_{i=1}^{k} (\gamma_i \triangle x_{t-i}) + \varepsilon_t \tag{5.21}$$

with the null hypothesis $H_0 : \delta = 0[x_t \sim I(1)]$ against the alternative hypothesis $H_a : \delta < 0[x_t \sim I(0)]$. If the null hypothesis can not be rejected, there is a unit root, a series is a random walk without drift, not stationary and not cointegrated. If the null hypothesis can be rejected, the alternative hypothesis holds that there is no unit root, we have a no random walk, stationary series that are cointegrated.

5.2.2 Cointegration test

> Definition: *The two series x_t and x_{t-1} are said to be cointegrated with each other, if each of the series are individually integrated in the order d, $I(d)$, while there exists a linear combination of the series, which is integrated in the order d - 1, $I(d-1)$. That is linearly combining the two series leads to a series of a lower order of integration.*[1]

Cointegration requires all the variables to be integrated of the same order. Also, as there are more than two time series in the cointegrating regression, there may be more than one cointegrating vector. Therefore, we test for the cointegration of our series by applying Johansen's methodology of modelling cointegration in a multivariate setting developed by Johansen (1988).

[1] Engle & Granger (1987)

The basic steps in Johansen's approach are:

1. Specify and estimate a VAR model for x_t
2. Construct likelihood ratio tests for the rank of Π to determine the number of cointegrating vectors.
3. If necessary, impose normalization and identify restrictions on the cointegrating vectors.
4. Given the normalized cointegrating vectors estimate the resulting cointegrated regression by maximum likelihood.

We start by describing *the Vector Autoregression, VAR(p)* process of order p.

$$x_t = A_1 x_{t-1} + A_2 x_{t-2} + \cdots + A_p x_{t-p} + \varepsilon_t \tag{5.22}$$

where x_t is a $n \times 1$ vector of integrated variables with order 1, I(1).

Such VAR model can be re-written as a *Vector Error Correction model, VECM*

$$\triangle x_t = \Pi x_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \triangle x_{t-1} + \varepsilon_t \tag{5.23}$$

where $\Pi = \sum_{i=1}^{p} A_i - I$ and $\Gamma_i = -\sum_{j=i+1}^{p} A_j - I$

Granger representation theorem states that if the coefficient matrix Π has reduced rank $0 \leq r < p$, where r is the cointegration rank, indicating the number of cointegrating vectors in the model with the p number of variables, then there exist $p \times r$ matrices α and β with ranks r such that $\Pi = \alpha\beta'$ and $\beta' x_t$ is I(0), with the β matrix of cointegrating vectors.

If the rank of $\Pi = 0$, there is no cointegration among the nonstationary variables and the VECM model is identical to the VAR(p) process in its first differences. However, if the rank of $\Pi = p$, then all of the variables in x_t are stationary, I(0), and there are r cointegrated vectors.

Johansen derives two different likelihood ratio tests to identify the number of cointegrated vectors and the significance of their relation, by computing how many eigenvalues corresponds to the matrix Π and its rank number. The tests include *the maximum eigenvalue test* , λ_{max} and *the trace test*, λ_{trace}.

The max test is constructed as

$$\lambda_{max}(r, r+1) = -Tlog(1 - \hat{\lambda}_r) \tag{5.24}$$

where $\hat{\lambda}$ is the estimated eigenvalue obtained using the Π matrix and T number of observations. The null hypothesis is that there exists the number of r cointegrating vectors, against the alternative of $r + 1$ cointegrating vectors.

The trace test is

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} log(1 - \hat{\lambda}_i) \tag{5.25}$$

where the null hypothesis is that the number of cointegrating vectors is r, against the alternative that the number of cointegrating vectors is equal to n.

5.2.3 Vector Error Correction Model

In our thesis, we are testing international stock market indices, which we believe are significantly cointegrated. If cointegrattion has been present among the series, we know there exists a long term relationship between them. Therefore we employ VECM to test for this relationship.

The equation for VECM follows the Equation 4.23, where in our model x represents the variable matrix consisting of two stock price indices, balance of trade, long and short term interest rates, the exchange rate and the index of industrial production.

5.2.4 Impulse Response Functions

The short-run dynamics of the series can be examined by modeling *the Impulse-response functions, IRFs*. The IRFs measure the dynamic marginal effects of each shock on all of the variables over time. It shows the response

of each variable in the system to a shock, or an impulse, in any of the other variables. The IRFs is calculated from *the Moving Average, MA*, representation of the VECM.
The impulse response function with the coefficients $\{A_p\}_{t=1}^{\infty}$ and a sequence of shocks $\{\epsilon_t\}_{t=1}^{\infty}$

$$x_{t+n} = \sum_{i=0}^{\infty} \Phi_i \epsilon_{t+n-1} \tag{5.26}$$

where Φ_0 is the identity matrix I_k and $\Phi_i = \sum_{j=1}^{i} \Phi_{i-j} A_j$. And

$$\{\Phi_n\}_{i,j} = \frac{\partial x_{it+n}}{\partial \epsilon_{jt}} \tag{5.27}$$

is the response of $y_{i,t+n}$ to a one-time impulse in $y_{j,t}$ with all other variables dated t or earlier held constant.

Chapter 6

Results

The following section presents the results of our analysis of the interconnectedness between international stock markets during the global financial crisis. First, we would like to present our own contribution to the already broad current literature and what exactly it is that makes our work unique.

We start by analyzing the comovements between countries, by employing Dynamic Conditional Correlation multivariate GARCH model. This approach has been commonly used by the previous researchers. In order to study the connection between the markets with an emphasis on the crisis, we take large sample of data, total of ten years, covering substantial period before and after the beginning of crisis. Most of the current literature does not cover sufficient amount of time after the crisis began. Based on our research[1], we believe, that crisis did not came to an end yet, at least not by the end of year 2012. Hence, it is useful to observe large period after the crisis began, which is in our case more than four years.

Most commonly used approach is to divide the stock markets into regions and analyze only one specific category of markets, for example, markets of Latin America or Asia. Another way is to study the major stock markets, which usually covers sample of up to ten countries. Our idea was to use the biggest markets based on the world market capitalization, a large sample in total of thirty-three countries.

The previous literature mainly intends to examine the general idea, whether the intensity of comovements within markets increases in period of crisis.

We conducted the Chow test to examine the structural breaks for the sample countries. We could reject the null hypothesis of stability at the 95% level

[1] Grey (2013)

of confidence, for most of the countries for September 2008, which proves the presence of structural break, caused by the crisis. Hence we define the begging of the crisis, by the day when the Lehman Brothers filed for Chapter 11 bankruptcy protection, September 15^{th} 2008.

We decided to estimate and compare the conditional correlation between the US and the rest of the market for the before crisis period, one year after the crisis began and the crisis period, which covers the whole period from the beginning of the crisis until the end of our sample. Using this approach, we are able to give evidence of the interconnectedness of the exact markets and their increase during the turbulent crisis period.

Other contribution of our work is that we apply two models, to explore the relationship between the markets even deeper. After obtaining the results from the DCC-GARCH approach, we employ the Vector Error Correction Model to explore the long term relationship between four, believed to be cointegrated markets and selected macroeconomic variables.

6.1 Markets interconnectedness

We apply the DCC- GARCH model to test for the conditional correlation between the stock market index returns. More precisely, we examine the correlation between the United States stock index and the stock market indices of the 33 countries overall for the sample period of 10 years, from January 2003 until December 2012. We also investigate the change in the correlation throughout the time, as we distinguish between the pre-crisis period and the crisis period.

6.1.1 Chow test

In order to test the differences in correlation between the period before and after the crisis began, we first need to determine what is the exact period of the begging of the crisis. We do this by applying the Chow test proposed by Gregory Chow in 1960 to test for structural breaks.

We were suspecting an existence of structural break in September 2008. We tested the data of stock market returns of each country, by setting the observation at which to split the sample to September 2^{nd} 2008 (first business day in September 2008). This tests, whether there is a structural break between the data before and after September 2^{nd} 2008. The null hypothesis notes stability of the series, while the alternative hypothesis suggests a presence of structural break.

For most of the countries, at 95% level of confidence, we were able to reject the null hypothesis of no structural break.

Now that we showed an evidence of structural break in September 2008, we decided to define the beginning of the crisis in our thesis by the date, when Lehman Brothers filed for Chapter 11 bankruptcy protection, September 15^{th} 2008.

6.1.2 Dynamic Conditional Correlation GARCH model

Table 6.1 on page 35 presents the results. Again we demonstrate the difference between the average correlations in the entire sample period, pre-crisis period and the crisis period.

The results indicate that the US stock market proves very little correlation, under 0.2, with stock markets in Australia, China, Indonesia, Japan, Malaysia, New Zealand and Taiwan. We find that New Zealand stock market is the only one with negative correlation with the US market during the whole sample period, -0.0014. In the pre-crisis period, the correlation is negative also for the stock market in China and there is no evidence of negative correlation during the crisis period. Following New Zealand are stock markets of Malaysia and China, with their correlation with the US under just 0.1. The last stock markets from the group of least correlated with the US market are, sorted by the degree of correlation, Japan, Taiwan, Australia and Indonesia.

On the other hand, the US stock market is most correlated with the Canadian, 0.7384, and Mexican, 0.7208, stock markets. The next off, with the correlation above 0.6 are Brazil, Germany, Euro Area and France.

The most correlated markets with the United States stock market are mostly in European and Latin American countries. The least correlated are the Asian countries, together with Australia and New Zealand. Our findings confirm the results presented by previous studies.

Table 6.1: Average correlations between the US market and the rest of the world: full, pre-crisis and crisis period

	Full Period	Pre-crisis Period	Crisis Period
Argentina	0.5682	0.3581	0.6968
Australia	0.1394	0.0354	0.1895
Austria	0.4774	0.2939	0.5456
Belgium	0.5697	0.4628	0.6233
Brazil	0.6993	0.5974	0.7816
Canada	0.7384	0.6264	0.7800
Chile	0.5321	0.4346	0.6067
China	0.0650	-0.0151	0.1381
Denmark	0.4522	0.3403	0.5042
Euro Area	0.6214	0.5203	0.6659
France	0.6048	0.5024	0.6501
Germany	0.6360	0.5309	0.6949
Greece	0.2924	0.2068	0.3206
Hong Kong	0.2286	0.0764	0.3093
India	0.2671	0.0920	0.3958
Indonesia	0.1399	0.0781	0.1785
Ireland	0.4597	0.3613	0.5086
Israel	0.2582	0.1794	0.3021
Italy	0.5697	0.4909	0.5955
Japan	0.1216	0.0868	0.1438
Malaysia	0.0676	0.0353	0.0825
Mexico	0.7208	0.6298	0.7923
Netherlands	0.5949	0.4786	0.6581
New Zealand	-0.0014	-0.0184	0.0037
Russia	0.3140	0.1500	0.3880
Singapore	0.2685	0.1438	0.3377
South Korea	0.2021	0.1053	0.2731
Spain	0.5585	0.4724	0.5892
Sweden	0.5561	0.4231	0.6263
Switzerland	0.5464	0.4347	0.6131
Taiwan	0.1354	0.0855	0.1697
Turkey	0.3066	0.1683	0.4456
United Kingdom	0.5766	0.4610	0.6306

When looking at the difference in the degree of correlation between the pre-crisis period and the crisis period, we observe some notable results. New Zealand remains the least correlated country even during the crisis period and therefore experiences the smallest shift in its correlation with the US over time. Malaysia, Japan and Taiwan are also countries, which proved to be relatively resistant to the effects of crisis, as the increase in their correlation with the US after the crisis began was not more than 0.1. The largest difference was reported in Argentina, with 0.3387 higher correlation with the US market in the crisis period than in the pre-crisis period. Similarly, in India the correlation increased by 0.3038. There are few countries with relatively low correlation with the US in the full sample period, but after detailed review, they show evidence of high correlation change from one period to another. These are for example, India, Russia, Hong Kong and Singapore. When countries are sorted according to their correlation with the US they are more or less in the same order for all three periods, the full sample, the pre-crisis and the crisis. The correlation increased after the begging of the crisis on average by 0.164. These results give support to previous literature that find that the stock market correlation increases during the period of crisis.

Figure 6.1 on page 38 models the conditional correlation between the US stock market and all the other stock markets. Each country's correlation is plotted separately in an individual graph. Similar patterns can be examined within these graphs.

We distinguish between five main trends. One of the trends can be summarized by very rapid, although modest, constant fluctuations throughout the entire period. This trend is characteristic for the lowest correlated countries, specifically for Indonesia, Japan, South Korea, China and Malaysia. However, the Chinese and Malaysian stock markets are somewhat different. They both present slightly bigger fluctuation, Malaysia within a range of 0.04 to 0.08 and China from 0.1 to 0.15, as compared to South Korea's range of only 0.000004. Also in China we see a drastic change, a rise in the first quarter of year 2007, same as in Malaysia, although not as dramatic, and two additional obvious falls after each other at the end of 2009 and the begging of 2010.

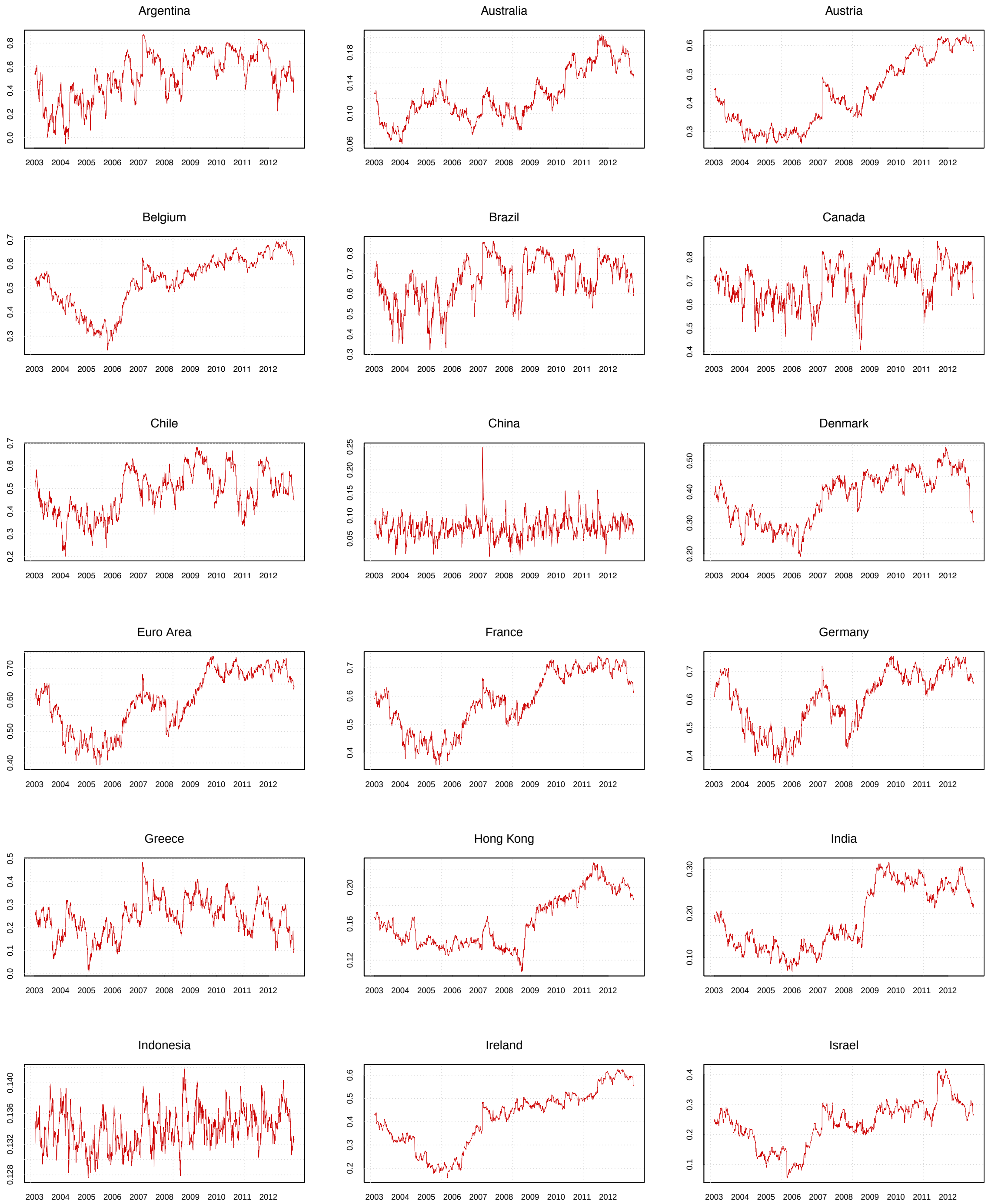
Other very specific trend is describing the correlation of markets in the Euro Area, Austria, France, Germany, Italy, Netherlands, Russia, Singapore, Spain, Sweden and United Kingdom. In 2003 the correlation starts at a relatively high level. It slowly decreases until it falls to its lowest stage between year 2005 and 2006. After 2006, a rapid growth begins, reaching its first peak in the first quarter of 2007. This is followed again by a fall in the degree of correlation, with slight, short term rise at the begging of 2008 and then significant increase after the third quarter of 2008, supporting all the previous evidence that the correlation between markets increases during the period of crisis. The growth continues until the year 2010, after which it remains almost steady with very modest fluctuation around its high level. The graphical representation of the correlation is almost identical for Euro Area, France, Germany and United Kingdom and also for Russia and Singapore. Also, in Spain, the correlation got very close to its lowest point from 2006 also in year 2008.

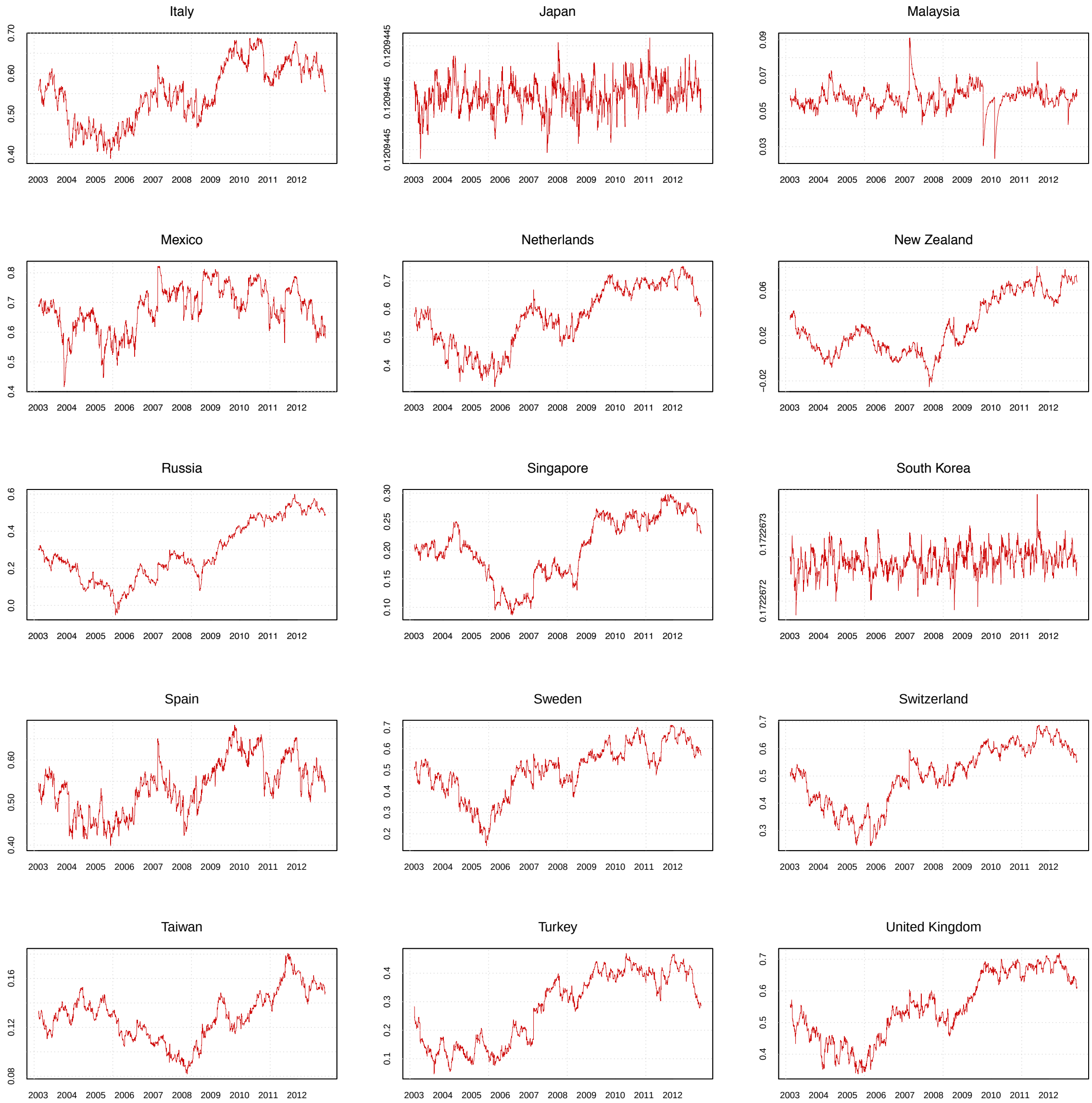
The next set of countries share very similar pattern to that of the previous one. The only difference is that after the decline in 2006, the correlation does not substantially decrease anymore. There is a consistent upward trend since year 2006 until the end of the sample period. These countries are Belgium, Denmark, India, Ireland, Israel, Switzerland and Turkey. Here, compared to other countries' steady increase in correlation, we notice a very sharp jump at the end of the year 2008 in India and in the middle of year 2011 in Israel.

Markets in Hong Kong, New Zealand and Taiwan share similar characteristics. Their markets experience the lowest correlation with the US market at the beginning of year 2008, after which the correlation begins to increase.

Last noticeable trend is typical for markets in Argentina, Australia, Brazil, Canada, Chile, Greece and Mexico. The correlation of these markets is characteristic for its large fluctuations over the full sample period.

Figure 6.1: The conditional correlations between the US stock market and the rest of the world




Italy
0.40
0.50
0.60
0.70
Japan
0.1209445
0.1209445
0.1209445
Malaysia
0.03
0.05
0.07
0.09
Mexico
0.4
0.5
0.6
0.7
0.8
Netherlands
0.4
0.5
0.6
0.7
New Zealand
−0.02
0.02
0.06
Russia
0.0
0.2
0.4
0.6
Singapore
0.10
0.15
0.20
0.25
0.30
South Korea
0.1722672
0.1722673
Spain
0.40
0.50
0.60
Sweden
0.2
0.3
0.4
0.5
0.6
0.7
Switzerland
0.3
0.4
0.5
0.6
0.7
Taiwan
0.08
0.12
0.16
Turkey
0.1
0.2
0.3
0.4
United Kingdom
0.4
0.5
0.6
0.7
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

Apart from studying the correlation between the US stock index market and the rest of the world stock markets, we decided to compare the correlation between other countries as well. We chose three sets of countries, which are analyzed in greater depth in the VECM section of the thesis. The countries include the United States and Euro Area, Euro Area and China and China and Japan. We believe this very combination of international stock markets may show some interesting results.

In the following section we briefly summarize the results obtained from employing DCC GARCH.

The plots of the conditional correlation can be reviewed in Figure 6.2 on page 41, with the shaded area covering one year after the begging of the crisis, from the September 15^{th} 2008 until the September 14^{th} 2009.

All three combinations of countries represent completely different kinds of change of conditional correlation over time, judging from their patterns in graphs. As was discussed before Euro Area belongs to the group illustrating a typical trend for most of the European, highly correlated with the US market, countries. In this graph we can clearly see the most rapid increase in the correlation took place exactly within the year after the crisis began.

Conditional correlation between the market index of Euro Area and China reaches value of 0.1351 during the entire sample period, January 2003 to December 2012. For the pre-crisis period, before September 2008, the correlation between the two countries is 0.0512 and for the crisis period, after September 2008, it increases up to 0.2173. The trend of the correlation is similar to that of the correlation between the US market and Indonesia, China, Japan, Malaysia and South Korea. It is characteristic by its rapid fluctuation around its mean throughout the entire period. Before year 2007 we can see more of negative shocks causing rapid drops of correlation, on contrary to the period after year 2007, where we see three significant positive shocks which led to increase in the correlation. After the last shock, which happened approximately around the September 2008, the correlation remains more stable until after year 2010, when the fluctuation starts again.

Figure 6.2: Conditional correlations: China, Euro Area, Japan, United States

The correlation between the markets of China and Japan is most similar to the correlation between the US and Turkish market. The correlation is fluctuating at its low level until around the middle of the year 2005, when it starts to slowly increase. It basically remains rising constantly through the whole period, with few substantial decreases right before the September 2008, before the September 2009, during the period from the third quarter of 2010 until the beginning of the second quarter of 2011 and at last, at the end of pla year 2012. Over the entire sample period, the degree of correlation between the Chinese and Japanese stock market is 0.2590, before the September 2008 it is 0.1798 and after the September 2008, 0.3488.

6.2 Cointegration and macroeconomic variables

6.2.1 Stationarity test

We start the empirical investigation by performing the unit root test, to determine whether the series are stationary or nonstationary. This is a necessary step as we need to ensure that all the stock index series are nonstationary and cointegrated of the same order, before we can proceed to the cointegration analysis. We test for the stationarity of our series by applying *the Augmented Dickey Fuller, ADF*, test with a constant and with no time trend and with maximum lag order of 12. The results are present in Table 6.2, reporting the number of lags, the test statistic (t-statistic, t-test or t-value) and the p-value. The critical values for the Dickey-Fuller test are listed in Table 6.3.

The first four variables show the absolute prices of the stock market indices. We examine the t-test and p-value. It is clear from large both t-test and p-value, that in this case, the null hypothesis of the unit root cannot be rejected, thus the variables are stationary and non cointegrated.

In the next step we calculate the differences of the variables and perform the ADF test again on the differenced data. We see that the values of the t-test are smaller than any of the critical values at different confidence levels and also all four p-values are less than 0.01, so the null hypothesis of the unit root can be rejected at most at the 99% level of confidence.

The last four variables show the stock market index returns. The returns were calculated by differentiating the log values taken from the stock prices and multiplying them by 100. The results of the ADF test for the returns are similar to those of the differenced values. At the 99% level of confidence we can reject the null hypothesis of the unit root test.

We conclude that the differences of the stock prices and the stock returns are stationary series, cointegrated, not a random walk, with no unit root. Because the series need to be differentiated once in order to become stationary, the stock prices are said to be integrated of order one, I(0).

The plots of the stock index market prices and the returns can be seen in Figure A.7 on page A.7 in the Appendix.

Table 6.2: Augmented Dickey-Fuller test

variable	lags	t-test	p-value
GSPC	4	-2.47132	0.1226
STOXX50E	4	-0.259725	0.5929
SSEC	6	-2.36456	0.152
N225	1	-1.65072	0.4565
d_GSPC	5	-4.38684	0.000308
d_STOXX50E	3	-3.93416	0.001804
d_SSEC	12	-4.07927	0.001049
d_N225	4	-4.65532	9.808e-05
GSPC_ret	5	-4.62951	0.0001
STOXX50E_ret	3	-3.90039	0.00204
SSEC_ret	12	-3.72028	0.003858
N225_ret	4	-4.81547	4.796e-05

Table 6.3: Critical values for the Dickey-Fuller test

N	1%	5%	10%
25	-3.75	-3. 00	-2.62
50	-3.58	-2.93	-2.60
100	-3.51	-2.89	-2.58
250	-3.46	-2.88	-2.57
500	-3.44	-2.87	-2.57
>500	-3.43	-2.86	-2.57

6.2.2 Cointegration test

Now that we confirmed that all of our series are non-stationary with stationary first differences, we can proceed to the next step. We want to investigate a dynamic relationship between two dependent cointegrated variables and ten exogenous variables. We believe that the series move together in a long run, with short run deviations caused by shocks to the system.

First we test for the lag order. We find that the values are fitted the best for the lag order of three, hence we use this number of lags further on in our analysis.

We briefly go through the two extreme possibilities of Π equal and not equal to zero. In the first case, if $\Pi \neq 0$, it is said to be *a full rank*, where the system is stationary, with no unit roots and also with no stochastic trends. In this situation, VECM converges to the stationary VAR model, as it does not include any short-term variables, $p - r = 0$.

In the second case, if the rank is zero, $\Pi = 0$ is a null matrix, indicating zero eigenvalues with the value other than zero, which means that there is no evidence of long term relationship. As the error correction term, Πx_{t-1}, becomes zero too, it is excluded from the model, thus $\triangle x_t$ does not depend on x_{t-1} anymore.

First we tested for more cointegrating relationship. We included each one of the exogeneous variables. One by one, based on the eigenvalues, we eliminated all the variables, as we found that none of them was a very strong candidate for a dependent variable. We came to the conclusion, that only the stock markets indicate a long run relationship.

We explore the cointegration relationship between our endogenous variables, specifically between three combinations of stock markets. This includes, the United States and Euro Area, Euro Area and China and China and Japan. The results can be reviewed in Table 5.3, Table 5.4 and Table 5.5. Results demonstrate the Π matrix and its decomposition into cointegrating vectors β, adjustment vectors, α, renormalized β and α and the long run matrix $\alpha\beta'$.

The two Johansen tests for cointegration are applied to identify the rank number of β. The tests are the λ_{max} test and the λ_{trace} test for joint hypotheses. We suppose the eigenvalues to be sorted from largest to smallest. The λ_{max} null hypothesis on the i-th eigenvalue states that $\lambda_i = 0$. The hypothesis of the corresponding λ_{trace} test is $\lambda_j = 0$ for all $j \geq i$.

The output of the model gives us β, presenting the long term relationship. In the β matrix, the ith column vector indicates the coefficients of each of the variables in the ith cointegrating relationship, the its variable equation. The ith row vector reports the contribution of the ith variable to each of the cointegrating relationships, equations. α indicates the magnitude of the adjustment of the cointegrated vector when the relationship is diverging from the long term trend or equilibrium in the process. The ith column vector in α notes the speed of adjustment of each variable to the disequilibrium in the ith relationship. And lastly, the row vector of α shows the speed of adjustment of the ith variable to each of the disequilibrium in relationship.

The results of Johansen cointegration test between the United States stock market and the market of Euro Area are presented in Table A.4 in the Appendix. In all four cases, α notes large positive values, which implies that the system diverges from the long-run equilibrium path.

In case of the cointegration between the markets of Euro Area and China, shown in Table A.5 in the Appendix, we report large positive value in case of the STOXX50E index, meaning that the coefficients of the index deviate from the long-run equilibrium. For the rest of the α, we note extremely small values, less than -2, for the Chinese SSEC stock index in the second relationship (close, but less than -2 in the first relationship), which represents an overshooting of economic equilibrium. The coefficients of the STOXX50E index in the second relationship have small value tending to -1, which indicates that a large percentage of disequilibrium is removed, adjusted.

For the cointegration test between Chinese and Japanese stock markets, the results in Table A.6 in the Appendix report one extremely small value for the Japanese N225 stock index, indicating an overshooting of economic equilibrium. The rest of the α values of the coefficients are positive, which means that the in these cases, the system diverges from the long-run equilibrium.

Both the maximum and trace tests at the 99% confidence level reject the null hypothesis $H_0 : r = 0$ of no cointegration vector in the process. This indicates that there is at least one cointegrating vector, hence we continue with the sequential testing. Both tests for $H_1 : r \leq 1$ suggests that there is more than or just one cointegrating relationship. When we continue further, there is no other hypothesis with a higher cointegration rank that can be rejected or even tested. We conclude that there is one cointegrating relationships.

The final number of the rank is equal to one, $\Pi = 1$, for all three stock market combinations. So far, all the conditions are met, the series are stationary, cointegrated, with the existence of long run relationship among the variables. Therefore, we proceed forward to estimate the VECM model.

6.2.3 Vector Error Correction Model

We present the estimated *Vector Error Correction model, VECM*, using three lags, with constant and the number of cointegrating vectors equal to one, $\Pi = 1$, based on the one significant cointegrating vector found by the Johansen cointegration test.

Tables A.7, A.8 and A.9 in the Appendix present the output for the Vector Error Correction Model. For the simplicity of the comparison of the results, we show each equation individually for the absolute values and their differences. One * denotes significance at the 90% level, two ** denotes significance at the 95% level and three *** denotes significance at the 99% level.

Table A.7 in the Appendix shows the results for the VECM of the United States and Euro Area stock markets and its first equation explaining the relationship between the coefficients of the GSPC stock index and the rest of the variables. The GSPC equation using the absolute values of the exogenous variables does not indicate any relationship within the coefficients of of both indices, the GSPC and the STOXX50E index, except a very weak relationship present for the coefficients on first lagged differences of the STOXX50E index. The coefficients of both of the exchange rates, Euro expressed in US Dollars and the US Dollar expressed in Euros also show a strong relationship, both positive. Another significant variables are Total trade of the Euro Area, *Index of Industrial production, IIP*, and short term interest rates of both the United States and Euro Area. The least significant among the exogenous variables is the index of industrial production of the United States. The constant is significant and negative. Also, the error correction term, EC, is significant and negative, indicating a convergence to the long run equilibrium. The R^2, indicating how well the data are fitted, is 0.521469 and R^2 adjusted is 0.451096.

The GSPC equation using the differenced values of the exogenous variables also does not find any relationship among the coefficients of both of the stock indices. It shows a strong relationship for the coefficients of the exchange rate, however, only one of the exchange rates is statistically significant in this equation compare to the previous one, that is the Euro expressed in the US Dollars. Other statistically significant variable, not significant in the output above, is the long term interest rate of the United States. Also the coefficients of the short term interest rate of the Euro Area shows a relationship, but with a weaker significance. The constant and the error correction term are both significant. The R^2 is 0.473805 and R^2 adjusted 0.396424.

The next two tables show the results for the second, STOXX50E equation. For the absolute values, the coefficients of the stock indices of both of the markets again do not show any significance, this time with an exception of a weak relationship present for the coefficients on the second lagged differences of the STOXX50E index. A significant relationship is found in the coefficients of the short term interest rates of both, Euro Area and the United States and the exchange rate of the Euro expressed in the US Dollars. Both the constant and the error correction term are negative and significant. The R^2 and the R^2 adjusted are 0.381872 and 0.290971.

The STOXX50E equation with the differenced values reveals contrasting results. The relationship between the coefficients of the US and the Euro Area stock index is not significant in any case. The most statistically significant explanatory variable is long term US interest rate. Less significant variables are the exchange rate of the Euro in terms of US Dollar, the constant and the error correction term. The weakest relationship is present in coefficients of the long term interest rate of the Euro Area. The error correction term is again negative. The R^2 is 0.289421 and R^2 adjusted is 0.184925.

The equations using the absolute values for the exogenous variables prove more statistically significant relationships within the model. The outputs are similar for each equation. The R^2 values are very low in case of the second, the STOXX50E equation.

In general, in case of the Unites States and the Euro Area market, the VECM gives evidence of a positive relationship between the stock indices and the exchange rates, therefore so far we can confirm our hypothesis of a positive relationship between stock indices and the exchange rate. In all cases the relationship is positive for the US interest rates and negative for the Euro Area interest rates, with the exception of one, in the GSPC equation using differenced values. This does not indicate any clear relationship yet, as our hypothesis states that the interest rate is inversely correlated with the stock indices. In VECM using the absolute values, we find positive relation for the index of industrial production and the total trade, which supports our hypothesis. The error correction term, EC, is significant and negative, for both equations, in both cases, thus for the whole VECM of the United States and Euro Area. Negative error correction term indicates that the relationship is corrected when the process deviates from its long run equilibrium. For example, suppose that the error correction term is -0.01, this implicates that the 1 percent of the disequilibrium will be corrected in the next period by converging to the long run trend.

We proceed to the next set of markets, the stock market of Euro Area and China. Table A.8 in the Appendix suggests the results of the first, STOXX50E index equation. There is a strong relationship for the coefficients on the second lagged differences of both of the indices, the STOXX50E and the SSEC index. The exchange rate of the US Dollars over the Chinese Yuan and the long term interest rate of China are significant, although showing a weaker relation. The signs are as expected, negative for the interest rate and positive for the exchange rate. The constant is insignificant. The error correction term is statistically significant. It has a negative value, indicating a convergence to a long run equilibrium. The R^2 is 0.298144 and R^2 adjusted is 0.194930.

In the same equation, in case of using the differences variables, the output notes different relationships. The most significance is reported for the coefficients on the second lagged differences of both of the indices and the exchange rate of the US Dollar over Euros. A smaller significance is reported for the short term interest rate of Euro Area and the constant. The least significance is found for the exchange rate of the Chinese Yuan in the US Dollars and the error correction term. The error correction term is also negative. The R^2 in this case is 0.320575 and R^2 adjusted is 0.220659.

We continue to the next two tables, where we examine the second, the SSEC index equation. With the use of the absolute values. The only statistically significant variables are trade of the Euro Area and the error correction term. Long term interest rates of China and Euro are also significant, but showing a weaker relationship. The weakest relationship is present for the coefficients on the second lagged difference for the STOXX50E and the SSEC index. The error correction term is positive. The R^2 is 0.270157 and R^2 adjusted is 0.162827.

The last combination from this set of endogenous variables employs the differenced values of exogenous variables. The relationships in this SSEC equation seems to be very poor. The most and the only statistically significant variables are both of the exchange rates. Less significance is in the coefficients on the second lagged difference for the SSEC index. The error correction term is positive, but not significant and the R^2 values remain low, with the R^2 0.228832 and R^2 adjusted is 0.115425.

In the case of VECM of Euro Area and China, it is not clear which exogenous variables provide more significant output. One of the few significant variables are the exchange rates. The coefficients of the US dollar over the Euro are negative, while the the coefficients of the US dollar over the Chinese Yuan positive relationship. This does not indicate any clear relationship. Regarding the interest rates, the relationship for the interest rates of China is negative and for the Euro Area positive, for both equations. Also, the long term interest rate is found to be more significant than the short term interest rate. Apart from interest and exchange rates, there is only one more significant relationship. It is the positive relationship for the total trade of the Euro Area in the SSEC equation using the absolute values.

The error correction term is strongly significant only in case of the SSEC equation using the absolute values. Its value is positive, which implies that the series will converges to the long run equilibrium. This has also been the output of the Johansen test, where the results indicated the large percentage of the shock to be removed within the next period, causing the series to converge back to the long run equilibrium. There is a small significance in the error correction term for the STOXX50E equation using differenced exogenous variables. It has a negative value, indicating a divergence from the long run equilibrium. This could also be related to the results of the Johansen test, which in this case implied an overshooting of economic equilibrium, meaning that the economy will overreact to shocks.

The last VECM examines the stock market of China and Japan. Table A.9 in the Appendix presents the output. The SSEC equation, reveals very poor relationship in both cases, using the absolute and the differenced values.

For the absolute values, the only significant relationship is found for the index of industrial production of Japan and for the error correction term. Weaker relationship is present for the total trade in Japan, for the coefficients on the second lagged difference of the SSEC index and the weakest relationship for the coefficient on the first lagged difference of the N225 index. The error correction term is negative, indicating convergence to a long run trend. The R^2 value is 0.241431 and R^2 adjusted 0.129877.

In the SSEC equation using the differenced values for the exogenous variables, the only significant relationship is represented for the coefficients on the second lagged differences of the SSEC index. The error correction term is insignificant and the R^2 values are very low. The R^2 value is 0.160883 and R^2 adjusted 0.037484.

The second, the N225 equation provides us with better results. For the absolute values of the exogenous variables, we do not get significant relationship for any of the coefficients of the indices. The most significant are the error correction term and the long term interest rate of Japan. The long term interest rate of China, the short term interest rate of Japan, and the exchange rate of the US Dollars over the Japanese Yen is less significant. The index of industrial production for Japan shows the least significance. The error correction term is positive, indicating divergence. The R^2 is equal to 0.269048 and adjusted R^2 is 0.161555.

The N225 equation using the differenced values presents several strong relationships. The coefficient on the first and second lagged difference of the SSEC index are both significant, implying weaker relationship. Very strong relationships are noted for the constant, the exchange rate of the US Dollars over the Japanese Yen, the index of industrial production of Japan and the long term interest rate of Japan. The Japanese short term interest rate shows weaker relationship and the index of industrial production of China the weakest, yet still significant. The error correction term is negative, indicating convergence. The R^2 and the adjusted R^2 is 0.420682 and 0.335488.

Overall, in this case, the last equation shows the strongest results. All the relationships are more significant for the variables of Japan. It is not clear which of the two kinds of exogenous variables presented more significant output.

We find positive relationship between the stock indices and the exchange rate, total trade and industrial production. These findings support our hypothesis. The relationship for the interest rates is both positive and negative. This does not indicate any certain relationship between the stock prices and the interest rates. However, the long term interest rate of Japan is significant and positive. The error correction term also shows different signs.

6.2.4 Impulse Response Functions

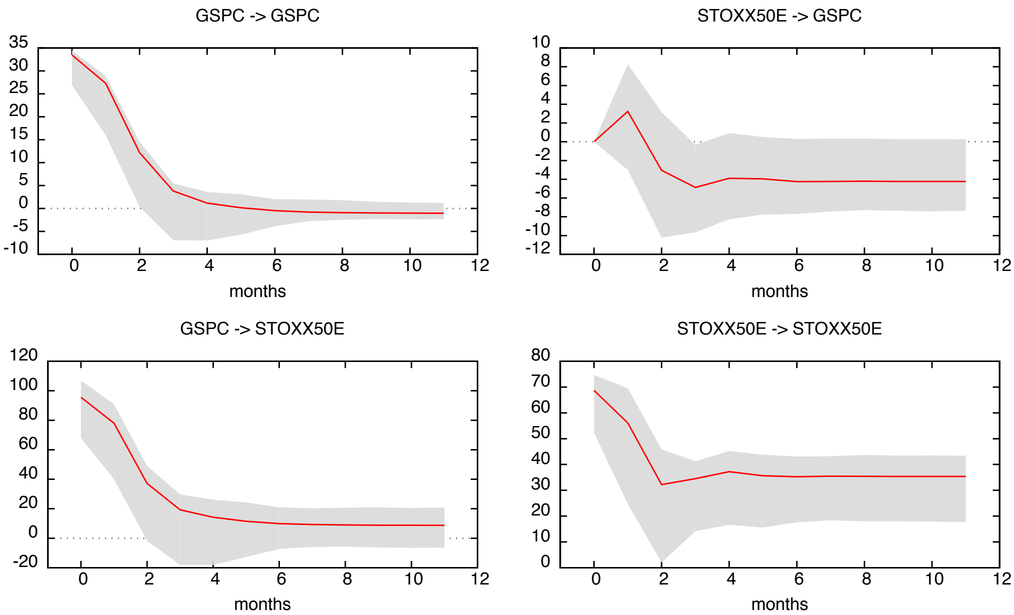
In the last section, we assess the output given by *the Impulse Response Funcitons, IRFs*. The IRFs explain the effects of the system when the model receives an impulse. If one standard deviation positive shock is given to one variable; how does the other variables reacts. In our case, the variables represent countries' stock market index. Tables A.10, A.11 and A.12 in the Appendix are showing the reaction of the variables for each period individually. The forecast horizon is set to 12 months and the confidence interval is at 95%. The beginning is noted to be period 1 and month 0.

First we look at the IRFs of the index of the United States and Euro Area, shown in Figure 6.3. All four graphs indicate negative reaction to unit of positive shock. The left graphs show the reactions to one standard deviation of positive shock given to the GSPC index. The GSPC shows a positive reaction to its own. The effect gradually goes down, until it becomes negative in period seven. It remains negative until the end of our period. The exactly same response is noted for the STOXX50E index. At first, the effect is very large. There is a positive slowly decreasing reaction, which dies out in month six. From this period the effect remains steady. However, its reaction does not reach negative values, as is the case of the GSPC index. It remains positive throughout the entire period.

The two graphs on the right side present the reactions to one standard deviation of positive shock given to the STOXX50E index. The reaction of GSPC is negative in the whole twelve months period. It becomes steady after six months. The effect does not revert to zero, it remains negative. The response of the STOXX50E index to its own shock is positive during the full period. It decreases to a point in period six, where it becomes steady. Its reaction does not return to zero.

The overall results indicate that after the period of time, specifically after six months, all four reactions become steady. After a unit of shock is applied to the GSPC index, the effect of both indices returns to very close to zero. Therefore, the effect of the GSPC index wears out after a year. The same cannot be said about the situation when a unit of shock is applied to the GSPC index. Both indices experience a permanent effect. In case of the GSPC index the reaction is negative and in case of the STOXX50E index positive.

Figure 6.3: IRFs: United States - Euro Area

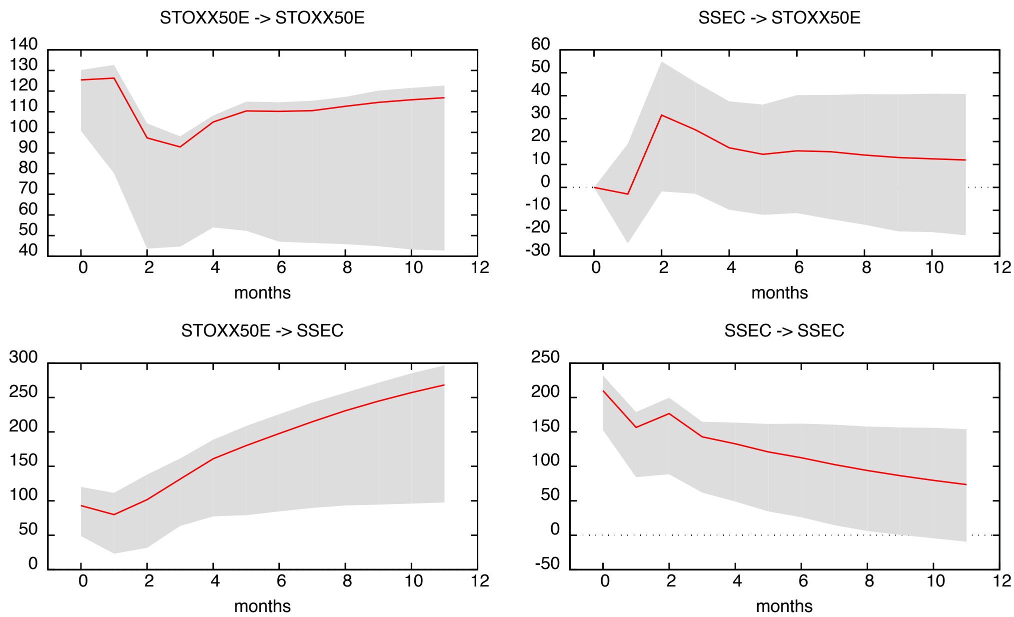


The next Figure 6.4 show the relationship of the index of Euro Area and the Chinese SSEC index. The reactions of the STOXX50E index to its own shock is completely different compared to the previous case. The effect remains at the same high level for the first month, after which it starts to decrease until the third month. From this period onwards the effect is gradually increasing until the end of our sample. The outcome remains very far from zero. The reaction of the SSEC index to one standard deviation positive shock given to the STOXX50E index is positive and increasing throughout the entire twelve months period.

The reaction of the STOXX50E index to a shock given to the SSEC index is very close to zero. At first it increases sharply, reaching the highest level in the second month. After the third period it starts to decrease. After the fifth period it continues to decrease but at a very slow pace, remaining almost steady. The response of the SSEC index to its own shock is positive but decreasing. There is a tiny fluctuation during the first three months. After, the effect gradually goes down, coming closer to zero.

Overall, the effect of the STOXX50E index is increasing over the full twelve months period, hence more permanent. The effect of the SSEC index is more transitory and eventually it becomes zero.

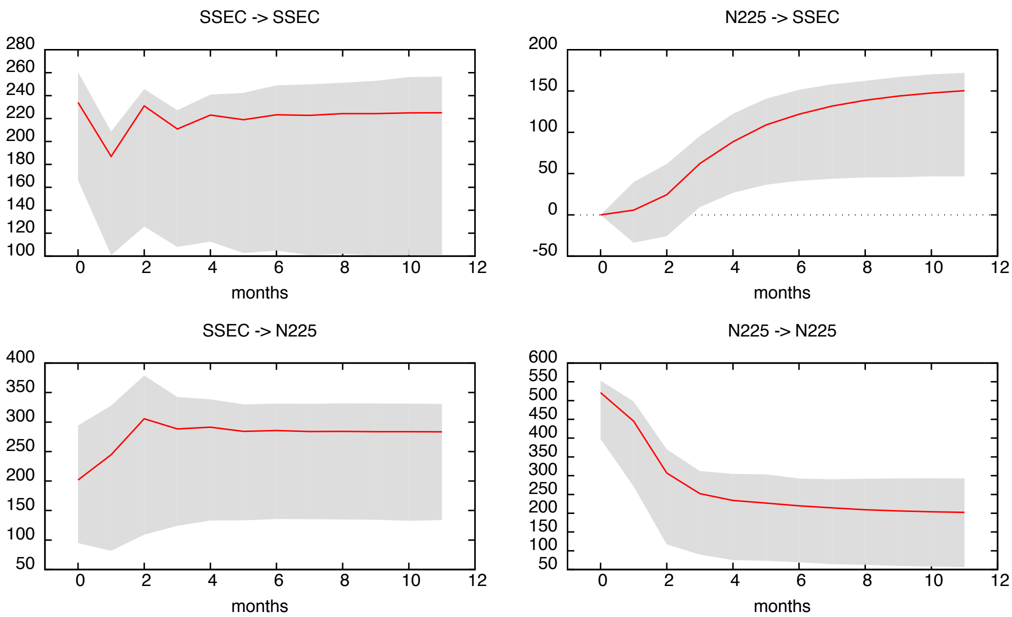
Figure 6.4: IRFs: Euro Area - China



The last Figure 6.5 present the relationship of the Chinese SSEC and Japanese N225 index. The response of the SSEC index to its own shock fluctuates around the same level in the first six months. The fluctuation slowly diminishes. Since period seven, the effect remains almost completely steady. The reaction of the N225 index to one standard deviation of positive shock given to the SSEC index is similar. The response increases in the first two months. The level of the outcome starts to settle down, until after the sixth month, when it becomes completely steady.

One standard deviation positive shock in the SSEC index leads to a positive reaction of the Japanese N225 index. The effect increases sharply in the first half and more modestly in the second half of the twelve months period. The response of the N225 index to its own shock has exactly opposite pattern to the response of the SSEC index. The effect decreases sharply in the first half and more moderately in the second half of the sample period.

Figure 6.5: IRFs: China - Japan



Overall, one standard deviation positive shock in the SSEC index leads to a very steady effect of both indices, but also very permanent. It does not look like the effect will revert to zero any time soon. The reaction caused by the N225 shock is exactly adverse for both indices. It begins to wear out after six months.

To sum up, the results of DCC-GARCH model show some similar trends of market correlation. Based on these findings we can categorize the sample into five main groups. This could lead to achieving more accurate results when estimating future co-movement of markets within the group. In terms of further research, it would be interesting to investigate whether the markets that belong to one group share some similar characteristics.

The largest increase in correlation after the crisis began was reported for Argentina and India. It indicates, that these two countries were most effected by the crisis that originated in US. This could be used for further analysis to test the response of Argentina and India to the US stock market. Also it could be useful to predict any future negative responses to shocks.

Knowing which markets are the least correlated, hence resistant to the shocks from the US stock market (in our research New Zealand, Malaysia and China, followed by Japan, Taiwan, Australia and Indonesia), could be useful information for investors in order to take advantage of international portfolio diversification.

Understanding the macroeconomic variables and their relationship with stock markets is important part of forecasting. The implications of our results support our hypotheses of positive relationship of markets with the exchange rate, total trade and industrial production. Changes in these variables could be used to predict future changes in stock markets.

Lastly, we show evidence that one standard deviation of positive shock given to one certain market causes similar response in more markets. This research could be taken further by examining larger sample of countries. The findings also indicate that most of the effects become stable after six months, which could be helpful for predicting possible consequences of a shock.

Chapter 7

Conclusion

We study the conditional correlation among the US and international stock markets by employing the Dynamic Conditional Correlation, multivariate Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH) model. The data include daily stock market returns from thirty-three international stock markets, chosen based on their world market capitalization. The sample period covers January 2003 to December 2012, with the emphasis on the period of recent world financial crisis of autumn 2008. We test for structural breaks, by applying the Chow test, to determine whether or not we can use September 2008 as the begging of the crisis. Based on our findings, we rejected the null hypothesis of stability. In order to set the exact date, we use September 15^{th} 2008, when Lehman Brothers filed for bankruptcy protection.

Our results indicate, that in the entire sample period, the US market presents the lowest correlation with stock markets of New Zealand, the only market with negative correlation, and under 0.1 with markets of China and Malaysia. The highest correlation, above 0.7 is reported for markets of Canada and Mexico, and above 0.6 for Brazil, Germany, Euro Area and France.

When investigating the effects of crisis on the correlation of the markets, we find that the largest increase in correlation, above 0.3, was noted in Argentina and India. The correlation of markets increased after the crisis began on average by 0.164. In the period of one year after the beginning of crisis, the highest correlation, above 0.8, was noted for Mexico and Brazil. When we looking at the representation of the results graphically, we categorize the markets into five main groups, according to the pattern of their correlation and its evolution over time.

In the second part of the thesis we analyze the long term relationship between four selected markets (China, Euro Area, Japan and the United States) and their macroeconomic variables (exchange rate, total trade, industrial production and interest rates) by applying the Vector Error Correction Model (VECM). The series are non-stationary in their values and stationary in their first differences, therefore it is the ideal choice of the model.

We find evidence of positive relationship of the stock markets with the exchange rate, balance of trade and the index of industrial production. The results for the interest rate are significant, however they do not reveal any specific, negative nor positive, relationship. Lastly, we conclude that different indices respond in a similar way to one standard deviation positive shock applied to one index.

In terms of future research, based on our findings, we believe that it would be worthy to cover larger number of markets when examining their relationship with macroeconomic variables.

The conclusion of our findings could be helpful for investors in order to take advantage of international portfolio diversification. The overall results are useful for improving the forecasts of stock market prices and the predictions of possible effects of shock.

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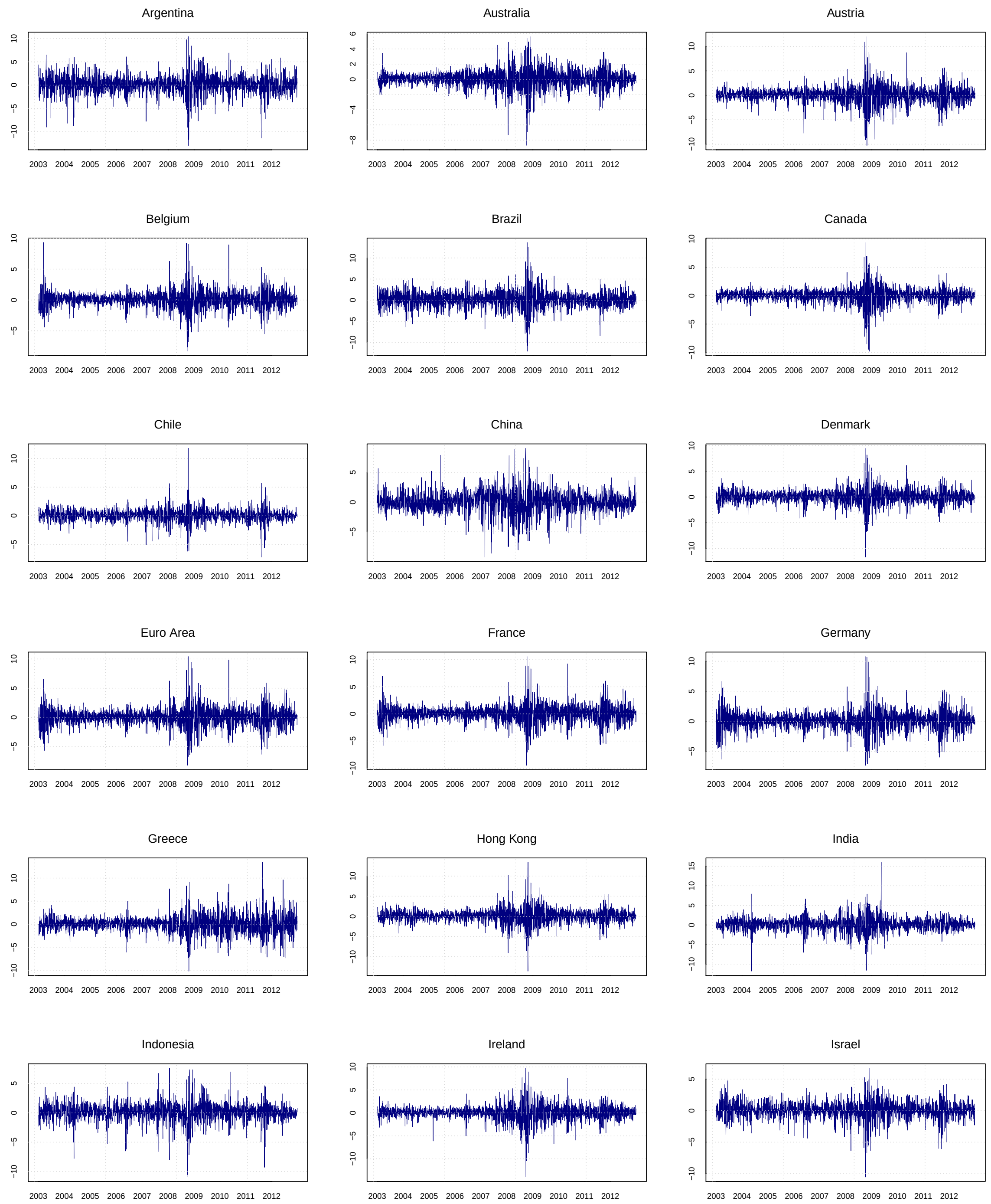
Appendix A

Appendix

Figure A.1: Daily returns of stock markets



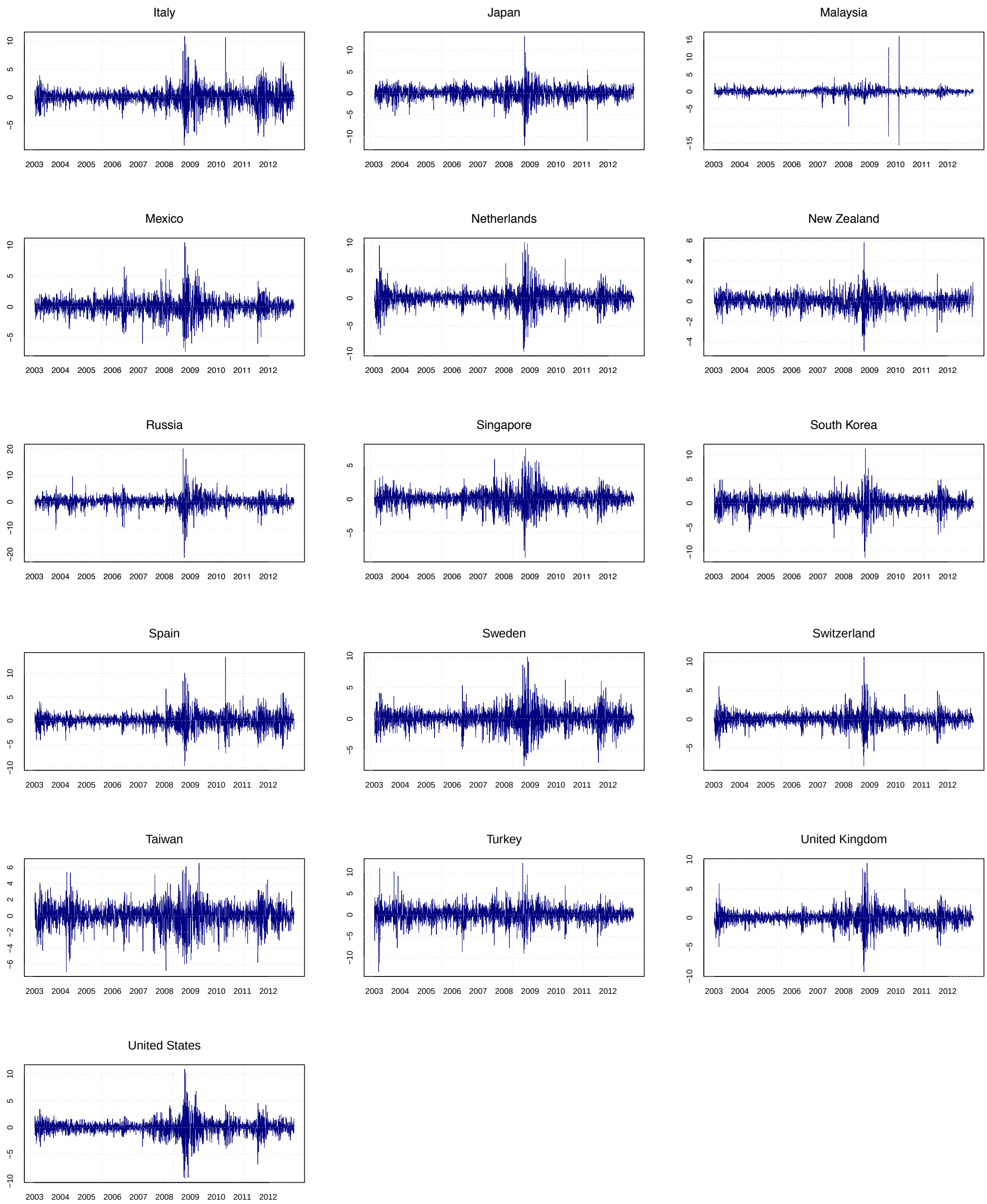

Italy
Japan
Malaysia
Mexico
Netherlands
New Zealand
Russia
Singapore
South Korea
Spain
Sweden
Switzerland
Taiwan
Turkey
United Kingdom
United States
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

Table A.1: Descriptive statistics of daily returns for the world stock indices

	Mean	Standard Deviation	Maximum	Median	Minimum	Skewness	Kurtosis	Jarque-Bera statistics	p-value
Argentina	0.0642	1.9186	10.4316	0.1154	-12.9516	-0.5538	4.5747	2228.80	0.0000
Australia	0.0158	1.1140	5.6282	0.0412	-8.7043	-0.4529	5.5792	3297.42	0.0000
Austria	0.0313	1.6650	12.0210	0.1197	-10.2526	-0.2777	6.1643	3865.81	0.0000
Belgium	0.0070	1.3316	9.3340	0.0365	-8.3192	0.0676	6.7140	4699.11	0.0000
Brazil	0.0671	1.8580	13.6766	0.1230	-12.0960	-0.0742	5.1018	2624.95	0.0000
Canada	0.0203	1.1850	9.3702	0.0547	-9.7879	-0.6892	10.7476	12333.40	0.0000
Chile	0.0619	1.0686	11.8034	0.0931	-7.2363	0.0042	13.4624	11078.36	0.0000
China	0.0215	1.6849	9.0345	0.0551	-9.2561	-0.2353	6.5236	1235.27	0.0000
Denmark	0.0323	1.3371	9.4964	0.0741	-11.7232	-0.2287	9.7087	4666.66	0.0000
Euro Area	0.0022	1.4888	10.4376	0.0121	-8.2079	0.1018	8.6448	3308.88	0.0000
France	0.0059	1.4892	10.5946	0.0404	-9.4715	0.1303	9.2127	4019.58	0.0000
Germany	0.0338	1.4818	10.7975	0.0847	-7.3355	0.0929	8.5086	3155.62	0.0000
Greece	-0.0199	1.7771	13.4310	0.0110	-10.2140	0.0474	7.4967	2103.89	0.0000
Hong Kong	0.0358	1.6097	13.4068	0.0559	-13.5820	0.0501	12.2449	8693.93	0.0000
India	0.0704	1.6444	15.9900	0.1212	-11.8092	-0.0333	10.7533	6031.85	0.0000
Indonesia	0.0924	1.4790	7.6231	0.1375	-10.9540	-0.6578	9.5976	4497.70	0.0000
Ireland	-0.0032	1.5384	9.7331	0.0427	-13.9636	-0.5364	10.7330	6323.66	0.0000
Israel	0.0332	1.2293	6.7377	0.0000	-10.5377	-0.6611	9.0948	4077.48	0.0000
Italy	-0.0137	1.5286	10.8742	0.0514	-8.5991	-0.0236	8.9350	3692.92	0.0000
Japan	0.0044	1.5527	13.2346	0.0393	-12.1110	-0.5629	11.8044	7786.52	0.0000
Malaysia	0.0381	0.9878	16.0204	0.0562	-15.5682	-0.4924	85.5737	681939.23	0.0000
Mexico	0.0745	1.3369	10.4407	0.1226	-7.2661	0.0914	8.8533	3503.75	0.0000
Netherlands	-0.0012	1.4779	10.0283	0.0517	-9.5903	-0.0270	10.6371	6063.64	0.0000
New Zealand	0.0275	0.7236	5.8146	0.0710	-4.9381	-0.4230	8.0481	2639.53	0.0000
Russia	0.0548	2.2458	20.2039	0.1689	-21.1994	-0.4698	14.1788	12873.34	0.0000
Singapore	0.0348	1.2190	7.5305	0.0606	-8.6960	-0.1710	8.2920	2902.46	0.0000
South Korea	0.0431	1.5061	11.2844	0.1061	-11.1720	-0.4831	8.5470	3175.57	0.0000
Spain	0.0120	1.5168	13.4836	0.0772	-9.5859	0.1930	9.8948	4917.78	0.0000
Sweden	0.0252	1.4936	9.8650	0.0483	-7.5127	0.0713	7.1300	1764.66	0.0000
Switzerland	0.0127	1.1799	10.7876	0.0506	-8.1078	0.0295	10.4016	5654.51	0.0000
Taiwan	0.0153	1.3626	6.5246	0.0688	-6.9123	-0.3737	5.8302	854.71	0.0000
Turkey	0.0738	1.8722	12.1274	0.0767	-13.3403	-0.2344	7.5032	2113.05	0.0000
United Kingdom	0.0139	1.2358	9.3842	0.0132	-9.2645	-0.0630	11.0632	6817.36	0.0000
United States	0.0144	1.3212	10.9572	0.0751	-9.4695	-0.3009	13.2383	10588.71	0.0000

Table A.2: Standard deviation: full, pre-crisis, post-crisis and crisis period

	Full Period	Pre-crisis Period	Post-Crisis Period	Crisis Period
Argentina	1.9186	1.6860	3.2887	2.1893
Australia	1.1140	0.9214	2.0281	1.3278
Austria	1.6650	1.1646	3.3763	2.1542
Belgium	1.3316	1.0790	2.3413	1.6031
Brazil	1.8580	1.6942	3.3349	2.0415
Canada	1.1850	0.8305	2.6903	1.5291
Chile	1.0686	0.9679	1.7369	1.1904
China	1.6849	1.7440	2.3847	1.5984
Denmark	1.3371	1.0600	2.5770	1.6343
Euro Area	1.4888	1.1454	2.6497	1.8425
France	1.4892	1.1469	2.6591	1.8447
Germany	1.4818	1.2331	2.6066	1.7553
Greece	1.7771	1.1681	2.5396	2.3448
Hong Kong	1.6097	1.3254	3.1976	1.9135
India	1.6444	1.5817	2.9589	1.7222
Indonesia	1.4790	1.3954	2.4178	1.5774
Ireland	1.5384	1.2502	2.8857	1.8494
Israel	1.2293	1.0627	2.1968	1.4192
Italy	1.5286	0.9647	2.7644	2.0521
Japan	1.5527	1.2874	3.0030	1.8429
Malaysia	0.9878	0.9129	1.1150	1.1618
Mexico	1.3369	1.1985	2.5263	1.4977
Netherlands	1.4779	1.2292	2.8485	1.7513
New Zealand	0.7236	0.6377	1.3138	0.8257
Russia	2.2458	1.7646	4.6701	2.7637
Singapore	1.2190	1.0706	2.3735	1.3862
South Korea	1.5061	1.3897	2.5348	1.6365
Spain	1.5168	1.0658	2.5037	1.9535
Sweden	1.4936	1.2318	2.6888	1.7842
Switzerland	1.1799	1.0227	2.1583	1.3534
Taiwan	1.3626	1.3185	2.0936	1.4140
Turkey	1.8722	1.9400	2.5958	1.7705
United Kingdom	1.2358	0.9794	2.3961	1.5062
United States	1.3212	0.9129	2.7652	1.6972

Table A.3: Descriptive statistics: exchange rate, trade, industrial production, interest rate

Variable	Mean	Standard Deviation	Maximum	Median	Minimum	Skewness	Kurtosis
Exchange Rate							
USD/EUR	0.7696	0.0667	0.9820	0.7670	0.6350	0.4319	0.4374
EUR/USD	1.3129	0.1124	1.5774	1.3034	1.0501	0.1813	-0.1711
USD/NCY	7.3729	0.7516	8.2770	7.3720	6.2900	-0.0226	-1.6383
USD/JPY	101.43	14.736	122.70	106.63	76.656	-0.3202	-1.3449
d_USD/EUR	-0.0018	0.0195	0.0560	-0.0020	-0.0560	0.0435	0.3195
d_EUR/USD	0.0023	0.0425	0.1283	0.0036	-0.1371	-0.4906	1.4248
d_USD/NCY	-0.0166	0.0266	0.0160	-0.0050	-0.1280	-1.8767	3.9386
d_USD/JPY	0.3184	2.2909	4.9800	-0.1750	-6.5730	-0.4171	0.2129
Balance of Trade							
China	13.528	9.5554	41.480	14.280	-17.510	0.0200	0.3209
Euro Area	0.8462	5.7672	13.620	0.8500	-18.240	-0.1181	0.0098
Japan	3.6867	5.5031	11.010	5.7200	-13.050	-1.0606	0.0156
USA	-58.299	10.013	-35.370	-59.230	-76.020	0.3905	-0.8690
d_China	0.1753	8.1590	34.640	0.5250	-42.710	-1.1596	9.3517
d_Euro Area	0.0628	3.2758	7.3900	0.1550	-10.140	-0.5818	0.7301
d_Japan	-0.1278	2.3038	7.7100	-0.2150	-8.2500	-0.2629	1.9748
d_USA	-0.0733	3.4836	16.510	-0.4450	-7.1100	1.0669	3.5029
Index of Industrial Production							
China	114.64	3.4308	123.20	115.10	105.40	–0.5559	-0.0163
Euro Area	103.09	5.4797	114.90	102.29	90.160	0.1508	-0.2808
Japan	102.56	8.3051	116.40	102.20	77.600	-0.5852	0.3749
USA	103.60	4.7052	111.40	103.60	92.400	-0.2860	-0.5632
d_China	-0.0383	2.8197	16.000	-0.1000	-13.300	0.5612	13.019
d_Euro Area	0.0113	1.1871	2.3200	0.1400	-4.0500	-1.0125	2.0167
d_Japan	-0.0233	2.4962	5.8000	0.3000	-16.200	-2.9785	15.132
d_USA	0.0658	0.8166	1.5000	0.2000	-4.6000	-2.2913	9.2419
Short-term Interest Rate							
China	3.0903	1.2422	6.8000	2.8400	1.0900	0.6256	-0.2280
Euro Area	2.2680	1.3512	5.1100	2.1300	0.1900	0.5455	-0.6706
Japan	0.3782	0.2654	0.8900	0.3300	0.0800	0.5231	-0.9085
USA	2.1002	1.9155	5.4900	1.2200	0.1900	0.6290	-1.1616
d_China	0.0133	0.5030	1.6700	-0.0050	-1.6500	0.4856	3.4891
d_Euro Area	-0.0229	0.1817	0.3200	0.0000	-0.9500	-2.8418	11.024
d_Japan	0.0018	0.0287	0.1300	0.0000	-0.1400	-2.8418	11.024
d_USA	-0.0092	0.2801	0.8000	0.0000	-1.9600	-3.4928	21.670
Long-term Interest Rate							
China	1.8971	0.5286	2.9700	1.8700	1.1300	0.2981	-1.2127
Euro Area	3.9497	0.4920	4.8100	4.0700	2.1000	-1.3302	2.6076
Japan	1.3123	0.3200	1.9600	1.3300	0.5300	-0.2651	-0.4854
USA	3.6755	0.9463	5.1100	3.8800	1.5300	-0.7063	-0.4284
d_China	-0.0111	0.1518	0.5300	-0.0100	-0.5200	0.0738	2.9126
d_Euro Area	-0.0193	0.1891	0.5300	-0.0250	-0.5900	0.0310	0.4055
d_Japan	-0.0017	0.1182	0.4500	-0.0100	-0.2600	1.0967	2.6930
d_USA	-0.0193	0.2352	0.6500	-0.0250	-1.1100	-0.5218	3.5897

Figure A.2: Exchange rate

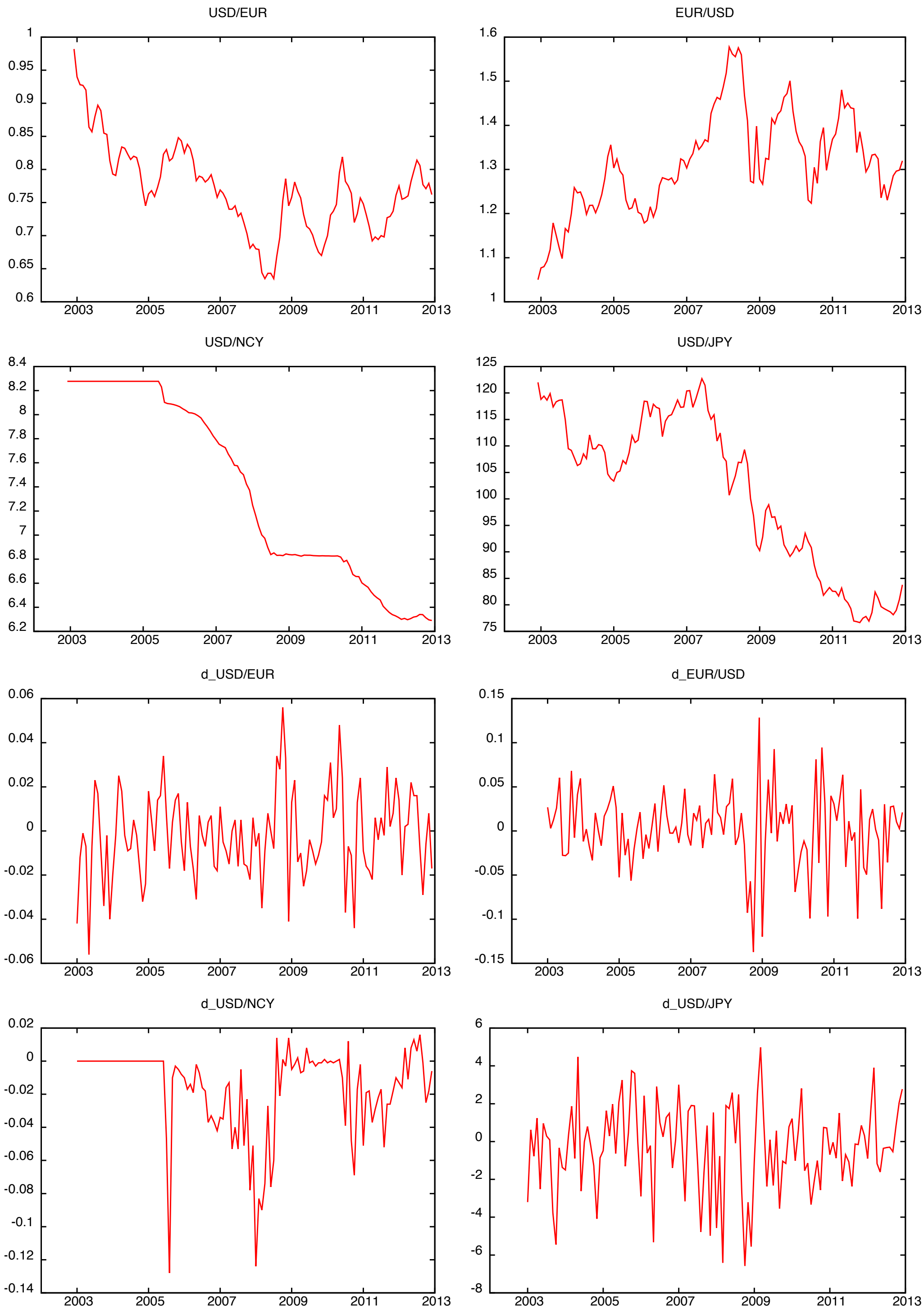


Figure A.3: International Trade

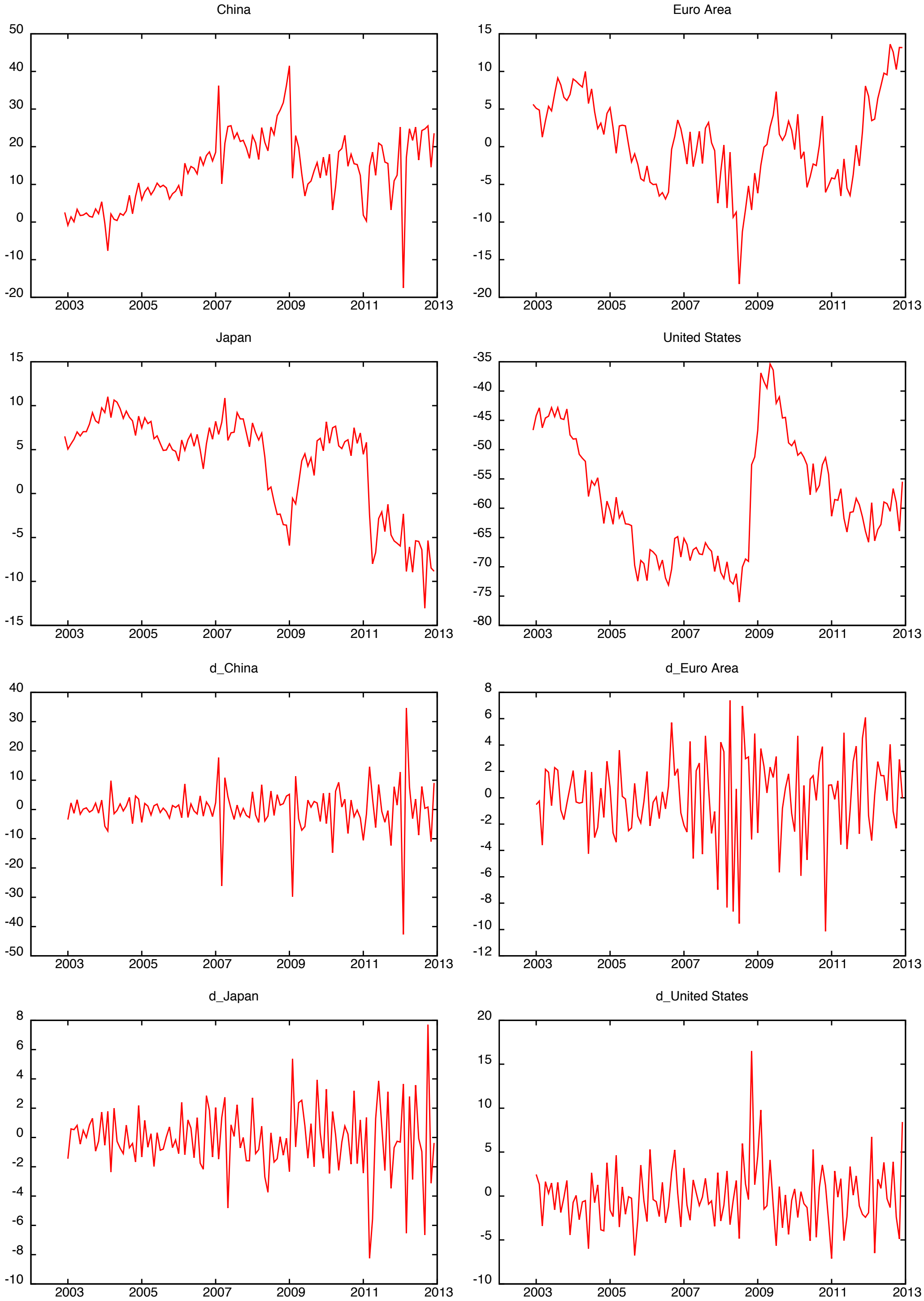


Figure A.4: Index of Industrial Production

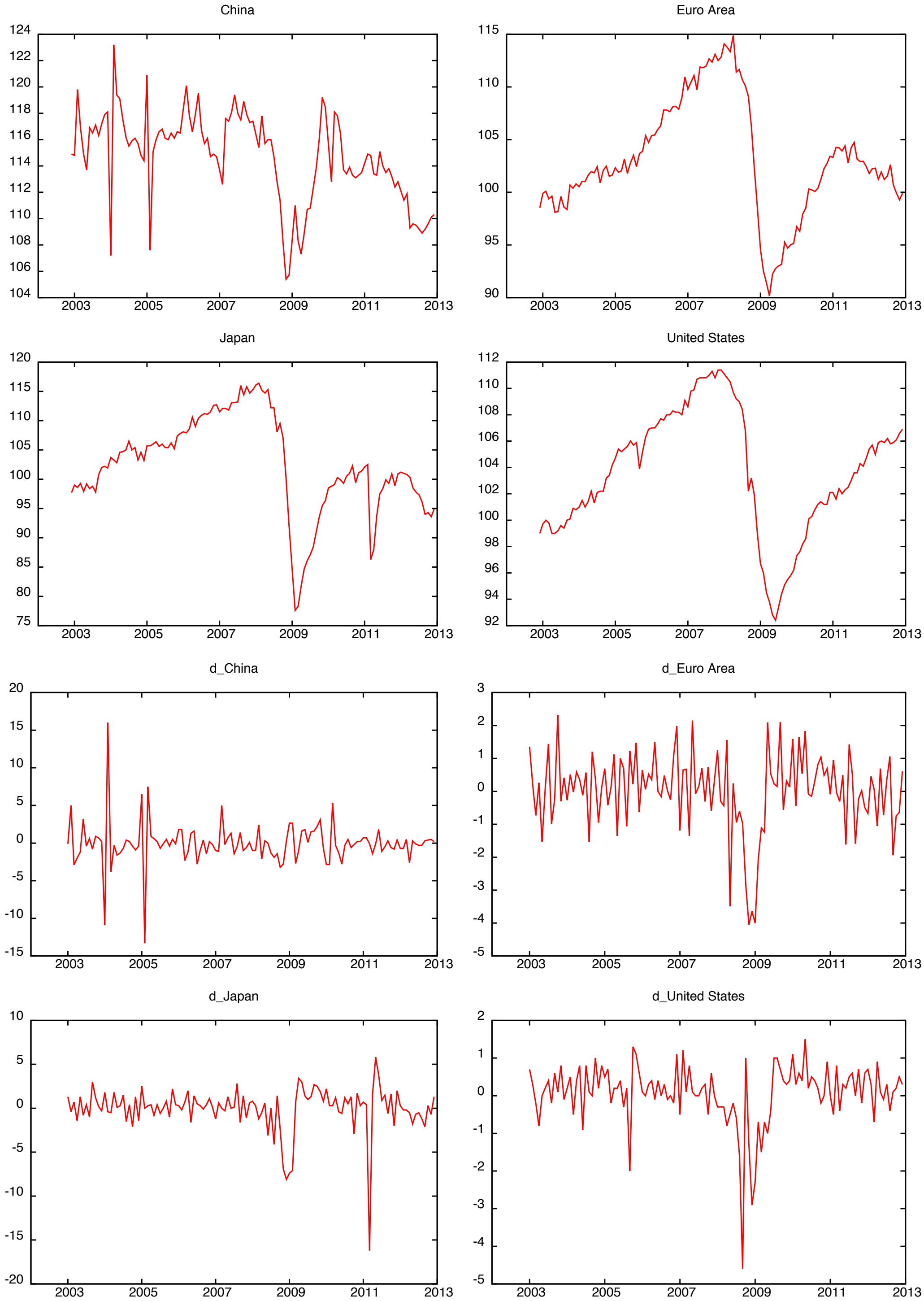


Figure A.5: Short-term Interest Rate

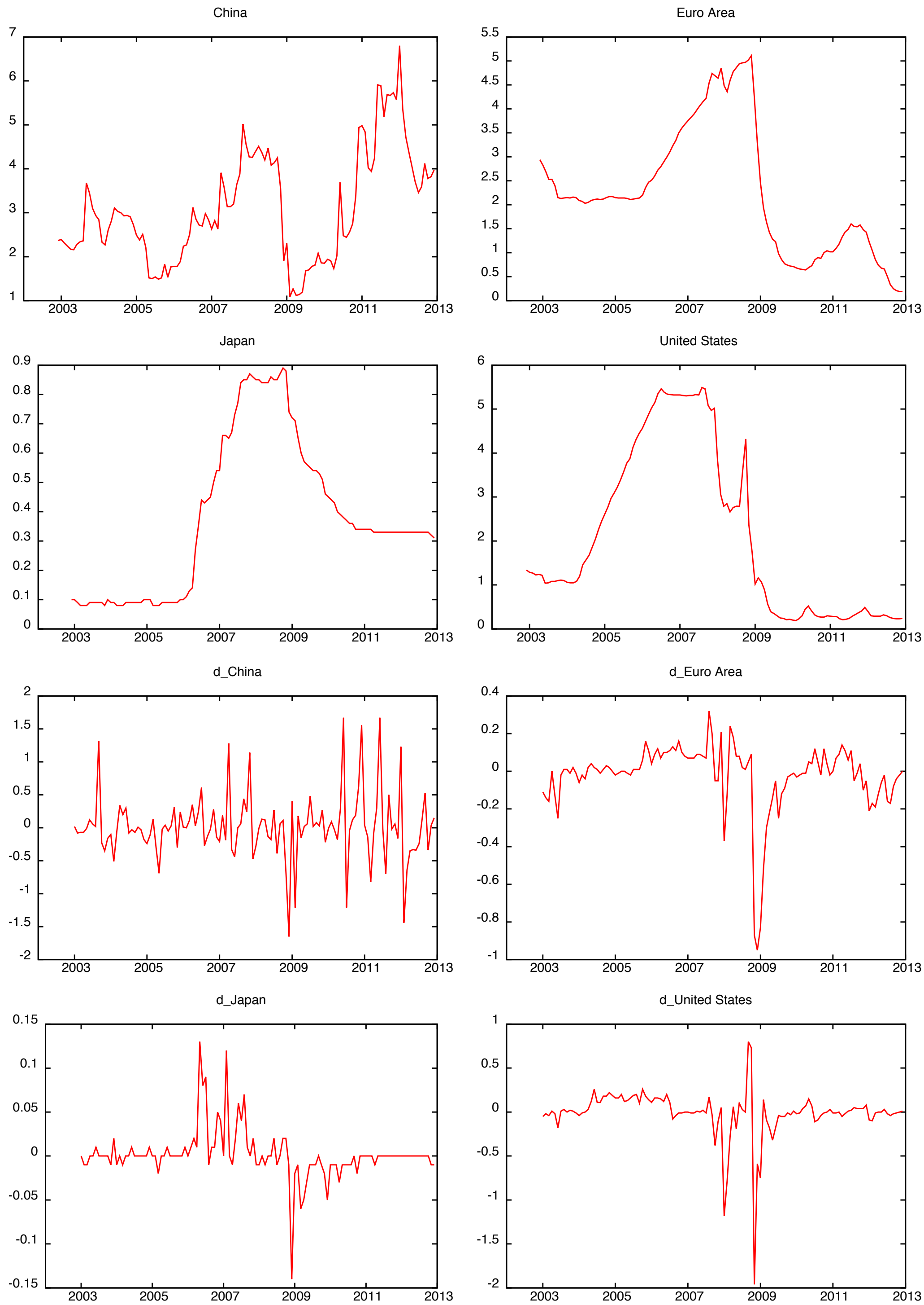


Figure A.6: Long-term Interest Rate

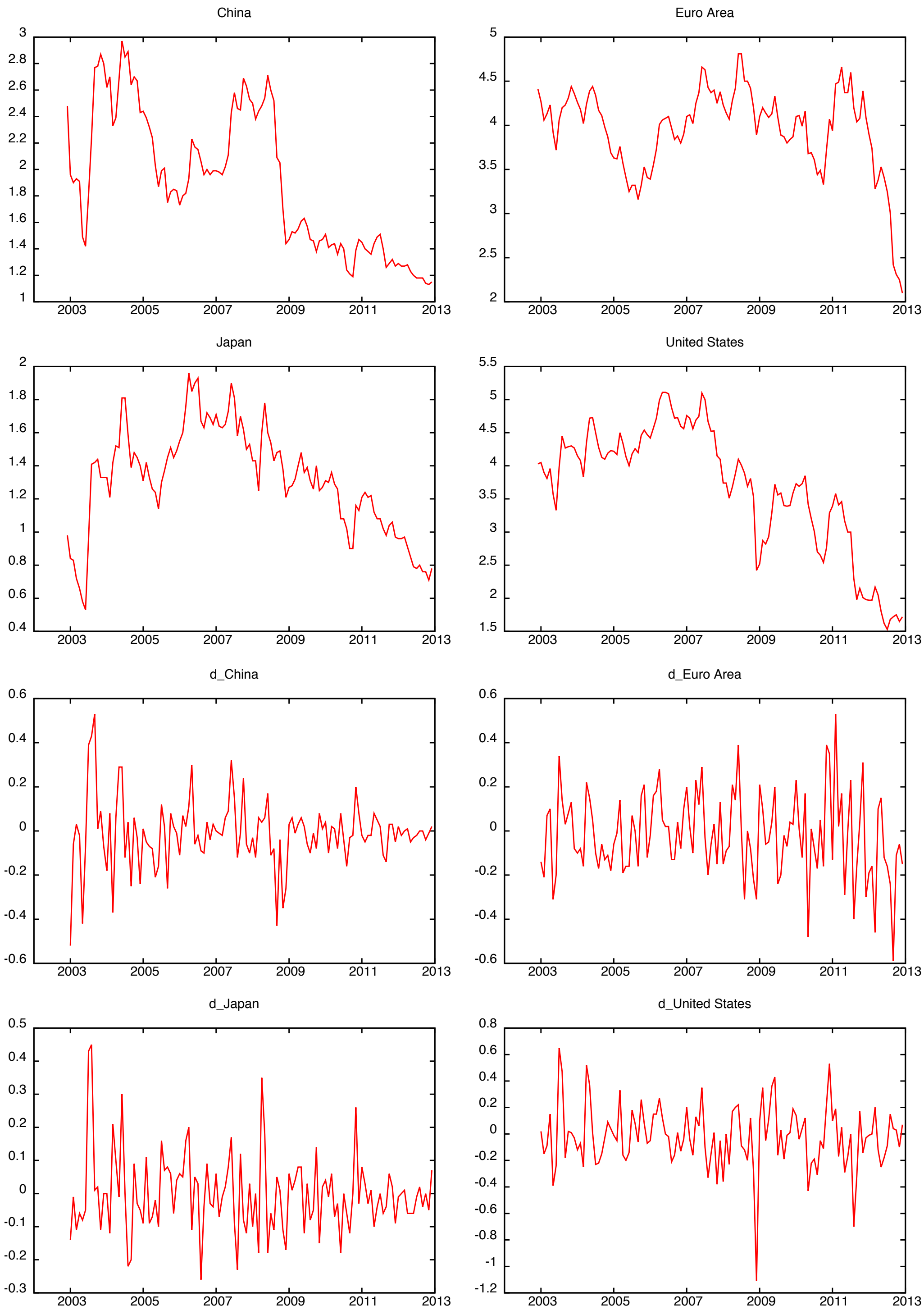


Figure A.7: Stock index market prices and returns

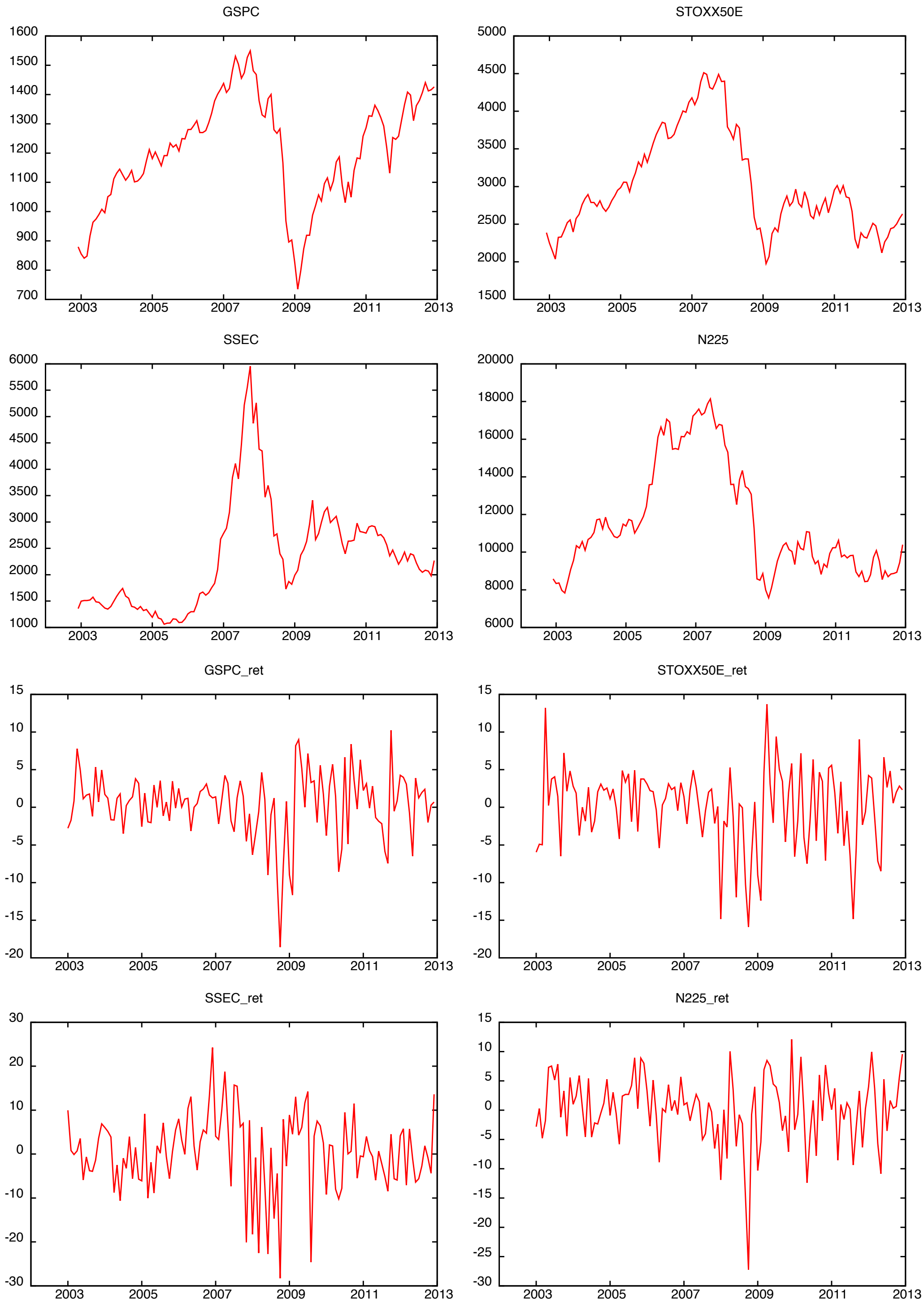


Table A.4: Johansen test: United States - Euro Area

```
Johansen test:
Number of equations = 2
Lag order = 3
Estimation period: 2003:04 - 2012:12 (T = 117)

Rank   Eigenvalue   Trace test    p-value   Lmax test   p-value
   0      0.26327       56.630   [0.0000]     35.748   [0.0000]
   1      0.16346       20.882   [0.0000]     20.882   [0.0000]

             beta (cointegrating vectors)    alpha (adjustment vectors)
GSPC_ret       0.50645     -0.62360           1.1231      1.6070
STOXX50E_ret  -0.63979      0.29605           2.5579      1.1478

               renormalized beta             renormalized alpha
GSPC_ret        1.0000     -2.1064          0.56881    0.47575
STOXX50E_ret   -1.2633     -1.0000           1.2955    0.33980

long-run matrix (alpha * beta')
                 GSPC_ret    STOXX50E_ret
GSPC_ret         -0.43332       -0.24282
STOXX50E_ret      0.57970        -1.2967
```

Table A.5: Johansen test: Euro Area - China

```
Johansen test:
Number of equations = 2
Lag order = 3
Estimation period: 2003:04 - 2012:12 (T = 117)

Rank   Eigenvalue   Trace test    p-value   Lmax test   p-value
   0      0.30277       60.674   [0.0000]     42.195   [0.0000]
   1      0.14610       18.480   [0.0000]     18.480   [0.0000]

              beta (cointegrating vectors)    alpha (adjustment vectors)
STOXX50E_ret     -0.32096      0.11626        2.5916     -1.2508
SSEC_ret          0.13746      0.13746       -1.7899     -3.2871

                renormalized beta             renormalized alpha
STOXX50E_ret      1.0000      0.83675       -0.83180    -0.17379
SSEC_ret        -0.42827      -1.0000        0.57450    -0.45670

long-run matrix (alpha * beta')
                 STOXX50E_ret    SSEC_ret
STOXX50E_ret       -0.97722       0.18245
SSEC_ret            0.19235      -0.70274
```

Table A.6: Johansen test: China - Japan

```
Johansen test:
Number of equations = 2
Lag order = 3
Estimation period: 2003:04 - 2012:12 (T = 117)

Rank   Eigenvalue   Trace test    p-value   Lmax test   p-value
   0      0.22444       49.117   [0.0000]     29.738   [0.0000]
   1      0.15265       19.380   [0.0000]     19.380   [0.0000]

             beta (cointegrating vectors)    alpha (adjustment vectors)
SSEC_ret       -0.13621   -0.13707            1.3169     3.4188
N225_ret        0.27166   -0.10919           -2.5071     1.3844

               renormalized beta           renormalized alpha
SSEC_ret        1.0000      1.2553         -0.17937    -0.37331
N225_ret       -1.9944      1.0000          0.34148    -0.15117

long-run matrix (alpha * beta')
                 SSEC_ret      N225_ret
SSEC_ret         -0.64798     -0.015558
N225_ret          0.15172      -0.83223
```

Table A.7: VECM: United States - Euro Area

Equation 1: d_GSPC

	coefficient	std. error	t-ratio	p-value	
const	-2664.18	402.210	-6.624	1.67e-09	***
d_GSPC_1	-0.00200477	0.143510	-0.01397	0.9889	
d_GSPC_2	0.0255055	0.139404	0.1830	0.8552	
d_STOXX50E_1	0.0852526	0.0467665	1.823	0.0712	*
d_STOXX50E_2	-0.0295627	0.0462405	-0.6393	0.5240	
USD/EUR	738.150	280.149	2.635	0.0097	***
EUR/USD	716.365	147.765	4.848	4.48e-06	***
Trade_USA	1.46466	0.973788	1.504	0.1357	
Trade_EA	2.55007	0.932765	2.734	0.0074	***
IIP_USA	7.82168	3.50515	2.231	0.0278	**
IIP_EA	8.89749	3.16276	2.813	0.0059	***
IRlong_USA	4.59445	7.94136	0.5785	0.5642	
IRlong_EA	15.6194	12.7194	1.228	0.2223	
IRshort_USA	25.2020	6.24411	4.036	0.0001	***
IRshort_EA	-52.5133	8.20253	-6.402	4.75e-09	***
EC1	-0.317895	0.0591652	-5.373	4.91e-07	***

Mean dependent var	4.957965	S.D. dependent var	48.61159
Sum squared resid	132304.9	S.E. of regression	36.01537
R-squared	0.521469	Adjusted R-squared	0.451096
rho	-0.062350	Durbin-Watson	2.121153

Equation 1: d_GSPC

	coefficient	std. error	t-ratio	p-value	
const	89.7051	26.6480	3.366	0.0011	***
d_GSPC_1	0.0780976	0.152487	0.5122	0.6096	
d_GSPC_2	-0.138769	0.151026	-0.9188	0.3603	
d_STOXX50E_1	0.0278329	0.0467365	0.5955	0.5528	
d_STOXX50E_2	-0.0123875	0.0475159	-0.2607	0.7948	
d_USD/EUR	-34.1543	300.802	-0.1135	0.9098	
d_EUR/USD	539.599	129.383	4.171	6.39e-05	***
d_Trade_USA	-0.720817	1.13215	-0.6367	0.5258	
d_Trade_EA	-0.260842	1.15376	-0.2261	0.8216	
d_IIP_USA	-1.88009	5.10490	-0.3683	0.7134	
d_IIP_EA	5.22578	3.79843	1.376	0.1719	
d_IRlong_USA	58.2444	20.5784	2.830	0.0056	***
d_IRlong_EA	-34.5170	24.3693	-1.416	0.1597	
d_IRshort_USA	-23.6585	19.6690	-1.203	0.2318	
d_IRshort_EA	83.3356	37.6369	2.214	0.0290	**
EC1	-0.0223058	0.00686843	-3.248	0.0016	***

Mean dependent var	4.957965	S.D. dependent var	48.61159
Sum squared resid	145482.9	S.E. of regression	37.76642
R-squared	0.473805	Adjusted R-squared	0.396424
rho	-0.021982	Durbin-Watson	2.039205

Equation 2: d_STOXX50E_ret

	coefficient	std. error	t-ratio	p-value	
const	-4856.59	1413.95	-3.435	0.0009	***
d_GSPC_1	0.744637	0.504502	1.476	0.1430	
d_GSPC_2	0.517815	0.490067	1.057	0.2932	
d_STOXX50E_1	-0.0937544	0.164405	-0.5703	0.5698	
d_STOXX50E_2	-0.291927	0.162556	-1.796	0.0755	*
USD/EUR	1304.61	984.849	1.325	0.1882	
EUR/USD	1380.79	519.459	2.658	0.0091	***
Trade_USA	2.61912	3.42330	0.7651	0.4460	
Trade_EA	7.52024	3.27908	2.293	0.0239	**
IIP_USA	17.6340	12.3221	1.431	0.1555	
IIP_EA	15.4968	11.1185	1.394	0.1664	
IRlong_USA	31.1547	27.9174	1.116	0.2671	
IRlong_EA	-19.0880	44.7143	-0.4269	0.6704	
IRshort_USA	70.9276	21.9508	3.231	0.0017	***
IRshort_EA	-115.395	28.8355	-4.002	0.0001	***
EC1	-0.746496	0.207992	-3.589	0.0005	***

Mean dependent var	4.196610	S.D. dependent var	150.3613
Sum squared resid	1635068	S.E. of regression	126.6100
R-squared	0.381872	Adjusted R-squared	0.290971
rho	-0.095728	Durbin-Watson	2.167462

Equation 2: d_STOXX50E

	coefficient	std. error	t-ratio	p-value	
const	204.063	95.7840	2.130	0.0355	**
d_GSPC_1	0.310069	0.548102	0.5657	0.5728	
d_GSPC_2	-0.496168	0.542851	-0.9140	0.3629	
d_STOXX50E_1	-0.0295050	0.167991	-0.1756	0.8609	
d_STOXX50E_2	-0.0404576	0.170792	-0.2369	0.8132	
d_USD/EUR	-442.538	1081.21	-0.4093	0.6832	
d_EUR/USD	1005.26	465.058	2.162	0.0330	**
d_Trade_USA	-2.03687	4.06941	-0.5005	0.6178	
d_Trade_EA	-2.68425	4.14710	-0.6473	0.5189	
d_IIP_USA	-4.37024	18.3492	-0.2382	0.8122	
d_IIP_EA	14.3490	13.6531	1.051	0.2958	
d_IRlong_USA	205.494	73.9675	2.778	0.0065	***
d_IRlong_EA	-151.133	87.5936	-1.725	0.0875	*
d_IRshort_USA	-1.43195	70.6986	-0.02025	0.9839	
d_IRshort_EA	188.119	135.283	1.391	0.1674	
EC1	-0.0523444	0.0246880	-2.120	0.0364	**

Mean dependent var	4.196610	S.D. dependent var	150.3613
Sum squared resid	1879619	S.E. of regression	135.7484
R-squared	0.289421	Adjusted R-squared	0.184925
rho	0.010192	Durbin-Watson	1.967799

Table A.8: VECM: Euro Area - China

Equation 1: d_STOXX50E

	coefficient	std. error	t-ratio	p-value	
const	-421.359	781.874	-0.5389	0.5911	
d_STOXX50E_1	0.0291363	0.105230	0.2769	0.7824	
d_STOXX50E_2	-0.340141	0.104983	-3.240	0.0016	***
d_SSEC_1	-0.0178514	0.0548027	-0.3257	0.7453	
d_SSEC_2	0.156515	0.0548265	2.855	0.0052	***
USD/EUR	-580.400	384.457	-1.510	0.1342	
USD/NCY	106.722	63.0902	1.692	0.0938	*
Trade_EA	4.54327	3.58951	1.266	0.2085	
Trade_China	-2.34546	2.18520	-1.073	0.2857	
IIP_EA	1.86528	7.06716	0.2639	0.7924	
IIP_China	2.99256	3.24935	0.9210	0.3592	
IRlong_EA	-42.3669	43.3226	-0.9779	0.3304	
IRlong_China	-102.825	58.9948	-1.743	0.0844	*
IRshort_EA	-10.6439	24.6294	-0.4322	0.6665	
IRshort_China	-2.35859	19.6732	-0.1199	0.9048	
EC1	-0.0118562	0.0629974	-0.1882	0.8511	

Mean dependent var	4.196610	S.D. dependent var	150.3613
Sum squared resid	1856546	S.E. of regression	134.9127
R-squared	0.298144	Adjusted R-squared	0.194930
rho	-0.054485	Durbin-Watson	2.085209

Equation 1: d_STOXX50E

	coefficient	std. error	t-ratio	p-value	
const	178.440	75.1537	2.374	0.0195	**
d_STOXX50E_1	0.0374583	0.0994597	0.3766	0.7072	
d_STOXX50E_2	-0.262739	0.0960797	-2.735	0.0074	***
d_SSEC_1	0.0186090	0.0536178	0.3471	0.7293	
d_SSEC_2	0.167577	0.0529350	3.166	0.0020	***
d_USD/EUR	-2350.08	718.525	-3.271	0.0015	***
d_USD/NCY	1095.29	631.543	1.734	0.0859	*
d_Trade_EA	-1.51781	3.94598	-0.3846	0.7013	
d_Trade_China	-0.0160559	1.61269	-0.009956	0.9921	
d_IIP_EA	11.7612	12.9079	0.9112	0.3644	
d_IIP_China	1.79221	2.36587	0.7575	0.4505	
d_IRlong_EA	1.54149	76.6707	0.02011	0.9840	
d_IRlong_China	-68.6006	101.074	-0.6787	0.4989	
d_IRshort_EA	204.970	88.0523	2.328	0.0219	**
d_IRshort_China	10.0970	27.7121	0.3644	0.7163	
EC1	-0.0449100	0.0228612	-1.964	0.0522	*

Mean dependent var	4.196610	S.D. dependent var	150.3613
Sum squared resid	1797213	S.E. of regression	132.7393
R-squared	0.320575	Adjusted R-squared	0.220659
rho	-0.018173	Durbin-Watson	2.016540

Equation 2: d_SSEC

	coefficient	std. error	t-ratio	p-value	
const	1002.37	1431.10	0.7004	0.4853	
d_STOXX50E_1	−0.324392	0.192607	−1.684	0.0952	*
d_STOXX50E_2	−0.285095	0.192155	−1.484	0.1410	
d_SSEC_1	−0.114064	0.100308	−1.137	0.2581	
d_SSEC_2	0.172301	0.100352	1.717	0.0890	*
USD/EUR	-201.630	703.691	-0.2865	0.7751	
USD/NCY	-59.0367	115.477	-0.5112	0.6103	
Trade_EA	23.3616	6.57006	3.556	0.0006	***
Trade_China	-0.283897	3.99968	-0.07098	0.9436	
IIP_EA	-20.2442	12.9354	-1.565	0.1207	
IIP_China	4.19789	5.94744	0.7058	0.4819	
IRlong_EA	178.936	79.2954	2.257	0.0262	**
IRlong_China	-217.352	107.981	-2.013	0.0468	**
IRshort_EA	7.69435	45.0804	0.1707	0.8648	
IRshort_China	-8.88720	36.0089	-0.2468	0.8056	
EC1	0.407565	0.115307	3.535	0.0006	***

Mean dependent var	6.416949	S.D. dependent var	269.8853
Sum squared resid	6219761	S.E. of regression	246.9373
R-squared	0.270157	Adjusted R-squared	0.162827
rho	-0.033104	Durbin-Watson	2.055487

Equation 2: d_SSEC

	coefficient	std. error	t-ratio	p-value	
const	-115.267	143.713	-0.8021	0.4244	
d_STOXX50E_1	-0.276079	0.190193	-1.452	0.1497	
d_STOXX50E_2	0.0734000	0.183729	0.3995	0.6904	
d_SSEC_1	-0.0541724	0.102531	-0.5284	0.5984	
d_SSEC_2	0.243686	0.101225	2.407	0.0179	**
d_USD/EUR	-4777.80	1374.01	-3.477	0.0007	***
d_USD/NCY	3651.21	1207.67	3.023	0.0032	***
d_Trade_EA	6.09489	7.54573	0.8077	0.4211	
d_Trade_China	-1.53482	3.08388	-0.4977	0.6198	
d_IIP_EA	-5.12711	24.6833	-0.2077	0.8359	
d_IIP_China	-0.429937	4.52415	-0.09503	0.9245	
d_IRlong_EA	148.825	146.614	1.015	0.3125	
d_IRlong_China	-88.2154	193.280	-0.4564	0.6491	
d_IRshort_EA	114.236	168.379	0.6784	0.4990	
d_IRshort_China	-27.0735	52.9927	-0.5109	0.6105	
EC1	0.0519497	0.0437165	1.188	0.2375	

Mean dependent var	6.416949	S.D. dependent var	269.8853
Sum squared resid	6571932	S.E. of regression	253.8320
R-squared	0.228832	Adjusted R-squared	0.115425
rho	-0.030236	Durbin-Watson	2.049835

Table A.9: VECM: China - Japan

Equation 1: d_SSEC

	coefficient	std. error	t-ratio	p-value	
const	2049.68	1455.18	1.409	0.1620	
d_SSEC_1	-0.101242	0.0973633	-1.040	0.3009	
d_SSEC_2	0.219312	0.0980484	2.237	0.0275	**
d_N225_1	-0.0764926	0.0457540	-1.672	0.0976	*
d_N225_2	-0.0480325	0.0456988	-1.051	0.2957	
USD/NCY	-63.0445	204.702	-0.3080	0.7587	
USD/JPY	-0.412451	7.02422	-0.05872	0.9533	
Trade_China	-0.596991	4.33099	-0.1378	0.8906	
Trade_Japan	21.9765	10.1233	2.171	0.0323	**
IIP_China	1.63133	5.97929	0.2728	0.7855	
IIP_Japan	-21.9530	7.57071	-2.900	0.0046	***
IRlong_China	-71.8879	126.758	-0.5671	0.5719	
IRlong_Japan	-223.136	197.614	-1.129	0.2615	
IRshort_China	32.9770	36.3708	0.9067	0.3667	
IRshort_Japan	55.6435	295.749	0.1881	0.8511	
EC1	-0.109733	0.0385753	-2.845	0.0054	***

Mean dependent var	6.416949	S.D. dependent var	269.8853
Sum squared resid	6464563	S.E. of regression	251.7500
R-squared	0.241431	Adjusted R-squared	0.129877
rho	-0.034935	Durbin-Watson	2.053117

Equation 1: d_SSEC

	coefficient	std. error	t-ratio	p-value	
const	94.6919	80.9681	1.169	0.2449	
d_SSEC_1	0.0254073	0.103644	0.2451	0.8068	
d_SSEC_2	0.308723	0.104803	2.946	0.0040	***
d_N225_1	-0.0405279	0.0445544	-0.9096	0.3652	
d_N225_2	-0.00600121	0.0446335	-0.1345	0.8933	
d_USD/NCY	1123.71	1136.56	0.9887	0.3252	
d_USD/JPY	2.38755	11.8084	0.2022	0.8402	
d_Trade_China	0.202563	3.38001	0.05993	0.9523	
d_Trade_Japan	12.4172	11.7186	1.060	0.2918	
d_IIP_China	2.05268	4.73279	0.4337	0.6654	
d_IIP_Japan	5.82174	10.9346	0.5324	0.5956	
d_IRlong_China	-98.1614	201.030	-0.4883	0.6264	
d_IRlong_Japan	255.586	228.948	1.116	0.2669	
d_IRshort_China	-41.3098	56.4702	-0.7315	0.4661	
d_IRshort_Japan	314.631	956.419	0.3290	0.7429	
EC1	-0.0237140	0.0296503	-0.7998	0.4257	

Mean dependent var	6.416949	S.D. dependent var	269.8853
Sum squared resid	7150996	S.E. of regression	264.7788
R-squared	0.160883	Adjusted R-squared	0.037484
rho	-0.010916	Durbin-Watson	2.010854

Equation 2: d_N225

	coefficient	std. error	t-ratio	p-value	
const	-2851.00	3474.32	-0.8206	0.4138	
d_SSEC_1	0.0528553	0.232460	0.2274	0.8206	
d_SSEC_2	0.344143	0.234096	1.470	0.1446	
d_N225_1	0.0578613	0.109240	0.5297	0.5975	
d_N225_2	-0.0861307	0.109108	-0.7894	0.4317	
USD/NCY	-328.266	488.736	-0.6717	0.5033	
USD/JPY	37.9425	16.7707	2.262	0.0258	**
TradeChina	-3.50826	10.3405	-0.3393	0.7351	
TradeJapan	-23.8200	24.1698	-0.9855	0.3267	
IIP_China	4.52137	14.2759	0.3167	0.7521	
IIP_Japan	30.9203	18.0755	1.711	0.0902	*
IRlong_China	-654.974	302.642	-2.164	0.0328	**
IRlong_Japan	1310.24	471.814	2.777	0.0065	***
IRshort_China	-57.5859	86.8372	-0.6631	0.5087	
IRshort_Japan	-1664.20	706.115	-2.357	0.0203	**
EC1	0.255129	0.0921005	2.770	0.0067	***

Equation 2: d_N225

	coefficient	std. error	t-ratio	p-value	
const	513.797	163.632	3.140	0.0022	***
d_SSEC_1	0.422664	0.209459	2.018	0.0462	**
d_SSEC_2	0.393751	0.211800	1.859	0.0659	*
d_N225_1	-0.0247587	0.0900416	-0.2750	0.7839	
d_N225_2	-0.0890846	0.0902017	-0.9876	0.3257	
d_USD/NCY	-2441.51	2296.92	-1.063	0.2903	
d_USD/JPY	75.3184	23.8640	3.156	0.0021	***
d_Trade_China	3.22798	6.83079	0.4726	0.6375	
d_Trade_Japan	-7.14204	23.6826	-0.3016	0.7636	
d_IIP_China	16.0078	9.56468	1.674	0.0973	*
d_IIP_Japan	63.8888	22.0982	2.891	0.0047	***
d_IRlong_China	-366.745	406.269	-0.9027	0.3688	
d_IRlong_Japan	1742.71	462.690	3.766	0.0003	***
d_IRshort_China	-41.5361	114.123	-0.3640	0.7166	
d_IRshort_Japan	-5016.26	1932.86	-2.595	0.0108	**
EC1	-0.175014	0.0599214	-2.921	0.0043	***

Mean dependent var	17.22152	S.D. dependent var	656.4248
Sum squared resid	29206050	S.E. of regression	535.1017
R-squared	0.420682	Adjusted R-squared	0.335488
rho	0.008848	Durbin-Watson	1.969842

Table A.10: IRFs: United States - Euro Area

Responses to a one-standard error shock in GSPC

period	GSPC	STOXX50E
1	33.485	95.577
2	27.280	78.003
3	12.179	37.125
4	3.7992	19.217
5	1.1728	14.215
6	0.15287	11.470
7	-0.48382	9.9277
8	-0.78330	9.3444
9	-0.91008	9.0453
10	-0.98102	8.8643
11	-1.0166	8.7894
12	-1.0310	8.7586

Responses to a one-standard error shock in STOXX50E

period	GSPC	STOXX50E
1	0.0000	68.713
2	3.2401	56.124
3	-3.0393	32.218
4	-4.8712	34.523
5	-3.8912	37.217
6	-3.9592	35.648
7	-4.2471	35.232
8	-4.2295	35.498
9	-4.2098	35.440
10	-4.2341	35.363
11	-4.2397	35.376
12	-4.2369	35.381

Table A.11: IRFs: Euro Area - China

Responses to a one-standard error shock in STOXX50E

period	STOXX50E	SSEC
1	125.43	93.059
2	126.32	79.847
3	97.308	101.64
4	92.965	131.47
5	105.02	160.98
6	110.40	180.34
7	110.15	197.78
8	110.54	214.88
9	112.62	230.84
10	114.55	244.76
11	115.78	257.12
12	116.80	268.35

Responses to a one-standard error shock in SSEC

period	STOXX50E	SSEC
1	0.0000	209.88
2	-2.8918	156.55
3	31.497	176.64
4	25.124	142.93
5	17.271	132.73
6	14.452	120.91
7	15.976	112.61
8	15.546	102.57
9	14.130	93.968
10	13.033	86.404
11	12.468	79.757
12	11.937	73.622

Table A.12: IRFs: China - Japan

Responses to a one-standard error shock in SSEC

period	SSEC	N225
1	234.06	201.87
2	186.91	244.54
3	230.96	305.59
4	210.85	288.26
5	223.04	291.21
6	219.03	284.22
7	223.35	285.57
8	222.76	283.95
9	224.25	284.22
10	224.30	283.61
11	224.87	283.55
12	225.01	283.30

Responses to a one-standard error shock in N225

period	SSEC	N225
1	0.0000	521.10
2	5.7655	445.17
3	24.305	307.05
4	62.122	252.25
5	88.454	233.86
6	108.89	226.88
7	121.93	219.80
8	131.83	214.08
9	138.75	209.42
10	143.96	206.18
11	147.67	203.81
12	150.42	202.13