

The interdependence between stock markets of BRIC and developed countries
and the impact of oil prices on this interdependence.

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The thesis is submitted as partial fulfilment of the requirement
for award of the degree of Doctor of Philosophy of the University of Portsmouth

November 2010

Abstract

In recent years there has been a surge in interest in two branches of research. The first is the analysis of cross-market linkages, arising from portfolio diversification analysis, in order to measure integration between countries. The second larger branch of research is the oil price effect, which has its roots in the effect of oil prices on economic activity. Specifically the impact of oil prices on stock market behaviour which, in turn, is regarded as being representative of economic activity.

This thesis attempts to measure the effect of the oil prices on cross-market linkages between stock markets. The analysis is performed utilising the Cheung and Ng (1996) causality-in-mean/variance test where the effect of the oil price on cross-market linkages is estimated as the percentage change of the magnitude of the CCF coefficient after adjustment for the oil price. Daily data non-synchronisation correction and the application of the rolling window method as a stability test contribute to the reliability of the estimation outcomes.

Recognising the significance of oil prices for the development of the world economy, the research is focused on BRIC and mature market economies providing a mix of countries regarding their economic profile (emerging/developed) and oil-status (net oil imported/self-sufficient/exporter).

A complementary effect of oil prices on cross-market linkages was found for the pairs of countries with similar oil status and economic profile. However, the outcome for mixed pairs does not demonstrate a prominent trend. In general, the effect of the oil price on cross-market linkages is found to be smaller in contemporaneous terms, while higher lag dependencies are described by a higher percentage change in the magnitude of cross-market dependencies.

The research demonstrates that the application of oil price adjustment, whilst exploring cross-market linkages, may be an appropriate technique for determining the level of integration between pairs of countries where the sign of the percentage change is confirmed as stable.

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Declaration

Whilst registered as a candidate for the above degree, I have not been registered for any other research award. The results and conclusions embodied in this thesis are the work of the named candidate and have not been submitted for any other academic award.

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Abbreviations

ADF	Augmented Dikey-Fuller
AIC	Akaike information criterion
APT	Arbitrage Pricing Theory
BR	Brazil
BRIC	Group of countries by first letters Brazil, Russia, India and China
CAPM	Capital Asset Pricing Model
CCF	Cross-Correlation function
CH	China
DE	Developed oil-Exporter
DI	Developed oil-Importer
DS	Developed oil-Self-Sufficient
EE	Emerging oil-Exporter
EI	Emerging oil-Importer
ES	Emerging oil-Self-Sufficient
EU	European Union
FPE	Final Prediction Error
FR	France
GARCH	Generalised Autoregressive Conditional Heteroscedasticity
GE	Germany
GMT	Greenwich Mean Time
HRM	Hypothesis Rejection Frequency
IRF	Impulse Response Function
IN	India
JP	Japan
RU	Russia
SIC	Schwarz Information Criterion
SP	Sign Prevalence
UK	United Kingdom
US	United States
VAR	Vector AutoRegression

Acknowledgments

To my Family and Parents: for their attitude and patience. To my Grandfather: for his inspiration.

To my supervisor: Professor Shabbar Jaffry for his advice and encouragement.

To my teachers: Dr. German Marchenko, Elizaveta Balashova, Foat Akhmetzianov and especially to Ilja, Alexander, Riem, George, Joshua and Raisa.

To my friends: Sasha, Cella, Timur, Ray, James and David Clark.

1. Introduction

The financial liberalisation and deregulation processes of the 1990's, which opened the floodgates to foreign capital, were conducive to the growth of national economies of the developing countries. As a result, this led to the intensification of integration process among the equity markets of various countries. Authors such as, Bekaert and Harvey (2000); de Jong and de Roon (2005) argue that the integration process of equity markets is an important determinant in the behaviour pattern of the expected return of international indices, and highlights the fact that a higher level of integration leads to a decrease in the cost of capital. In the initial stage, as suggested by Levich (1998) and Canela, *et al.* (2006), capital flowed into the developing markets¹, thus providing a redistribution of liquid assets from the developed markets to the emerging ones. Against this background the global economy demonstrated a high and relatively stable period of growth of approximately 3-4% annually², which was mainly brought about by the rapid development of the emerging economies. This was despite periods of high turbulence due to the effect of the Russian debt default and collapse of Long-Term Capital Management in 1998; the "dotcom" crash of 2000; and the aftermath of the September 11, 2001, terrorist attacks ("International Monetary Fund. World Economic Outlook Globalization and Inequality, October 2007," p. 16).

At the same time, the heterogeneity of developing economies, on account of their macroeconomic, territorial and demographic indicators, reveals a number of key growth leaders. Thus, the introduction of the BRIC³ notion is a natural step for singling out the countries, displaying high levels of current growth and good growth prospects for the future⁴. The abbreviation (BRIC) refers to the group of emerging countries: Brazil, Russia, India and China.

¹ Source: ("International Monetary Fund. World Economic Outlook Globalization and Inequality, October 2007," pp. 105,107).

² Ibid, (p.9)

³ BRIC abbreviation is first introduced by O'Neill (2001). An extensive discussion by Wilson and Purushothaman (2003), forecasts projections of the countries' development. The work discusses the intersections of development trend forecasts for G6 (US, Japan, UK, Germany, France and Italy) and BRIC countries. It concludes that "If things go right, in less than 40 years, the BRIC economies together could be larger than the G6 in US dollar terms and by 2025 account for over half the size of the G6. Of the current G6, only the US and Japan may be among the six largest economies in US dollar terms in 2050".

⁴ The article had a strong resonance among financial analysts and academics, evoking both approval and criticism. Differences in the macroeconomic and demographic make up of the BRIC countries results in some uncertainty of the appropriateness of the grouping procedures. Opponents argue against that the inclusion of Russia, due to the fact that Russia's demographical and macroeconomic parameters are different from other BRICs (Macfarlane, 2006). However Russia's physical size and stock of natural resource assets (including energy) suggest that it will also see significant real GDP growth ("International Energy Agency. World Energy Outlook 2006," p. 289) either with or without the impact of growth in other BRIC countries.

Canela, *et al.* (2006) highlight the fact that the BRIC countries raised their collective share of global GDP from 18% in 1990 to 22% in 2000 with a further increase to 27% by 2005 (at purchasing power parity exchange rates). Moreover, the accumulated reserves⁵ strengthen the credit rating of the BRIC economies and, on the whole, enable them to overcome the unevenness of the investment climate and specific peculiarities of a particular country. Low market capitalisation to GDP ratios⁶ are another indirect indicator of the future economic potential of BRIC countries. This suggests that these economies and their equity markets will continue to grow.

Such results offer an incentive to investors and thus attract ever more liquid assets into the leading emerging markets. This, in turn, reinforces the integration processes and improves the magnitude of linkages⁷ between the national markets of other developed countries and emerging markets as a whole (de Jong and de Roon, 2005), as well as the BRIC economies in particular (Bhar and Nikolova, 2009a). The analysis of market interdependency for investors, seeking portfolio diversification or optimal trading strategies⁸, as well as for regulatory institutions, in order to improve stability of the market's development, is deemed to be of growing significance.

Besides this, the rapid development of emerging markets has raised the demand for all commodities as well as for the energy resources. Goldman Sachs argues that significant GDP growth cannot be achieved in BRIC countries without large increases in energy usage because of inefficient⁹ energy usage. It is suggested that this is a natural state of affairs since the industrialising countries need more energy resources¹⁰, whilst, in the developed countries, energy demand in relation to GDP growth tends to decrease (Hooker, 1996; Bernanke, *et al.*, 1997). Overall energy demand in BRIC countries has increased markedly since the year 2000 with China's demand growing at the same speed as GDP growth (compared to one third in the previous two decades)¹¹. The data shows that India and China together accounted for more than half of the estimated global increase in energy

⁵ See Portman (2008) regarding accumulated reserves of BRIC countries.

⁶ Source: ("Standard&Poors. Global Stock Market Factbook 2008," p. 24).

⁷ In studies on stock market linkages authors usually start with papers by Eun and Shim (1989), Koch and Koch (1991) and Malliaris and Urrutia (1992a) for regression and VAR models. The introduction of the GARCH family models opened up opportunities to investigate the second order dependencies (variance spillovers) for a discussion on multifactor univariate GARCH family models see Cheung and Ng (1996), for the multivariate form Koutmos and Booth (1995), Theodossiou and Lee (1993).

⁸ For instance, cross-market feedback trading Pritsker (2001), Kordes and Pritsker (2002) and Pericoli and Sbracia (2003).

⁹ Goldman Sachs points out that Russia and China are the most carbon-intensive economies ("Goldman&Sachs. BRICs AND BEYOND 2007," p. 106). However, relative comparisons with developed countries are not provided in respect to carbon emission/territory size ratio and carbon emission/per capita.

¹⁰ Source: ("Standard&Poors. Global Stock Market Factbook 2008," p. 6).

¹¹ Source: ("International Energy Agency. World Energy Outlook 2007 - China and India insights," p. 54).

use for the period from 2000 to 2006. Chinese and Indian oil demand has increased by 45% and 14% respectively, whilst in Russia and Brazil it has increased by 4% and 1% over the same period. In aggregate¹² BRIC countries' share in of global oil demand rose from 15.9% in 1995 to 18.6% in 2006.

There is a body of evidence to suggest that a rapid surge in demand for crude oil, without a concurrent increase in supply, will lead to rising prices. Oil price, in its turn, has an oppressive effect on the global GDP growth in further periods, which is induced by depressed economic activity¹³ in national economies.

Studies pertaining to the effect of crude oil prices on the equity market, using various tools for the analysis of interaction between the markets, have been underway since the end of the 1980s. The initial publications on the effect of oil prices on the stock markets in the developed countries are attributed to Chen, *et al.* (1986), Hamao (1988), although the most frequently quoted authors are Jones and Kaul (1996), Huang, *et al.* (1996), Sadorsky (1999). Furthermore, due to the growing interest in oil as a commodity, the scope of the crude oil price effect has been expanded¹⁴. Studies of oil price interaction with emerging stock markets started to appear recently (see, for instance, Maghyreh, 2004; Driesprong, *et al.*, 2008; Ramos and Veiga, 2009), especially with respect to the countries with a net oil exporter profile (see, for instance, Anatolyev, 2005; Hayo and Kutan, 2005; Jalilov and Miyakoshi, 2005; Hammoudeh and Choi, 2006; Malik and Hammoudeh, 2007). However, studies on market linkages of the BRIC countries are not so numerous. Moreover, studies on the BRIC countries' interactions with oil prices refer to the BRIC countries separately, the exceptions being the study by Bhar and Nikolova (2009b) and Chang, *et al.* (2009). There is research literature on the sensitivity of the BRIC markets to the oil prices influence for Russia and to some extent China, but hardly any in respect to India and Brazil.

Besides this, there little analyses regarding the oil price effect on the dependencies between stock markets. It is worth noting that efforts to carry out such analysis were undertaken in the studies by

¹² Source: ("Goldman&Sachs. BRICs AND BEYOND 2007," p. 260).

¹³ The depressing effect on economic activity is confirmed mainly for the developed countries in studies for oil price in relation with: GDP growth (e.g. Hamilton, 1983; Rotemberg and Woodford, 1996) and connection to monetary policy (e.g. Dotsey and Reid, 1992b; Hoover and Perez, 1994), inflation (e.g. Clarida, *et al.*, 2000; Hooker, 2002), consumer behaviour (Bernanke, 1983; Pindyck, 1991; Kilian, 2008a), production indices (e.g. Kim and Loungani, 1992; Backus and Crucini, 1998) and unemployment (Leblanc, 2004). Moreover, there is reference to the potential role of the oil price in causing recession, as suggested by Hamilton (1983), who found the oil price precedence of the recession periods in the US, usually accompanied by tightening of the monetary policy (Bernanke, *et al.*, 1997).

¹⁴ Nowadays, it is possible to highlight the established research studies relating the oil price effect on the stocks of particular companies (e.g. Huang, *et al.*, 1996; equity market indices, e.g. Faff and Brailsford, 1999; industry sectors, e.g. Hammoudeh, *et al.*, 2004).

Hayo *et al.* (2005), Anatolyev (2005), Jalolov *et al.* (2005). At the same time, the number of analysed pairs of indices was usually limited to just one or two pairs.

This thesis, attempts to extend the existing empirical evidence of linkages between BRIC and mature market countries both in mean and variance forms. The research is focused on a number of aspects. Firstly, similar to Gebka *et al.* (2007) analysis, it took particular interest in investigating the linkages among the BRIC markets. Secondly, despite the suggestion by Gebka *et al.* (2007) that mature markets' effect on the emerging markets is already extensively examined, there are few studies regarding the BRIC group.

Research objective 1: To examine linkages in mean and variance for BRIC and mature market countries.

For this purposes, the Cheung and Ng (1996) CCF GARCH causality test is applied. The benefit of this test lies in its ability to determine causality in mean and variance. The linkages are observed on a certain lag through the cross-correlation function on pair-wise bases, which gives a powerful instrument when number of series are large and "long lags in causation pattern are expected" (Cheung and Ng, 1996, p. 36). As mentioned above, two groups of countries will be examined, namely: BRIC (Brazil, Russia, India and China) and the countries with mature markets (Japan, Germany, France, the UK and the US), while the oil price is represented by Brent Crude Oil.

The examination of the oil price effect on stock market linkages is mainly neglected in published literature on stock market linkages and oil price effect apart from a few studies such as (Anatolyev, 2005; Hayo and Kutan, 2005; Jalolov and Miyakoshi, 2005). The attempt to organise this investigation on a systematic basis is a preliminary goal of the research, which leads to the following additional research objective:

Research objective 2: To examine the effect of oil price on detected linkages between BRIC and mature markets countries.

Estimations are first performed without the oil price effect and subsequently with the oil price adjustment using the CCF GARCH causality test. Comparing the two results will demonstrate the oil price effect on traced parameters that represents the existence of the linkage between two participating countries. The oil price effect on the linkage can be revealed from the sign of the percentage change of the traced parameters in the oil adjusted and unadjusted cases.

However, heterogeneity of the countries under investigation, in terms of oil status and economic profile, may affect the cross-market linkage response characteristics of the countries pairs.

Therefore, detection of the specific response of each possible type of country pair is part of the analysis performed in this thesis which is organised as a following additional research objective:

Research objective 3: To distinguish a pattern of the oil price influence on linkages with respect to the oil status and economic profile of the participating countries.

The traditional examination of the relationship between the oil price and the stock market behaviour similar to Sadorsky (1999) and Maghyereh (2004) is also tested in order to investigate the response to the oil price fluctuations from the stock market regarding oil status and countries' profile. However, the CCF causality test is not applied for oil price and stock market indices, except in studies where this test is applied for analysing stock market indices (e.g. Hu, *et al.*, 1997; Fujii, 2005) or for crude oil price or its products (Bhar and Hamori, 2002; Hanabusa, 2009). In addition, the testing procedure allows the stock market to be tested in its attempt to cause the oil prices, assuming possible endogeneity of the oil prices¹⁵. This leads to a further research objective thus:

Research objective 4: To examine the oil price and the stock market lead-lag relationships.

All examinations of the cross-market linkages are performed with the correction of the equations for the non-synchronism problem. Apart from the fact that the problem is frequently mentioned in published literature (see, for instance, Eun and Shim, 1989; Furstenberg, *et al.*, 1989), and various treatments and ways of avoidance of the problem are suggested (e.g. King and Wadhwani, 1990; Gjerde and Sættem, 1995; Martens and Poon, 2001), the consequences of ignoring this problem is a lack of clarification. Therefore, the consequences of ignoring daily data non-synchronism, is also investigated as a separate research objective.

Research objective 5: To investigate the consequences of ignoring the non-synchronism problem.

The continuing discussion of the Furstenberg, *et al.* (1989) on the non-synchronism problem and, especially, on the phenomena of the early and late market closing is important. This raises concern regarding the substantial role of the GMT timeline in setting up the gap duration between closing values of international stock markets. The thesis examines the affect of exposure of market pairs to the non-synchronism problem providing gap duration and causality disparity between earlier and later closing markets, when the classic econometric model is applied. Thus, an examination of the

¹⁵ Studies of the oil price effect on stock market behaviour mainly focus on one direction of causality: "oil price -> to stock market". The alternative effect "Stock market -> Oil price" is less frequently found in the literature and it is said that oil price in that structure is assumed to be endogenous. The discussion is mainly given in Kilian's studies (Barsky and Kilian (2001, 2004), Kilian (2006).

causality (spillover) of late closing markets against earlier closing markets condition is represented as an additional research objective.

Research objective 6: To investigate the effect of the later closing market when the condition of the early closing market is applied using the virtual time shift on traditional GMT line.

The discussion on parameter (significance) stability of cross-market linkages is another issue raised in the current research. For this purpose the comparison summary between recursive and rolling techniques is given on the fields of studies on integration and co-integration, where the question of test statistics stability is sharper compared to the other tests and models. The rolling window technique is chosen whilst accepting the imperfections of recursive estimation mainly associated with structural breaks inside the sample (Leybourne, *et al.*, 1998; Awokuse, *et al.*, 2009) and sample size sensitivity when the unit root test is applied as part of co-integration test (Pascual, 2003). In general the application of recursive (e.g. Lucey and Voronkova, 2008) or rolling (e.g. Awokuse, *et al.*, 2009) estimation together with co-integration, when unit root test applied of full sample only, may lead to potential bias associated with the fact that some of the recursive (rolling) sub-samples may have $I(0)$ characteristics instead of expected $I(1)$. This fact may violate the preliminary condition (sample should be integrated at order 1) of standard (Engle and Granger, 1987; Johansen and Juselius, 1990) and more complex co-integration tests that utilise recursive (Gregory and Hansen, 1996) or rolling estimation (Pascual, 2003). The $I(0)$ cases may be treated as anomalies and detection of such anomalies, by the means of time varying unit root test, is performed under an additional research objective.

Research objective 7: To disclose possible anomalies in the unit root of the series when the time varying test is applied.

The normally overlooked drawback of the rolling window technique is the fact that the rolling window size determination does not merit sufficient substantiation on the part of researchers (e.g. poor ground was given for the choice of window size equal to 150 observation in study by the Smith, *et al.*, 1993). For this purpose in this thesis the rolling window technique is applied for different window sizes observing the hypothesis rejection frequency parameter (HRF) following the approach taken by Swanson (1998). Therefore, the existence of the unit root anomalies are indicated by percent of total number of rolling sub-samples where the hypothesis of non-stationarity was rejected confirming $I(0)$ nature of the sub-sample.

By applying HRF together with non-causality hypothesis in a Granger (1969) sense and Sign Prevalence (SP) for examination of the sign stability (Goriaev and Zabotkin, 2006) of the percentage

change between oil unadjusted and adjusted cases, it is possible to examine parameter (significance) stability of applied models with further comparison with the results of the full sample estimation. Such a comparison may indicate potential instability and delusiveness of the full sample estimation and this issue is discussed as a part of the separate research objective.

Research objective 8: To investigate the potential problems that may occur when parameter (significance) stability is ignored.

The above research objectives suggest the following structure for the thesis:

Section 1 provides a brief introduction into the problem and identifies the main research objectives. Section 2 discusses market linkages, including a summary of the linkages of the BRIC countries. Section 3 reviews the crucial role of the oil price and the observed effect on macroeconomic activity and stock market indicators. Section 4 is devoted to the additional research question: the daily data non-synchronism problem and significance stability testing, which is observed in the case of the unit-root and co-integration tests. Section 5 gives a discussion on methods applied in the study with an attendant adjustment, represented by non-synchronisation correction and rolling technique. Section 6 provides a discussion of the data set. Section 7 presents the results from the research, while Sections 8 and 9 provide Discussion and Conclusion respectively.

2. Stock market integration of international stock markets and BRIC countries

Chapter 2 provides the review on cross-market linkages literature embracing both theoretical aspects for the analysis and summary of empirical findings.

As an introductory section to the literature review, attention focused on most frequently used terminology and the typical methods for scrutinising the market linkages. Therefore, Section 2.1 examines the established notions when analysing the cross-market linkages as an indicator of cross-market integration.

Further discussion is devoted to general trends regarding stock market integration, which are based on findings of stock market linkages studies, as well as factors that may affect stock market linkages. Section 2.2 provides a summary of findings of mature and emerging markets specificity and aspects that authors focused on while analysing stock market linkages.

By establishing features of the mature and emerging markets and factors that may affect stock market linkages, the thesis further identifies a summary of cross-market linkages of the BRIC countries with respect to the country's specificity. The summary of the cross-market linkage findings of the BRIC countries is given in the Section 2.3.

Section 2.4 finalizes the chapter of stock market linkages by identifying the rationale for the first research objective and highlighting the key aspects that should be taken into account in the examination of the stock market linkages. These aspects are then employed in the research contained within this thesis.

By establishing the schedule of Chapter 2, it is possible to proceed to the discussion in detailed form.

2.1. Analysis of stock market linkages as a determination of the degree of stock market integration.

In the research literature on the subject, there exists an established opinion that the integration of financial markets is carried out through the unification¹⁶ of strategies and methods used by economic agents when making decisions relating to purchasing or selling, as well as choosing the trading strategy on market. Rational incentives of profit maximisation predetermined the behaviour patterns of market agents striving to minimise their portfolio risks and search for assets with stable growth perspectives.

It is the market agents, guided by the main postulates of asset diversification (Markowitz, 1952; Sharpe, 1964; Lintner, 1965), as well as the knowledge of fundamental factors and the sum total of relevant news, which is the driving force that organises the inner market interrelationships between separate classes of assets and external interrelationships with other markets.

Cappiello, *et al.* (2006), among other things, emphasize, that: *“portfolio diversification is achieved using two main strategies: investing in different classes of assets thought to have little or negative correlation or investing in similar classes of assets in multiple markets through international diversification”*. Thus, correct evaluation of interactions between markets and the use of the information for decision-making, gain even more importance. Goodhart (1988, p. 85) stated that: *“exchange practitioners will tend to look, perhaps especially in setting initial prices at the opening in the morning, at what assessments have already been made in stock exchanges abroad. This tendency will, no doubt, be most marked when the “news” either arrives initially in, or is most easily interpreted by, the other stock exchange”*. Regarding the rising importance of the information transmitted from the other markets, Engle, *et al.* (1990, p. 526) suggested investigating a specific domestic autocorrelation (heat wave) or information transmitted from financial markets of other regions (meteor shower) as an econometric hypothesis. Koutmos *et al.* (1995, p. 747) emphasis that buy and sell decisions, which are made not only on information produced by domestic markets but also by other financial markets, confirms the Efficient Market Hypothesis (EMH). This means that the dynamics of other markets is part of the available information, which can be used in the decision making process of market agents. At the same time, as suggested by Shawky, *et al.* (1997, p. 319), the idea that the existence of a time stable lead-lag effect between two markets seems to contradict Koutmos’s *et al.* (1995) suggestion, since, investors will use information provided on the leading market to forecast and invest in a lagging market. Which, in its turn, will suggest that investors could

¹⁶ Rational behaviour organised by the rule of portfolio diversification or other rules as well as the natural incentives to make a profit (e.g. strategy feedback trading discussed by Pritsker, 2001; Kodres and Pritsker, 2002).

predict the behaviour of a market and could gain abnormal profit, and this fact, by itself, refutes the efficiency of the market in the sense of Fama's (1970) concept.

The use of information from other stock markets for devising the market strategy and decision making is quite normal for market agents, which, in its turn, is conducive to improved interaction between the markets. This interaction is normally characterized by authors of research studies as proof of the on-going evolution and reinforcement of integration processes between the markets.

On the whole, the process of market integration is subdivided into the following states: segmented market, integrated market, partially segmented¹⁷ (see Bekaert and Harvey, 1995, p. 404). First and foremost, this information may be directly beneficial for market players themselves, for example, when searching for assets with negative or low correlation (Cappiello, *et al.*, 2006). The policy makers may benefit from understanding the consequences and specific characteristics of integrated and segmented national markets, as well as transitions between them (Masih and Masih, 1997a).

There is a growing body of evidence which uses the existence of various aforementioned interrelations as confirmation of further development of integration processes between the markets and assets within one market. However, the behaviour of market agents is not the only factor relating to the integration processes. Authors are inclined to single out a number of other prerequisites which promote the integration of financial markets and which are frequently mentioned in related literature as intrinsically fundamental; these prerequisites may include the following: liberalisation process¹⁸; decrease in cost of transaction (Hassan and Naka, 1996, p. 390); buy and sell decisions started to be instantaneous (Shawky, *et al.*, 1997, p. 309); improvements in market information spread, information availability and accessibility (Friedman and Shachmurove, 1997, p. 527).

At the same time, the literature on market linkages has produced different kinds of definitions that contribute to the ambiguity and unnecessary entanglement, so much so that, studying the same type of data and often using the same type of model, one might get the impression that the researchers use different notions as a subject of their study. Regarding the definitions and terminology relating to market linkages, Antell (2004) singles out the following: "interdependence",

¹⁷ See Bekaert *et al.* (1995, p. 404) for the summary of the studies regarding integration with respect to each category.

¹⁸ See Bekaert, *et al.* (2003) for the investigation of the effect of the liberalisation. The official date of the liberalisation Bekaert, *et al.* (2003, p. 276) defined as "*the date of formal regulatory change after which foreign investors officially have the opportunity to invest in domestic equity securities and domestic investors have the right to transact in foreign equity securities abroad*". Official liberalisation date for Brazil is May 1991, for Russia January 1994, for India is February 1992, for China is July 1993 (Bekaert, *et al.*, 2003; Bhar and Nikolova, 2009a).

“co-movement”, “contagion”¹⁹, “transmission”²⁰, “spillover”. Antell (2004) emphasizes that some of the terms and definitions are more restrictive than the others. Essentially, all the previous mentioned definitions serve one purpose: to establish the factual existence of the integration process. At the same time, they can be combined into a more general notion. Bracker, *et al.* (1999, p. 2) state, among other things, that international stock market integration is represented by a broad area of studies that involves different aspects of interactions among markets, emphasized the notion of a *lead-lag* relationship.

If a lead-lag relationship exists, Bracker, *et al.* (1999) suggested interpreting it as a presence of integration between two markets. And it is true, since various forms of econometric models have a variable structure, which can be treated as a lead-lag relationship directly or indirectly. In this regard, the lead-lag effect hypothesis testing is implicitly incorporated in the significance testing²¹ of the single parameter of the model or could be performed in a joint test using the Granger Causality framework (Granger, 1969).

Thus, a process of integration between markets presupposes a thorough study, determining and measurement of market integrations. The practical aspect of such interactions involves the defining of a group of market indicators (such as stock price, market index, etc.) over a certain period of time, with their subsequent modelling in pair wise or multivariate form and a possible addition of supplementary exogenous variables, which might have an effect on linkages between markets.

Most of the studies²² can be assigned to groups regarding the investigation of conditional first moment return spillovers and conditional second moment representing volatility spillovers. Early studies are mainly applied correlation and regression analysis; they include research papers by Grubel (1968), Agmon (1972), Grubel *et al.* (1971), Lessard (1973, 1974, 1976), Levy *et al.* (1970),

¹⁹ According to the World Bank the contagion can be distinguished to the following definitions. In a broad sense “*Contagion is the cross-country transmission of shocks or the general cross-country spillover effects*”. In the restrictive definition “*Contagion is the transmission of shocks to other countries or the cross-country correlation, beyond any fundamental link among the countries and beyond common shocks.*” The most restrictive definition given by the World Bank states that “*Contagion occurs when cross-country correlations increase during “crisis times” relative to correlations during “tranquil times”*” (Source: World Bank. Definitions of contagion.). See also Pericoli and Sbracia (2003).

²⁰ Milunovich (2006, pp. 145,147) provides his own definitions for these interactions: “information transmission through lagged return” and “lagged information transmission in volatility”, thus emphasizing the precedence of information exchange between markets.

²¹ Significance testing of the single parameter in equation (e.g. *t*-statistics, *z*-statistics) could be treated as a testing for the lead-lag effect, since it assumes the hypothesis that estimated parameter is equal to zero.

²² The discussion is restricted to models that are widely used in the literature of cross-market linkages. Those models also represent a majority of the techniques, which are used in the analysis of cross-market linkages observed in the literature review.

Ripley (1973), Panton, *et al.* (1976), Solnik (1974). The results were consistent with the notion that investment in the asset outside the domestic market is likely to provide greater opportunity of risk reduction. Granger *et al.* (1970) and Hilliard (1979) suggested that linkages between markets are likely to be stronger during times of crisis.

More recent studies that shaped the general structure of the interdependence studies usually involve examination of the dynamic linkages across national markets using VAR²³ and regression accompanied with the Granger Causality (Granger, 1969). The given dynamic models are usually concentrated on the transmission mechanism stock price innovation represented by mean spillovers (return spillovers).

Notable studies that focus on market linkages are by Eun and Shim (1989), Furstenberg, *et al.* (1989), King and Wadhvani (1990), Koch and Koch (1991), Malliaris and Urrutia (1992a), Smith, *et al.* (1993), Brocato (1994), Gjerde and Sættem (1995), Mann, *et al.* (1995), Friedman and Shachmurove (1997).

These studies of market linkages are used to investigate²⁴ short run dynamics of the linkages. Meanwhile, the introduction of co-integration methods by Engle and Granger (1987) and Johansen and Juselius (1990) opens the opportunity for investigation of the long run relationship. This is applied in a studies by Kasa (1992), Chung and Liu (1994), Kwan, *et al.* (1995), Chaudhuri (1997). Application of the co-integration gave rise to further examination of the market co-movements, both in the short and long run utilising VECM model, which is applied in the studies by Arshnapalli and Doukas (1993), Masih and Masih (1997a, 1997b; 2001), Ratanapakorna and Sharma (2002).

Volatility (variance) spillover models are mainly observed together with the mean spillover in GARCH family models (see Bollerslev, 1986)²⁵. However, volatility modelling may be performed using

²³ Vector Autoregression (VAR) proposed by Sims (1980).

²⁴ Investigation of the market linkages is performed through the framework of econometric modelling, by applying two or more market indicators “one against the other” in the econometric model. Implementation may be performed assuming first order dependence (dependences in mean) represented in short run dynamics (e.g. for VAR modelling Eun and Shim, 1989; e.g. block recursive simultaneous equation Koch and Koch, 1991; e.g. in regression form Malliaris and Urrutia, 1992a) or long run dynamics (e.g. Kasa, 1992; Chung and Liu, 1994), as well as studies that examine second order dependencies (dependences in variance) on model which provides mixture of first and second order dependencies (e.g. Theodossiou and Lee, 1993). Discussion on first and second order dependencies can be found in Koutmos and Booth (1995).

Detecting of the market linkages both in first and second order dependencies is performed by finding significant coefficient estimate in the outcome of the equation, where one of the indicator (explanatory variable) when it tries to determine behaviour of the other indicator (explained variable). Value of the estimate demonstrates the magnitude of the linkage, while relative comparison of values of significant estimates detects the dominant market among observed.

²⁵ See also studies by Hamao, *et al.* (1990), Theodossiou and Lee (1993), Lin, *et al.* (1994), Longin and Solnik (1995).

methods of mean modelling, when standardized errors derived from return are applied in correlation, regression or VAR models, a good example of such models is Cheung and Ng (1996) CCF GARCH test based on Granger causality in mean (Granger, 1969), where the same method of testing is applied for the first and second moment of dependencies. The ease of implementation and possibility of non-synchronism correction makes this model a powerful instrument in examining dependencies between series.

2.2. Findings on international markets' cross-market linkages and integration

The theory of portfolio investment initiated the research in the field of markets interdependence. Evans *et al.* (1968) demonstrated the possibility for investors to reduce risk in the portfolio by rising the total number of stocks. The opportunity of risk reduction is performed through the diversification of the assets which are less than perfectly positively correlated. The search for such assets was performed in the US market usually on an intra-market level, with further investigation of cross-market opportunities on an international basis. Authors are agreed that the findings of the studies vary according to the model, variable specification, data frequency and sample period (depends on model and sample period Chen, *et al.*, 2002, p. 1114; Melle, 2003, p. 4; Miyakoshi, 2003, p. 392; Caples, *et al.*, 2006, p. 86; Rahman and Khan, 2009, p. 2), but overall, confirm the existence of the linkages.

The group of markets that were examined at the beginning were the markets of the US and also EU countries. The early literature of stock market interdependence mainly confirmed the interdependence of mature markets.

Agmon (1972) demonstrated the existence of the dependence between US, Japan and European markets using a regression model. He found that the US mainly led other markets within one period (lag 1). Bertoneche (1979), by applying spectral analysis over the time period 1969-1976, demonstrated the existence of the lead-lag relationships on the weekly returns of six European Union countries but relationships with the US are found to be insignificant. The findings by Hilliard (1979) are in line with Bertoneche (1979), confirming that contemporaneous relationships of the European markets have higher dependencies, compared to their dependencies with the US.

Further discussion is consistent with earlier findings and conforms to a general finding of US market dominance, which can be traced on the findings of authors listed below. A study by Eun and Shim (1989) applied the VAR model in order to investigate dependencies across the group of developed markets, documenting the existence of interdependence across them with a crucial role of the US stock market. Koch and Koch (1991), by utilising a dynamic simultaneous equations model, allowing contemporaneous structure of dependencies, confirmed the existence of the innovation transmission from the US to other world markets, while other market effects on the US market were found to be low. Cheung and Mak (1992) investigated the causal relationship to 8 countries from the Asia-Pacific region, represented by the stock market indices of the US and Japan for the period January 1977 to June 1988. The leading role of US was confirmed with the Japanese stock market seeming to play a less important role compared to the US. Brocato (1994) used the VAR variance

decomposition technique to observe 6 major countries' stock markets over the period 1980-1987. The dominance of the US stock market was again confirmed, but was found to be declining during the given period. Some of the findings for other major countries include: 1) Great Britain plays a smaller role in the US market; 2) Germany absorbed most of the linkage strength lost by US; 3) Japan, Germany and Hong Kong have absorbed the strength lost by UK for the period under investigation; 4) the US-Japan connection strengthened over the period. Shawky, *et al.* (1997) analysed 10 major European countries and the US for the period from January 1993 to December 1995. The research confirmed the existence of lead-lag relationships among the stock markets, but found the relation is unstable over time. The UK was found to be the most influential market in a given sample; it caused²⁶ the markets of Austria, Belgium Denmark, Norway and Spain. Surprisingly, the US caused only Belgium and the Netherlands. The paper points out that international diversification may even be stronger when emerging equity markets are used for portfolio diversification. Bracker, *et al.* (1999), applying the daily data of 9 national stock indices into the Geweke (1978, 1981, 1982) technique for 22 annual samples (from 1972 to 1993), found that the US displays a significant lagged impact on the UK market in most of the sample. Switzerland and Japan are the next lagged markets after UK. The influence of other countries on the US was detected in 11 out of 176 numbers of annual samples. The authors drew the conclusion that the US is more likely to lead other markets than vice versa. Balios and Xanthakis (2003) performed the bi-variate Granger Causality test for the UK, Germany, France, Spain, Italy, the US and Japan on daily data for the period 2 January 1995 to 31 August 2001. The US and UK are the most significant influence among other examined indices. Germany caused Japan and France; Japan caused by US and Spain; France caused all other indices except Spain.

Despite the traditional interest in mature markets for portfolio diversification strategy, the emerging markets, in the last 15 years, have experienced rising interest from the investors and academics. There are specific characteristics which are usually ascribed to emerging markets:

Firstly, emerging markets' returns are historically characterised by high average return, large volatility (Bekaert and Harvey, 1995; Levich, 1998, p. 209) and substantial deviation from normality (Bekaert, *et al.*, 1998). Secondly, it is important to underline that interest is explained by the low correlation of the emerging markets with developed ones, which provides a great opportunity for the portfolio diversification (Bekaert and Harvey, 1995; Bekaert, *et al.*, 2003). Thirdly, the strategies

²⁶ "Caused" here and further in the thesis is a short form of collocation "Granger Cause" or "caused in a Granger sense" which is the outcome of the Granger (1969) non-causality hypothesis. It is also used for describing Cheung and Ng (1996) causality test as a special case of Granger (1969) non-causality hypothesis observed both in mean (causality-in-mean) and variance (causality-in-variance).

that include a mix of developed and emerging markets consistently outperform strategies that include developed market only (Harvey, 1994). Fourth, the predictability characteristics of emerging markets are greater compared to mature markets and local factors plays a more important role compared to global factors (Bekaert and Harvey, 1995; Carrieri and Majerbi, 2006; Bhar and Nikolova, 2009a). Fifth, the liberalisation process reduces the volatility of emerging markets (Bekaert and Harvey, 1997; Nguyen and Bellalah, 2008). Sixth, the causality pattern between emerging markets does not appear to be strong (Levich, 1998, p. 223; Gebka and Serwa, 2007; Hashmi and Tay, 2007). Seventh, some evidence is found in favour emerging markets as a local and global leader (Levich, 1998, p. 233; Gebka and Serwa, 2007).

Despite the difference between mature and emerging markets there are a number of issues that affect dependencies among markets.

Firstly, the discussion on both mature and emerging markets linkages can be also considered from the intraregional and interregional perspective. Studies mainly confirm that intraregional dependencies are likely to be stronger in magnitude and more significant, compared to interregional. The possible explanations are the similarities of the economies and industrial structure, international trade as well as trading with the neighbours, regional proximity to other economies and the time zone factor. Lessard (1974) pointed out the crucial role of the industrial structure in explaining international stock market correlation. Gultekin, *et al.* (1989) suggested that policy coordination, trade and capital flows are the main factors that contributed to the industrial and economic similarities and led to higher interdependence between markets. Roll (1992) suggested that the sectoral compound of the index is a potential source of cross-market interdependence that induces markets to move synchronically. However, the studies by Furstenberg, *et al.* (1989, p. 164) and Heston and Rouwenhorst (1994) pointed out that national factors play a dominant role in explaining market correlation between equity markets, while the role of the industrial structure is substantially less. The controversy may be explained by the differences in models and dataset. Bessler and Yang (2003, p. 276) analysed a set of the 8 developed markets and found evidence that the intraregional dependencies tend to be stronger than interregional. In contemporaneous correlation structure the study confirmed the passive role of the Japan, which was found to be consistent with the study by Malliaris and Urrutia (1992a).

Secondly, macroeconomic similarities and regional trade are another potential source of market co-movements, especially during a period of common shocks. That source of the co-movements is intensively researched as a part of the contagion studies. Findings by Eichengreen, *et al.* (1996) suggest that contagion is more easily spread between countries which are closely tied with

international trade than with macroeconomic similarities. Claessens, *et al.* (2001) suggested that revelation of the weak macroeconomic environment after the shock will induce rational investors to think that similar countries will face similar problems and the adaptation by the investors to the new macroeconomic conditions will possibly lead to the contagion. This finding is also supported by Glick and Rose (1999), who demonstrated that the spread of a currency crisis is due to the trade links factor, while the macroeconomic similarities do not help in explaining cross-country contagions. Caramazza, *et al.* (2000) found that countries which have a low sensitivity to trade and financial linkages do not express additional exchange rate vulnerability. Hernández and Valdés (2001) analysed the impact of direct trade, neighbourhood effects and financial competition in banking centres on contagion of the bond and stock market during the Asian, Russian and Brazilian crisis. The authors found that trade was found to be important in explaining contagion on stock market returns during the Asian and Brazilian crisis. Therefore, significant foreign trade and investments constitutes the environment that creates the conditions for the shocks transmissions among financial markets (Kaminsky and Reinhart, 2000; Claessens, *et al.*, 2001; Canela, *et al.*, 2006). This puts the foreign trade as one of the fundamental factors that increases dependencies among the countries.

Thirdly, the effect is often burdened by the application of cross-market feedback trading²⁷. Pritsker (2001, p. 81) and Kordes and Pritsker (2002, p. 779) emphasised that the use of a cross-market feedback trading strategy may provide a potential channel for the contagion. The first possible implication of cross-market feedback trading to contagion is the fact that investors may rebalance their portfolio across markets based on the price trend of one particular market, where the new trend or shock originated, regardless of expectations of market fundamentals. The second driver for possible contagion is the case when investors try to readjust their hedges with respect to the macroeconomic risks. Pritsker (2001, p. 81) stated that: *“cross-market hedging can transmit shocks between two countries whose macroeconomies share no macroeconomic risk factors in common provided, that both countries share risk factors with a third country”*. The third driver is the “wealth” shock, which occurs when investor may optimally choose to move their portfolios toward less risky assets as their wealth declines. This channel of contagion is given as a less strict form of liquidity shock, where the investor in wealth shock chooses to liquidate, instead of to be forced to liquidate in case of liquidity shock. Feedback trading in one market may also be a potential originator of co-

²⁷ Investors may use cross-market feedback trading to provide dynamic hedging. Pritsker (2001) gives an example: *“..... if firms that are derivatives dealers have written options whose value depends on the value of securities in more than one market, then their hedging strategy will involve cross-market feedback trading”*.

movement with other markets. This means that investors follow a positive feedback strategy²⁸, which may provide excess volatility for the given market (Nofsinger and Sias, 1999; Pritsker, 2001).

Fourth, the time zone factor is another issue that may facilitate markets' co-movements. The factor is difficult to distinguish from the effect of regional proximity, since countries located in the same region are likely to have overlaps of markets' trading time. Similar trading time means that markets acquire the daily innovations at approximately the same time or simultaneously; this suggests a greater synchronicity in co-movement of the markets. Markets without overlaps in trading time are exposed to the so-called non-synchronism (asynchronism) problem. The problem has a long tradition of discussion in the literature on interdependence. The ignoring of a non-synchronism problem may lead to an underestimation of the linkages among the markets²⁹ (see, for instance, Gjerde and Sættem, 1995).

The application of the non-synchronism correction technique allowed the distinguishing of simultaneous and lagged effects while analysing cross-market linkages (Gjerde and Sættem, 1995; Bessler and Yang, 2003). Contemporaneous relationships (lag 0) are likely to be higher in magnitude and more frequently significant compared to the lag 1 (Wang and Firth, 2004; Singh, *et al.*, 2010).

2.3. Findings on BRIC countries' cross-market linkages

This section represents a summary of the findings on each of the BRIC countries found during the research for this thesis. Whilst this is not exhaustive, it represents to the best available given limitations of time, access and language.

It is important to note that empirical literature on stock market integration is abundant and results vary according to models, variable specification, participating countries and sample period. In this regard, generalisation is made complex. The second problem is that some studies which analyse a group of countries provide only general conclusions or overall trends rather than results for each country. For these studies information relevant to participating BRIC countries, in terms of market linkage analysis, has been extracted. Therefore, this section represents an attempt to accumulate the evidence of BRICs stock market linkages in order to construct an overall picture of the country's cross-market linkages.

²⁸ Positive feedback trading strategy assumes buying when the price rises, and selling after price started to decline. This strategy tends to push the price in the same direction, while the negative feedback trading assumes selling after the price rise, or buying after its fall (Pritsker, 2001).

²⁹ Non-synchronism problem is discussed in Section 4.1. The possible treatment of the problem is summarised in Section 5.1 together with equation correction technique used in this thesis.

The examination of the findings is performed in order to shed light on the dynamics of the process of the integration of the BRIC countries. By investigation of the dynamics of the process of integration it is important to reveal the direction of the integration, in other words, whether the markets are becoming more or less integrated in the observed periods.

Another important point is whether the BRIC countries exhibit higher integration with the countries in regional proximity. Studies which examine this are usually performed in an examination of the actual comparison of the BRIC countries with other countries from their region, as well as studies that are devoted to the relationship of the BRIC countries with the regional and world indices. The issue that may be treated as a part of this question is linkages of the BRIC countries with mature and emerging markets.

Finally the integration can also be observed with respect to the first and second order dependencies, regarding the division used in Koutmos and Booth (1995).

Grouping the findings is achieved by taking into account specific characteristics and crucial time periods where the models are expected to have different regimes. This was organised along with the Table of the summary of findings regarding each of the BRIC countries (Table 2.3-1, page 24).

This table represents a summary of stock market linkages of BRIC countries. Each article is presented as a general set of classifications: author(s), data, sample period, method or model and findings. The later gives a short synopsis which provides a portrait of the participating country in terms of “Intra/Inter -regional linkages”, dependencies from the US (“US influence”), evidence of the cross-market linkages among BRIC countries (“BRIC linkages”), evidence that describes the country as a regional leader (“Regional leader”) and evidence of the trend of rising integration of the country with economy and countries in particular (“Rising integration”).

Application of such summary helps to demonstrate the position of the country in a global economy and involvement of its stock markets in the global trends.

Having established the form of representation of cross-market linkages it is now possible to continue the discussion in the detailed form.

Brazil

Table 2.3-1 gives a discussion of the findings on cross-market linkages of the Brazilian stock market with the international markets. Similar to the tendency of the rising integration of the world markets (Bracker, *et al.*, 1999, p. 2) the Brazilian stock market is also found to be more integrated in recent years than in the past. This can be traced to studies by Yang, *et al.* (2004), Fujii (2005), Rivas, *et al.*

(2006), Khalid and Rajaguru (2007), Aktan, *et al.* (2009), Rivas, *et al.* (2008). However, a lack of relationship is found in the studies that utilise co-integrating techniques, (e.g. Tabak and Lima, 2002; Ozdemir, *et al.*, 2009), and for the study by Chen, *et al.* (2002), where it is confirmed during the Asian crisis time only.

Moreover, some evidence is found regarding the position of Brazil as a regional leader, which is emphasized in the studies by Chaudhuri (1997), Nguyen and Bellalah (2008), Gebka and Serwa (2007), Bhar and Nikolova (2009a) by confirming the existence of cross-market dependencies of Brazil with Latin American countries.

Nevertheless, as suggested by Gebka and Serwa (2007, p. 205), emerging markets are likely to have higher interactions with the nearest developed markets, due to strong economic ties through international trade and substantial fund flow. Moreover, the Brazilian stock market has trading time overlaps both with the US and the EU markets, which allows it to absorb all the day innovations of the given markets. Such dependencies are confirmed in the studies by Pagan and Soydemir (2000), Fernandez-Serrano and Sosvilla-Rivero (2003), Johnson and Soenen (2003), Ozdemir, *et al.* (2009) for the US, with some dependencies detected between Brazil and developed markets of the EU (Rivas, *et al.*, 2006). Some effects in developed markets are also confirmed in volatility spillover (Diamandis, 2008; Weber, 2008), as well as the study by Verma and Ozuna (2008), where volatility spillover is confirmed with the neighbouring countries or both cases (Bhar and Nikolova, 2009a).

Russia

The critical date of the Russian crisis imposes specific characteristics of analysis and the pattern of research, where the linkages are firstly observed, in a pre-crisis, crisis (optionally) and post crisis period. At the same time, there is research where Russian linkages with other markets are analysed on an overall bases.

Russian sections of Table 2.3-1 is devoted to a review of the main findings in literature regarding Russian equity indices linkages. It is possible to summarise some conclusive remarks. First, the early article regarding the stock market linkages of Russia and other countries in the period before the Russian Crisis shows a lack of conformity. This can be partly explained by the use of different indices to present the equity market and different data frequencies (e.g. weekly and daily frequencies Linne, 1998; Pesonen, 1999) and different methods of analysis.

Second, the integration level during turbulent periods is more pronounced³⁰, compared to tranquil periods. Thus, with rare exceptions, most authors confirm the existence of linkages, emphasising their increase during a crisis period (excluding Jochum, *et al.*, 1999). In addition, the authors provided evidence that the events occurring in Russia during the time of the crisis were the main source of shock for the other equity indices around the world (Gelos and Sahay, 2000; Alper and Yilmaz, 2004; Khalid and Rajaguru, 2007; Saleem, 2009).

Finally, the analysis of the post-crisis period is likely to confirm the tendency of integration of the Russian market with other equity markets and dynamics of global and regional indices.

India

India's linkages are also observed in the separate sub-samples in order to investigate changes in magnitude of the cross-market linkages in dynamics or to distinguish the effect of the Asian crisis on Indian stock market. However, there is the possibility of grouping according to the type of econometric model, with a split of the linkages according emerging/developed profile of the participating countries. Indian's stock market linkages with international stock markets are observed in India's section of the Table 2.3-1.

Summarising the empirical literature on India's interactions with other markets it is possible to conclude that, with rare exceptions, research studies analysing the post Asian crisis period found the evidence of stock market co-movements of the returns mostly with mature markets (Bhar and Nikolova, 2009a), while volatility transmissions are mainly found between India and other emerging equity markets, excluding the case of Wang, *et al.* (2005a) and Aktan, *et al.* (2009), where the US volatility spillover effect to India is tested at lag 0. Strong relationships of India with other countries from the region confirms that it is in the position of a strong regional player, with strong ties to other countries in the region (Bhaduri and Samuel, 2009; Guidi, 2010), which also may be observed in the high dependence on regional indices (Bhar and Nikolova, 2009a). More recent articles examine the effect of emerging markets on mature markets, and at least two of them (Mukherjee and Mishra, 2010; Singh, *et al.*, 2010) found evidence of the existence of such spillovers.

The authors, in most cases, tend to explain increased interdependence by the rising integration among countries and financial markets, the consequences of the liberalisation process performed in the early nineties and the consequences of the Asian crisis of 1997. This sheds light on the tendency

³⁰ Note that rising magnitude of correlation as an indicator of rising integration may be explained by the rising heteroscedasticity during crisis time (Forbes and Rigobon, 2002), which overestimates the degree of dependencies among stock markets and may cloud the real relationship between stock market indices.

to treat the world financial market system as becoming less fragmented, where each market becomes more synchronised with the others.

China

The analysis of the Chinese market threw up additional groups of articles. The first group involves analysis of the linkages between special classes of shares³¹ and second group examines various forms of cross-market relationships of Greater China³² stock markets. Being research on cross-market relationships, these groups of studies are omitted from the literature review, since the thesis is focused on cross-market linkages of BRIC countries, observed on an international basis. The summary of Chinese stock market linkages with international markets are shown in China's section of Table 2.3-1 and it is split into studies on first and second order dependencies.

The majority of studies on cross-market linkages analysis that includes China confirm the lack of interactions of China with other markets, which one can call China holding a solitary or detached position in the Global Economy. This could be traced to the confirmed lack of the co-integration relationships (Huang, *et al.*, 2000; Bahng and Shin, 2003; Ozdemir, *et al.*, 2009; Samaratunga, 2009), on regression and VAR models (Huang, *et al.*, 2000; Bahng and Shin, 2003; Baur and Fry, 2009; Wang and Lee, 2009), despite a few authors finding some causal interactions (Aktan, *et al.*, 2009), which are likely to be detected in contemporaneous terms (Wang and Firth, 2004; Singh, *et al.*, 2010).

The lack of volatility spillovers between China and developed countries is found in a study by Chen, *et al.* (2006), while the same study confirmed the existence of return and volatility slipovers with neighbouring India. This could be also attributed to the stronger role of the regional factor, despite the lesser role of world factors, which may partly be ascribed to lesser interdependencies with developed markets. The studies by Beirne, *et al.* (2010), Bhar and Nikolova (2009a) confirmed the significance of the regional factor variables in the equations. However, the trend of rising integration is found in studies that investigate the effect of sub-prime crisis on the cross-market linkages of China (Cheung, *et al.*, 2010; Johansson, 2010; Yoshida, 2010).

³¹ The description on Chinese market could be found in the study by Lane and Schmukler (2007). The Chinese market is different compared to the other countries' stock market. The organisation of different types of share (e.g. A,B,H) makes authors to look at the Chinese market from a different angle. Therefore, there is a special branch of studies that is devoted to the cross-linkages between different types of shares on one market and different types of shares on cross-market bases. The empirical studies regarding linkages with a different shares type can be found in the following papers: Poon and Fung (2000); Yang (2003); Chiang and Tan (2005); Wang and Di Iorio (2007); Shen, *et al.* (2007); Qiao, *et al.* (2008).

³² This type of analysis assumes measurement of the cross-market linkages among China, Hong Kong, Taiwan. The following papers give the empirical investigation of such dependencies: Zhu, *et al.* (2004); Groenewold, *et al.* (2004); Hatemi-J and Roca (2004); Zhang, *et al.* (2009); Johansson and Ljungwall (2009).

Overall, these findings may suggest less integration by the Chinese equity market into the world financial system, or China may be treated as a self-oriented country, where internal trends³³ predetermine its current phase of development.

³³ This can partly be confirmed by the co-integration between markets inside China (Huang, *et al.*, 2000; Wang, *et al.*, 2005b).

Table 2.3-1
Findings on cross-market linkages of BRIC countries.

Author(s)	Data	Period	Method	Brazil	Russia	India	China
Relationships in mean							
Harvey (1994)	21 developed and 20 emerging countries (including Brazil)	from 1976 to 1992, monthly	Unconditional correlation CAPM model	Brazil like other emerging countries was characterized by a low correlation with developed and other emerging countries, with a slight rise with respect to the geographical proximity and same time zone factor. (Intra-regional linkage)			
Chaudhuri (1997)	6 Latin American countries (including Brazil)	from 1985 to 1993, monthly	Engle and Granger (1987) co-integration test	Brazil is found to be co-integrated, and significant bi-directional causalities are found with all other participating markets. (Intra-regional linkages)			
Pagán and Soydemir (2000)	Latin American countries (including Brazil)	from December 1988 to September 1994, weekly	VAR model	The results demonstrated the existence of stronger linkages among Brazil, Argentina and Chile than compared to Mexico. Impulse response to the US shock is found to be significant only for the first, ninth and tenth weeks. Overall, besides the confirmed heterogeneity in magnitude of the response to the US shock of the participating emerging markets, the authors found that it is more pronounced compared to the other of developed markets in a study by Soydemir (2000) (Intra-regional linkages)			
Pagán and Soydemir (2001)	Latin American countries (including Brazil)	from 1995 to 1999, daily	asymmetric response in regression model	The asymmetric response among four Latin-American countries including Brazil is analysed to the upturn and downturn in return of the Mexican market. Existence of such response points to the substantial degree of cross-market linkages between markets. (Intra-regional linkages)			
Tabak and Lima (2002)	Latin-American countries (including Brazil) and the US	January 1995- March 2001, daily	Johansen co-integration test	Brazil caused all other Latin-American countries within the study. The possible gap in the analysis is the omission of the measurement of contemporaneous causality patterns. (Intra-regional linkages)			
Chen, <i>et al.</i> (2002)	six Latin-American countries	from 1995 to 2000, daily	VAR, co-integration (Johansen, 1988; Johansen&Juselius, 1990) and VECM	Some evidence of co-integration is found in multivariate form before and after the Asian crisis and prior to the Russian crisis, while no co-integration is found in the rest of the sample. The application of Granger Causality in a VECM form demonstrated the existence of bi-directional causal linkages between Brazil to Argentina, and unidirectional from Mexico, Venezuela and Columbia. (Intra-regional linkages)			
Fernández-Serrano and Sosvilla-Rivero (2003)	Latin-American countries (including Brazil) and the US	from 1995 to 2002, daily	co-integration	The evidence provided by the authors suggests that, allowing for structural breaks in the model provides strong evidence of co-integration among the observed markets while, in the case of Brazilian and the US markets, the co-integration is confirmed without modification for structural breaks. (US influence)			
Johnson and Soenen (2003)	nine (North/South) American equity markets including the US and Brazil	from 1988 to 1999, daily	Geweke (1982) contemporaneous feedback measurement	The significant contemporaneous relationship is confirmed between Brazil and the US at 1% level of significance in the years: 1991, 1994-1999. Overall, the author pointed that the results suggested a high degree of market integration and market efficiency, since the contemporaneous relationships are found to be significant. (US influence)			
Yang, <i>et al.</i> (2004)	Brazil and India in relation to the US market	From 1976 to 2001, monthly	Hansen and Johansen (1993, 1999) co-integration	The overall conclusion is that co-integration was raised after the Asian and Russian crisis turmoil of 1997-1998. (Rising integration)		The overall conclusion is that co-integration was raised after the Asian and Russian crisis turmoil of 1997-1998. (Rising integration)	
Rivas, <i>et al.</i> (2006)	US, 5 European mature markets and three Latin-American countries including Brazil	from 1988 to 2004, weekly	regression model	The regression model is used where each Latin-American country is assumed to be explained by the US and the participating European countries simultaneously. In the first sub-sample the US and European countries fail to explain the behaviour of the Brazil equity market, while in the second and third sub-samples Brazil is explained by the equity markets of the US and Spain. The magnitude of the Spanish stock market index parameter estimate is found to be persistent, positive and stable across observed sub-samples. However, the value of the US estimate in the third sample declined, compared to the second sub-sample. The authors tried to attribute such strong dependence on Spain by the existence of significant trade between the two countries. (Intra-regional linkages)			
Khalid and Rajaguru (2007)	26 Countries from different regions of the worlds	1 of august 1998 to 31 March 1999, daily	VAR model, Granger Causality, IRF	Brazil is found to be caused in the Granger sense by Argentina, Japan, Singapore and Poland, while no causal effect is found from Brazil to the other markets. (Intra-regional linkages)	The causality test in relationships among stock market indices found to be much stronger compare to exchange rate effect and interest rate effect of Russia. The causality from Russia was detected in Columbia, Indonesia, Japan, Thailand and Czech Republic. Generalised impulse response function proposed by (Pesaran and Shin, 1997) revealed significant effect of Russian stock market on markets of South Asia, Middle-East, Africa and Eastern Europe. Also, the IRF shows that Russian stock market shock lasts for 2 days in the observed period. (Intra/Inter -regional linkages)		

Author(s)	Data	Period	Method	Brazil	Russia	India	China
Rivas, <i>et al.</i> (2008)	five European countries on Brazil, Chile and Mexico	from 11, January 1991 through to December 31, 2005, daily	VAR model and IRF are used for this purpose	In IRF, the authors found positive and statistically significant responses to France, Italy, the United Kingdom, Spain, and Germany. The authors ascribe this to the fact that Brazil has greater international trade and openness of her economy, compared to Chile. (Intra-regional linkages)			
Diebold and Yilmaz (2009)	Argentina, Brazil, Chile and Mexico	from 1 January 1992 through to 10 October 2008, weekly	VAR model	The authors developed the index to assess equity return and spillovers. A rolling 100-weeks VAR is used and the spillover index calculates for every possible VAR ordering. The findings indicate that both the return and volatility spillovers fluctuate widely over time. Thus, return spillover is smoother, whereas a volatility slipover has sharp shifts usually observed in crisis events. The article raises the question of the importance of parameter (significance) stability when analysing stock market dynamics. However, no substantiation is given for choosing a 100 weeks rolling window. (Intra-regional linkages) , (BRIC), (US influence)			
Ozdemir, <i>et al.</i> (2009)	BOVESPA and S&P500	from 8 October 1994 - 24 March 2006, daily	Johansen and Juselius (1990) co-integration	The null hypothesis of no co-integration failed to be rejected in trace statistics at 10% level of significance. However, Granger Causality in pair wise form is found from the US to Brazil at a 5% level of significance, but not the opposite. (US influence)			The null hypothesis of the no co-integration vector is rejected at 10% level of significance. The Granger Causality in pair wise form is found from the US to China at 1% level of significance, but not in the opposite direction. (Lack of US influence observed in cointegration, some influence in short term relationship)
Meric, <i>et al.</i> (2009)	Latin-America countries (including Brazil)	from January 5, 1995- December 27, 2007, weekly	principal component analysis	Brazil expresses a similar movement pattern with Chile, Argentina, Mexico, Peru and Columbia. Moreover, Brazil has the largest highest value of the factor which may point to the fact that the Brazilian economy has a significant weight and influence among other Latin-America equity market indices. (Regional leader)			
Aktan, <i>et al.</i> (2009)	BRIC, Argentina and US	January, 2002 - February, 2009, daily	VAR, IRF, Granger Causality.	The inclusion of US return at lag 0 into the VAR model is rather questionable, since it ignores indices' trading time non-synchronism. Nevertheless, all indices except the Chinese have at least one lag to be significant in explaining the behaviour of Brazil index in VAR form. Brazil has bidirectional causality with Russia and India, and unidirectional from Argentina. According to the findings of the study, Brazil is found to be the most integrated index following the Russian equity market. (BRIC), (US influence)	First, the US stock market has a significant effect on all BRICs and Argentina on the same trading day; second, Russia is found to be the most integrated market since the linkages from other markets to Russia are found to be significant; the existence of causality at lag one from Brazil to Russia is confirmed. (BRIC), (US influence)	India is found to be in all lags of Brazil in VAR frame works, Argentina at lag 2 and the US at lag 1. The result of Granger Causality test confirmed that India causes Brazil, Argentina, and caused by Brazil and Russia. (BRIC), (US influence)	The US at lag 0 and Argentina at lag 3 are found to be significant in explaining the behaviour of the Chinese index in a VAR form. Bi-directional causality is detected between China and Russia and unidirectional causality from China to Argentina. IRF suggest that all BRICs are mainly self oriented in terms of response to innovations. (BRIC), (US influence)
Ozdemir, <i>et al.</i> (2009)	Brazil, China and US	from 15 September 1993 - 24 March 2006, daily	Johansen and Juselius (1990) co-integration test	The null hypothesis of no co-integration failed to be rejected in trace statistics at 10% level of significance. However, Granger Causality in pair wise form is found from the US to Brazil at a 5% level of significance, but not the opposite direction. (US influence)			The null hypothesis of no co-integration vector is rejected at 10% level of significance. The Granger Causality in pair wise form is found from the US to China at 1% level of significance, but not the opposite direction. (US influence)
Relationships in variance							
Christofi and Pericli (1999)	Argentina, Brazil, Chile, Columbia and Mexico	from 25 May 1992 to 16 May 1997, daily	VAR–EGARCH model	Examination of the equation output table suggests that Brazil has strong mean dependencies with Mexico over the observed period, while Mexico is not affected by Brazil returns. Volatility spillover from Brazil is found to be positive and significant for all other markets, but the magnitudes are smaller compared to the other market's volatility spillovers. Overall it can be seen that volatility spillovers are greater compared to mean spillovers. The possible drawback of the model is that it does not assume instantaneous interaction, thus, all dependencies start from lag 1 or higher. (Intra-regional linkages)			
Alper and Yilmaz (2004)	the US, the UK, Hong Kong, Brazil, Korea and Russia	January 1992 to December 2001, daily	Rolling regressions analysis; GARCH model.	The real return contagion from the Brazilian stock market is found to be significant at 5% level. The application of Brazil's unconditional volatility to the conditional variance equation of the GARCH model for Turkey is not so prominent, since the parameter is found to be small and not significant. The average magnitudes of volatility contagion to Turkey from mature markets is greater compared to the emerging ones (including Brazil and Russia). (Inter-regional linkages)	Results of the correlation revealed the existence of the response on the Turkish market to the Russian market; it is strong compared to the other emerging markets. The plot of adjusted R2 shown that the Russian crisis had a direct impact on the Turkish economy. The effect is immediately reflected on the Turkish index after the Russian crisis in the form of increased volatility. However, the application of Russian unconditional volatility in the conditional variance equation of the GARCH model for Turkey is not so prominent, since the parameter is found to be small and not significant. The same could be said of the Russian real return in the mean equation, which is found to be small and significant at 10% level. (Intra-regional linkages)		

Author(s)	Data	Period	Method	Brazil	Russia	India	China
Fujii (2005)	Asia and Latin America	from January 1990 to November 2001, daily	CFF GARCH causality test	The author detected significant contemporaneous and lag 1 causality-in-mean and causality-in-variance for the markets from the same region, while higher lag causality varies by market pair. Regarding the interregional linkages, the author suggested that despite bidirectional causality-in-mean, the causality-in-variance mainly runs from Latin American to Asian countries. This may partly be explained by the difference in time gap, which is smaller from Latin American countries to Asian countries than vice versa. The listed findings are also ascribed to Brazil, which is observed in relation with Mexico and Thailand. The study is remarkable due to the controlling for the US market effect and use of the rolling window method with the fixed window size (240 observations). (Intra/Inter-regional linkages)			
Fasolo (2006)	Brazil, Mexico, Argentina and Chile	August 1, 1994 - May 5, 2003, daily	DCC-GJR-GARCH	The Brazilian market is found to be significant on its own previous day's lag and the previous day lag of the Chilean market. (Intra-regional linkages)			
Verma and Ozuna (2008)	US, Brazil, Chile, Mexico	from April 3, 1995 to October 10, 2001, daily	multivariate EGARCH	Return spillover was found from Chile to Brazil, while no return spillover is found from US to Brazil and Mexico to Brazil. The volatility spillover has also confirmed the absence of transmission from US to Brazil, but the bi-directional spillover is detected between Brazil and Mexico with Chile. The author explains the findings on Brazil by suggesting that the Brazilian market is a more closed compared to other Latin-American countries that took part in the study. (Intra-regional linkages)			
Nguyen and Bellalah (2008)	Argentina, Brazil, Chile, Colombia, Mexico, Malaysia and Thailand are used in the study.	January 1985 to January 2003 monthly	bi-variate GARCH-M model	The findings from the bi-variate form suggest that conditional covariance has significant impacts on Brazil stock market returns, while the local market risk is found to be significant and positive. Since the overall estimation is applied for such a long period, the authors also investigated structural changes in stock market dynamics by applying the stability test and found three break points in Brazilian data. The authors concluded that these break points are directly linked to the date of liberalisation, also supported by Aggarwal et al (1999). However, the effect of official liberalisation is insignificant. The authors also concluded that liberalisation does not increase volatility. (Intra-regional linkages)			
Weber (2008)	Brazil, Canada and Mexico equity markets in relation to the US	from 01/02/1989 to 03/31/2008, daily	structural VAR with conditional volatility	The paper examines the contemporaneous effect of causality in variance. The author found strong contemporaneous impacts from US to foreign volatility and, in the case of Brazil, the effect is confirmed at 10% level of significance. (US influence)			
Diamandis (2008)	Argentina, Brazil, Chile, and US Mexico represented by MSCI	from January 1988 to July 2006 with weekly observations	DCC-GARCH(1,1) and SWARCH-L	The author found evidence of an increasing trend of interdependence between Brazil in relation to the US and Argentina, and with a significant rise in correlation with the US during the Asian crisis. (US influence)			
Gebka and Serwa (2007)	Asian, Eastern European, Latin American emerging markets (including Brazil and Russia)	from April, 1998 to January, 2006, daily	CCF GARCH causality test	Brazil is found to be affected by a return spillover from the Latin American countries (Argentina, Chile and Mexico) only in the contemporaneous term. The contemporaneous return and lag 1 spillovers is found in the direction of Brazil from the Asian region, excluding Malaysia, and from the Eastern European countries, excluding the Czech Republic (Gebka&Serwa, 2007, p. 212). Regarding the return spillover, Brazil had an effect on all the participating countries, excluding Malaysia. Besides this, the intraregional return cross-correlation coefficient has a higher magnitude compared to the interregional one. (Intra-regional linkages)	Application of CCF GARCH causality test demonstrated that the intraregional return spillover is likely to be stronger compared to the interregional but, in comparison to the Brazilian intraregional interdependencies, the Russian cross-correlation coefficients are significantly smaller, while the interregional ones are higher in magnitude. Intraregional spillovers in variance are small in magnitude compared to the cross-linkages of other emerging countries in Central and Eastern Europe. This illustrates the involvement of the Czech Republic, Hungary and Poland in relation to the EU, rather than to Russia in terms of variance spillovers. Besides this, the authors found that Russia is the main source of the inert-regional causation. Finally, an interesting fact is that controlling for the Russian crisis (1998) does not modify the intensity of spillovers. (Intra-regional linkages)		
				Moreover, the highest detected interregional cross-correlation is found between Russia and Brazil (0.101). Further, by observing the variance causality adjusted for the existence of the mean causality, the author found fewer cases of variance spillover compared to return slipover, and these are mostly represented with higher lag dependencies. However, no variance spillover is found between Brazil and Russia. (BRIC)			

Author(s)	Data	Period	Method	Brazil	Russia	India	China
Bhar and Nikolova (2009a)	Russia is represented by (AK&M Composite) Europe (Financial Times World Index All Countries Europe) and the MSCI World.	January 1995-October 2006, weekly	Multivariate EGARCH model	The Brazilian return is determined by both world and regional indices through return spillover. The significant effect of the world index, as well as regional ones, could be attributed to the US effect. The authors suggest that approximately 50% weight of the world index is accounted for by the US. Thus, it is assumed that the US has a significant effect on the Brazilian equity market. The existence of asymmetric volatility is detected in the case of Brazil. The spillover from the world index is found in conditional volatility of the Brazilian equity market, while regional spillover is not confirmed. The volatility spillover is found from the Brazilian equity market to the regional level. Brazil has a relatively stable level of conditional correlation with the world and regional index after a significant upsurge at the beginning. The asymmetric volatility is found to be high, both with the regional and global indices. (Intra/Inter-regional linkages)	It is found that Russia has some explanatory power on the Global equity index. It is also found that Russia is responding equally to positive and negative shocks. Russia has relatively stable level of conditional correlation with the world index. However, the regional conditional correlation is volatile. (Intra/Inter-regional linkages)	The asymmetric volatility is found to be high, both with the regional and global indices. India also demonstrated a negative effect in conditional volatility in its relationship to the Asia-Pacific index. Based on the level of spillovers, the authors concluded that India has highest level of integration with the world and regional indices among BRIC. (Intra/Inter-regional linkages)	The regional (Asia-Pacific) and World index is not influenced by return spillovers from the Chinese market. China, like all BRICs is affected by regional and global shocks through the conditional variance equation. Interestingly, the Chinese equity market's relative asymmetry is less than one, which may cause lower conditional volatility in response to the negative innovation in the previous period. Also, low negative volatility spillover is detected from the world market, while the existence of spillover from Asia-Pacific region is not confirmed. Finally there is no evidence of a spillover effect from China to world or regional index. The authors also emphasise that China demonstrates the lowest level of integration among BRICs. No evidence of regional integration for China. As for the dynamic conditional correlation, the only weak stable positive correlation is found with the regional index, and volatile mainly negative correlation is found with the world index, which gives good diversification opportunities for investors. The authors ascribe this result to the relatively closed nature of the Chinese financial system. (lack of Intra/Inter-regional linkages)
Relationships in mean							
Linne (1998)	Emerging European countries (including Russia) and mature markets (Germany, UK, France, Italy, Switzerland, US and Japan)	from 1991 to 1997, weekly	Co-integration		The main conclusion of the work is that emerging markets are mainly driven by domestic factors rather than foreign market dynamics. As for Russia, no long-run linkages are found between two Russian equity indices and other analysed markets. (Lack of Intra/Inter-regional linkages)		
Jochum, et al. (1999)	Eastern European countries (including Russia)	Pre-crisis 01/02/1995-31/08/1997; Crisis period 01/09/1997-21/09/1998, daily	Hansen and Johansen (1993) co-integration		The co-integration is found in the first period between Moscow and US, Hungary in bivariate form and Moscow with Poland, Czech Republic, and Hungary in multivariate form. The later period demonstrates a lack of co-integration, which the author suggests is due to the change in previous long-run relationship because of the dynamics of the crisis. Russia and the US are able to explain more than 90% of their variation. The authors highlight the relative independence of the Russian market, and ascribe this to the fact that the crisis has been governed by events in Russia. (US influence), (Intra-regional linkages)		
Pesonen (1999)	The UK, The US, Russia and set of Asian countries	January, 8 1997 to February 26, 1998, daily	Granger Causality		Evidence found that pre-crisis linkages are different compared to post-crisis ones. In the post crisis period Russia, at a different lag, is found to affect Thailand, Malaysia, Philippines and Hong Kong, the latter is not apparant pre-crisis. The author suggests that this fact is due to the effect of the US reflected by the Russian market. In fact, the contemporaneous relation was ignored in the analysis, since lag 0 was not considered (instantaneous causality in Granger, 1969). Thus, the result for Asia post crisis, as well as for whole sample estimation, might be biased since the Russian market is assumed only to affect from the previous day. Similar bias could also affect other countries, e.g.: the UK and Japan. (Intra/ Inter-regional linkages)		
Fedorov and Sarkissian (2000)	Russia. Company level, sector level.	October 1995 to November 1997, weekly	Regression		The main findings are that the the less diversified industries of Russia have a lesser degree of integration with world markets. The result is that companies, with stocks that are traded on foreign stock markets (communication sector) and those, which have export oriented production (Oil & Gas, metallurgy sectors) have a greater likelihood of integration. (Intra-regional linkages)		
Rockinger and Urga (2000)	Russia, US, Germany and UK	from April 1994 to July 1997, daily	GARCH model		The authors suggest the Russian stock market behaviour pattern is different compared to the others participating countries. The negative correlation with US and Germany has a tendency to disappear after 1995. The paper reveals the general tendency of rising correlation after the market liberalisation. (US influence), (Rising integration)		
Gelos and Sahay (2000)	Russia, Hungary, Poland and Czech Republic	15.07.1998-15.10.1998, daily	VAR, Granger Causality, IRF		The Granger Causality test shows that the Russia stock market affected returns in the Czech republic Hungary and Poland. The variance of Russian stock market returns lasting for approximately 5 days in each of the participating countries. Strong evidence is found of the asymmetric effect; negative shocks had much stronger effect than positive. (Intra-regional linkages)		

Author(s)	Data	Period	Method	Brazil	Russia	India	China
Anatolyev (2005)	MSCI US and Russia, and additional economic indicators including Brent Crude oil price	January 1995 - January 2005; October 1999 - January 2005, daily	Rolling regression		The results demonstrate that a large proportion of Russian market movements are explained by US equity market behaviour and the Crude Oil price. In the second period the author found the diminishing effect of the Oil price in influencing the Russian equity market, while US return volatility index positively influence Russian stock prices and was getting stronger closer to the end of observed sub-sample. (US influence), (Rising integration)		
Jalolov and Miyakoshi (2005)	German and US on Russian (RTS) equity market	September 1995 - March 2003, monthly	AR-EGARCH model		The results demonstrated that German equity market has significant and positive effect in a given sample, while the US effect found to be not significant. The author concluded that in the Granger causality sense the Russian market is caused by spillover effects from the German equity market, pointing out that the Russian economy has a strong relationship with the German economy. (Intra-regional linkages)		
Lucey and Voronkova (2008)	MSCI indices: Russia, EMU Countries, UK, USA, Japan, Hungary, Czech Republic and Poland.	Crisis 30/12/1994–31/07/1998; Post-crisis 01/08/1998–14/10/2004, daily	- Johansen and Juselius (1990); - Gregory and Hansen (1996) test; - McCabe, <i>et al.</i> (2003) stochastic co-integration test; - Breitung (2002) non-parametric co-integration test; - Regime-switching cointegration by Gabriel, <i>et al.</i> (2002);		Only Gregory–Hansen test demonstrated existence of bivariate co-integration overall and in the post-crisis period. (Some evidence Intra-regional linkages), (Some evidence US influence)		
Saleem (2009)	Russia, EU (Datastream EMU) index, Emerging Europe (Datastream EM) index and Asia (Datastream Asia)	pre-crisis period January 1995–July 1998; crisis period August 1998–December 1998); post-crisis period January 1999–June 2007, Daily	GARCH(1,1)-BEKK model; Johansen (1988; 1991) co-integration test.		Saleem (2009) concluded that the Russian market is partly integrated with other markets due to small value of the coefficient. The Johansen (1988, 1991) co-integration test confirmed existence of interdependence among indices during the crisis. (Some evidence of Intra-regional linkages during the crisis)		
Aktar (2009)	Russia, Turkey and Hungary	January 5, 2000- October 22, 2008, daily	Johansen and Juselius (1990) co-integration; VECM; Granger Causality Test.		The significant linkages are found between Russia and Turkey. However, the Russian return found to be significant in explaining the behaviour of Turkish and Hungarian returns. The application of pair wise Granger Causality found bidirectional causality between Russia and Turkey, and unidirectional causality from Russia to Hungary. However, the results of VAR and pair wise Granger Causality are given without taking into account the existence of contemporaneous linkages among countries. (Intra-regional linkages)		
Beirne, <i>et al.</i> (2010)	41 countries from group Emerging Asia, Latina America, Europe, Middle East and North Africa.	12, June 1993 to 12, March 2008, weekly	Multivariate GARCH (1,1)-in-mean		First, separately tested hypothesis of no spillover in mean from regional to local market and global markets are rejected, which means that Russia is affected by regional and global shocks. Second, separately tested hypothesis of no spillover in variance from global markets and regional are also rejected, which refers to the significant effect from the global and regional shocks to the volatility of Russian equity market. The separately tested hypothesis of GARCH-in-mean from volatility of global and regional shocks is not rejected, which may address the issue that volatility does not affect the Russian equity market return directly. This confirms significant dependencies on return spillover from the global markets and volatility spillover from the regional shocks. (Intra-regional linkages), (US influence)	This confirms significant dependencies on return spillover from the global markets and volatility spillover from the regional shocks. (Intra/Inter -regional linkages), (US influence)	For China it is possible to extract the following. First, separately tested hypothesis of no spillover in mean from regional to local market is rejected, which means that China is affected by regional shocks. Second, no spillover in variance is found from global and regional markets. Finally, the GARCH-in-mean from volatility of global shock is rejected. This may be ascribed to the features of the Chinese market, where dependence is likely to be observed through the conditional return rather than conditional variance. Overall, it confirms the existence of integration of the Chinese equity market. (Intra-regional linkages), (US influence in variance)
Cheung, <i>et al.</i> (2010)	Developed US, UK, UK, Hong Kong, Japan Australia and emerging Russia, China.	January 2003- June 2007; June 2007-April 2009, weekly	VAR models, Granger causality, Johansen (1988; 1991) co-integration and VECM.		Authors found a weak power of Russian index return and squared return to explain the dynamics of the US market before and after the beginning of the Global Financial Crisis. In case of the UK the relationship is found both in lagged and lagged squared returns. The Granger Causality analysis unveils no causal links between the US and Russia pre-crisis, while in the second time period bidirectional causality is found. The co-integration analysis between Russia and the US demonstrate that both periods are characterised by the long run relationship, however the later period demonstrate an increase in the co-integration coefficient. (US influence), (Inter -regional linkages) , (Rising integration)		

Author(s)	Data	Period	Method	Brazil	Russia	India	China
Anoruo (2003)	Asian (including India), the US and Japan	January 4, 1988 to December 31, 1999, daily	Johansen and Juselius (1990) and Johansen (1991), Causality test in VECM form			Results of the causality in a VECM form India is found to be the most integrated country among participating emerging economies in a later period and in the full sample estimation, which is described by the causality from other countries to India. Influence of the US is stronger in a later period as well. (US influence), (Intra-regional linkages), (Rising integration)	
Kaur (2004)	S&P500 and NASDAQ to SENSEX and S&P NSE NIFTY	January 1993 - March 2003 and November 1995 - March 2003, daily	Univariate EGRACH(1,1), TARCH(1,1)			The author found mixed evidence of return and volatility spillover from the US to Indian markets. The author found no distinguishable trend between India and the US stock market interactions. (Some evidence of US influence)	
Wong, <i>et al.</i> (2005)	India, US, UK and Japan	January 1, 1991 to December 31, weekly	Engle and Granger (1987) co-integration; VECM and Granger Causality test. Johansen (1988)			Co-integration is found in bivariate form between India and all participating mature markets. The study confirms existence of long term and short term dynamics, which confirms that India is successfully integrating with other indices. Indian stock market is confirmed to be influenced by mature markets. (Intra-regional linkages), (US influence)	
Gunasinghe (2005)	Japan, Pakistan, Sri Lanka and India	1992: 01 to 2002: 01, monthly	Johansen and Juselius (1990) co-integration			The sample is divided into the pre- and post- Asian crisis periods. The multivariate co-integration test does not provide any evidence of long run relationship. No cointegration is found between Japan and India. (lack of Intra-regional linkages)	
Relationships in variance							
Wang, <i>et al.</i> (2005a)	US and Japan India, Pakistan and Sri Lanka	Pre-crisis 01/1993-06/1997; in-crisis 07/1997-12/1999; post-crisis 01/2000-12/2003, daily	Univariate EGARCH			In the full sample analysis, return spillover is confirmed from the US and Japan to all three countries, while volatility spillover effect from the US to India is confirmed only at 10% significance level. At the same time, post-crisis, volatility spillover is confirmed both from the US and Japan. The author concluded that after the crisis the effect of mature markets increased significantly. (Some evidence of US influence), (Rising integration), (Intra-regional linkages)	
Chen, <i>et al.</i> (2006)	US, India, China	January 2, 1991 - December 29, 2004, weekly	Engle and Granger (1987) two-step procedure Fractionally Integrated VECM-BEKK			US-India First, markets are found to be fractionally integrated with each other. Second, for pairs of markets it is possible to conclude the following: No return transmission is found between India and the US, while unidirectional information transmission is found from the US to the Indian market. The error correction coefficient is found to be significant in explaining the behaviour of the Indian market. (US influence)	US-China There is a return transmission found from the US to China, with a negative sign suggesting that China moves in the opposite direction. The co-integration relation is significant and negative, with a value near unity only in explaining China. This implies that disequilibrium is corrected within a period of about 1 week. However, no information transmission between two markets is found in conditional volatility. (US influence)
						India-China As for the relation between India and China, the following is found: return transmission is found from Chinese to Indian markets at the 10% level of significance; the adjustment parameter is negative and significant at 10% level, indicating that India tries to restore the equilibrium relationship with China. Unidirectional volatility spillover is found from the Indian to the Chinese market. (BRIC)	
Mukherjee (2007)	India, Hong Kong, South Korea and Russia	1995-1997; 1998-2000; 2001-2003; 2004-2006; daily	Unconditional Correlation		The findings suggest that the correlation coefficient between Russia and India rose up to 0.941, while in the previous periods the value varied from 0.386 to 0.548. (Rising integration), (BRIC)		
Mukherjee and Mishra (2010)	13 Asian countries including (India, China and Japan)	July 1997 to April 2008, daily	GARCH-M(1,1)			Only a few countries affected India through the foreign variance in the mean equation, however the reverse is found to be insignificant. The foreign volatility transmission in a variance equation is found from Hong Kong, Indonesia, Korea, Singapore, Thailand, while India affected only Pakistan and Sri Lanka. However, the lagged transmission of return and volatility are found less frequently. Thus, most of the information transmission is performed without delays. It confirms the fact that contemporaneous information transmission cannot be ignored. (Intra-regional linkages)	
Mukhopadhyay (2009)	G7 and BRIC (excluding Russia)	2002-2007; 2007-2008; Monthly and daily	Unconditional Correlation			Correlation with emerging markets doubled, while for the UK and US rose considerably. (Rising integration), (US influence)	Correlation coefficient rises significantly between China and a set of emerging and mature markets in the period from 2007-8, while in the period from 2002-07 correlation with the same set of countries is near 0 with insignificant divergence under 10%. (Rising integration), (Intra-regional linkages), (US influence)
Poshakwale and Thapa (2009)	MSCI index for the India, Korea, Taiwan and World indices	January 2001–31 March 2003; January 2004–30 March 2007, daily	Rolling Unconditional Correlation Co-integration in Johansen (1988), VAR, VECM, Variance Decomposition and IRF.			Correlation of India with World index rose from 0.25 to 0.4 with significant fluctuations inside the sample. In bi-variate co-integration one co-integrating vector is found between India and the World index both in sub-sample2 and full sample. Based on this outcome the author confirms the second period reveals a greater level of integration, which is also supported by greater equity investment flows into India. (Rising integration), (US influence as World index)	

Author(s)	Data	Period	Method	Brazil	Russia	India	China
Naeem (2002)	Four South Asia countries (including India), US and UK.	January 1994 – December 1999; January 1994 – April 1998, monthly	Johansen (1988)			Found no co-integration between India and the US and the UK. The results show no co-integration between all the participating South Asian countries with relation to the US and the UK. (Lack of US influence)	
Awokuse, <i>et al.</i> (2009)	10 Asian countries in relation to US and UK.	January 1, 1988 to December 31, 2003, daily	Rolling co-integration Johansen (1988; 1991)			The following intervals are where strong co-integration is detected using rolling cointegration technique: 1991:Q2-1992:Q1, 1992:II–1995:III, 1997:II–1998:II, and 1998:III–2003:IV. The strong time varying co-integration exists among the countries both during market liberalisation in early 90-ties and as a result of the Asian crisis 1997. (Lack of US influence), (Lack of Intra-regional linkages)	
Bhaduri and Samuel (2009)	S&P NSE (Nifty)	1 July 1997 to 31 December 2005, daily	Logistic Smooth Transition Regression regime changing model			India is represented by S&P NSE (Nifty). The study concludes that in the post-Asian crisis period the Indian stock market was becoming more integrated, confirming the highest level of correlation with Asian countries. However, the integration with mature market is found to be low. Bhaduri and Samuel (2009) ascribe this to the structural, operational and economic constraints. (Rising integration), (Intra-regional linkages)	
Baur and Fry (2009)	China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand	April 30, 1997 to October 22, 2003, daily	VAR model with regional, global and fixed time effect factors			Five contagion episodes are detected by the significance of a fixed time effect. The estimation of the model without Japan, China and India shows a rise in the total number of detected contagions. The authors emphasise that the inclusion of those countries into the model reduces the severity of the shocks. (Low Intra-regional linkages during the Asian crisis)	
Singh, <i>et al.</i> (2010)	10 Asian countries and US, Canada, France, Germany , UK	1st January 2000 to 22nd February 2008, daily	VAR, Univariate AR-GARCH			From the outcome of the augmented AR-GARCH model it is possible to conclude that indices, whose trading time is either overlapped or preceed the trading time of Indian (BSE30) have strongly significant volatility spillover. Finally, results of the study confirm that ignoring the contemporaneous nature (“same day effect”) may cloud the true relationship among stock market indices when daily data is applied. (Intra/Inter -regional linkages), (US influence)	No linkages with other markets are found in VAR form in both types of return, while in open-to-open returns of the SSE index are explained by their own lag. The VAR with contemporaneous structure demonstrated the linkage from Malaysia to China in both types of returns, while Chinese close-to-close return at lag 0 is found to be significant at 1% level in explaining Hong Kong (Hang Seng). The Chinese open-to-open return is found to be significant in explaining UK (FTSE100) and Canadian (S&PTSX). China also stays in the general trend so that contemporaneous return in conditional variance equation has a stronger effect, compared to the lagged returns. Japan, Singapore and Malaysia are found to be significant in explaining the Chinese market in the AR-GARCH model in close-to-close return in a conditional variance equation. However, China is found to be significant in explaining other indices also only at lag 0. The authors emphasised that contemporaneous information transmissions have a strong effect compared to the lagged ones. The study also has some similarities with the study by Wang and Firth (2004) in terms of applying the foreign market innovations into the conditional variance equation in the “all-in-one” equation form. (Intra/Inter -regional linkages), (US influence)
Yoshida (2010)	The 11 Asian including India, Japan and US	April 1996 - October 1998 June 2007 - December 2009, daily	Johansen (1988; 1991) cointegration, Bi-variate GRACH(1,1), Granger Causality			The time varying correlation from bi-variate GRACH(1,1) in the period from March 26, 1994 to December 21, 2009 demonstrated positive unstable correlation for India. No co-integrations are found for India in both periods. For India the correlation is raised in both crisis periods. Granger causality in pair wise form is found from US to India during sub-prime crisis. (Intra-regional linkages), (US influence), (Rising integration during the crises)	The time varying correlation from bi-variate GRACH(1,1) in the period from March 26, 1994 to December 21, 2009 demonstrated small and stable correlation. The Johansen (1995) trace test confirmed co-integration only between China and US during the Asian crisis. Unidirectional Granger causality in pair wise form is found from China to US during the same time period. (Rising integration during crisis time), (US influence during crisis time)
Guidi (2010)	Indian, Hong Kong, Singapore and Japan	1999-2009, daily	Engle and Granger (1987), Johansen (1988; 1991), Gregory and Hansen (1996) co-integration tests, Pair wise Granger Causality, DCC-GARCH (1,1)			The application of Engle-Granger co-integration test found no evidence of co-integration. In application of Johansen co-integration no long-run relationship is found between India and other countries under investigation. However, the hypothesis of no co-integration (Gregory-Hansen, 1996) is rejected, in favour of the alternative hypothesis of co-integration with a structural break. Indian stock market does cause the Japanese stock market, but Japan stock market causes India only on the same day. The Indian stock market causes all other indices at lag 1 and is caused by Hong Kong at lag 0 and Singapore indices at lag 0,1. The investigation of dynamic conditional correlation suggests that time varying correlation between India and other markets rose dramatically in periods of crisis. (Intra-regional linkages)	

Author(s)	Data	Period	Method	Brazil	Russia	India	China
Relationships in mean							
Huang, <i>et al.</i> (2000)	US, Japan, Taiwan, Hong Kong, Shanghai and Shenzhen (South China Growth Triangle (SCGT))	October 1, 1992 through to June 30, 1997, daily	VAR model Gregory and Hansen (1996) co-integration test				The Shanghai and Shenzhen stock markets demonstrated the existence of the co-integrating vectors, while no co-integration is found between China and the US, Japan and Taiwan markets. However, being insignificant, the co-integration test statistics are greater in the case of the US-SCGT than with the Japan-SCGT, which the authors ascribe to the greater effect of the US on SCGT countries. The absence of this relationship allowed the application of the Granger causality test in the VAR model on a short-term basis, which revealed no causal interactions between the Shanghai stock market and the US with Japan. (Intra-regional linkages), (Lack of US influence)
Bahng and Shin (2003)	China, Japan and South Korea	January 1991 to December 2000, daily	Regression VAR models Johansen and Juselius (1990) co-integration				Each index regressed on asymmetric basis against the other participating indices, with and without inclusion of the US market. The outcome of the regression equation demonstrates that China is not found to be affected by Japan and Korea. Moreover, no significant influence is found from the US to China. Application of the Johansen and Juselius (1990) co-integration as a preliminary test before the implementation of the VAR model demonstrated the absence of the co-integrating vectors. Finally, the Chinese index is found to be not well explained by variation of other participating markets. (Lack of US influence)
Wang, <i>et al.</i> (2005b)	Two Chinese markets (Shanghai and Shenzhen) across different market sectors.	May 3, 1993 - November 16, 2001, daily and monthly	Generalised forecast error variance decompositions				The study found evidence of a high degree of interdependence between markets. A shock to any sector has a strong reflection on other sectors, due to the fact that 70% of forecast variance in a sector can be referred to shocks in other sectors. The study confirms the existence of a strong information flow between the sectors inside one market and also across markets within China. (Intra-regional linkages)
Samaratunga (2009)	Four emerging markets (including China) and four developed (Australia, Hong Kong, Japan and Singapore)	from 11 July 1997 to 16 May 2008, weekly	Johansen (1988; 1991) co-integration test				The Johansen co-integration test cannot reject the null of no co-integration vectors among the developed and emerging countries of Asia-Pacific region. Further investigation for the emerging group of countries (including China) also found no evidence of co-integration. (Lack of US influence)
Wang and Lee (2009)	nine Asian countries including China	from February 21st of 1992 to November 15th of 2000, daily	volatility spillovers are examined using Granger Causality in a multivariate VAR framework and IRF are applied				The authors pointed out that bidirectional spillovers are more likely to appear during high fluctuation periods, return volatility spillovers are found less frequently compared to stock return spillovers. China has demonstrated a relatively small frequency of rejections, which may refer to the lesser integration of the Chinese equity market into the regional net of equity markets in the observed time period. However, China demonstrated the highest value of cumulative impulse response value for the stock returns during the tranquil period (18.84%), while Japan showed the smallest (4.95%) ratios. During the high fluctuation period the return volatility of China demonstrated the smallest ratio (4.17%) impulses of innovations to other countries. This may suggest that China was exempted from being either an originator or a good transmitter of shocks during the Asian crisis. The article is important due to the use of non-causality hypothesis rejection frequency and percentage terms because of the use of large amounts of figures in outcomes. (Intra-regional linkages), (Rising integration during the crisis)
Cheung, <i>et al.</i> (2010)	US (S&P500) and UK (UKX) to the group of global indices including China (Shanghai Composite)	period1: January 2003-June 2007; period2: June 2007-April 2009, weekly	squared returns in the VAR model				The authors found evidence that interdependence between China and the US markets is weak in the pre-crisis period. However, the spillover effect from the US to the China rose both for the returns and volatility spillovers. The causal linkage is detected from the US to China during the examination of indices returns. The co-integration is found between the US and China during the period of crisis confirming the existence of a long-term relationship. (Rising integration during crisis time), (US influence during the crisis)

Author(s)	Data	Period	Method	Brazil	Russia	India	China
Relationships in variance							
Wang and Firth (2004)	Greater China emerging markets and Japan, the UK and the US	GJR-GARCH model	open and close price data from 25 November 1994 to 28 September 2001, daily				The specific feature of the study is the application of the innovation of other market's dynamics as exogenous variables into the conditional variance equation with respect to the trading time non-synchronism. The findings are the following: first, the overnight return of Greater China equity markets could be explained by the innovation from at least one of the mature markets day time returns. Second, the return spillovers in contemporaneous time in general are unidirectional, usually from mature markets to Greater China markets mainly observed in the pre-crisis period. Bi-directional spillover is also found mainly in the post-crisis period. The one lag spillover effect from mature markets is found only for Taiwan, which confirms that contemporaneous effect should be taken into account during the analysis. The author concluded that the Chinese markets are partly integrated with mature stock markets. (Rising integration after crisis time), (Intra/Inter -regional linkages), (Some evidence of US influence)
Liu (2007)	US, Shanghai, Shenzhen and five ASEAN countries (Indonesia, Malaysia, Philippines, Singapore and Thailand)	augmented GARCH (1,1) model	December 23, 1998 to December 27, 2006, weekly				The augmented GARCH (1,1) model is used where the mean equation consists of own lag of the market, the previous day lag of the US and China, and volatility spillover represented by idiosyncratic shock from the US and China. The decomposition of idiosyncratic shock allows one to observe global (US), regional (China) and local (country's own specificity) effects for each participating ASEAN country. Asymmetric parameters of the effect are also allowed in the additional model. Significant spillovers from both the US and China (with the exception of Philippines) to participating ASEAN countries are found. However, the magnitude of the Chinese spillovers is rather small compared to the US. The result is also confirmed on variance ratios, where for the Chinese volatility spillover on average accounts 0.2%-2.6% of conditional variance of unexpected return, while US contributed 1.9%-19.3%. Spillover from the US to China is not confirmed. The split of the full sample into two sub-periods due to China's entrance into the WTO organisation confirms the trend of rising integration of ASEAN together with China and the US. No spillover from China is found in the first sub-period, however the second sub-period demonstrated a similar result with the full sample output. The asymmetric effect based on joint hypothesis testing of positive and negative shocks has shown no return spillover effect from China in the second sub-period, while Chinese shocks were found to be significant at 5% level for Philippines and Thailand. The study demonstrates the rising role of China as a regional source of innovation, especially intensified after the Chinese entrance into the WTO. (some evidence of US influence), (Intra-regional linkages)
Johansson (2010)	China, Japan, US, Hong Kong as well as MSCI Europe and World	GARCH, TGARCH and EGARCH models	period 1993-2008, monthly				The author found evidence that the Chinese financial market has become more integrated and the financial crisis, which started in 2008, demonstrated that the process of integration is continuing. (Rising integration during crisis time), (US influence during crisis time)

2.4. Summary of the literature review of stock market integration

Section 2.1 commenced with a discussion of using measurement of the cross-market linkages as a tool for decision making in the theory of portfolio diversification and its transformation into an instrument of the measurement of a degree of market integration. This also shed light on the degree of integration between countries. The section demonstrated the necessity of such measurement, as well as an ambiguity that usually accompanies studies in this area. It also highlighted the econometric methods that are widely used to detect the existence of cross-market linkages, which authors tend to interpret as an indicator of the existence of the integration.

Section 2.2 reviewed the main findings from the relevant literature regarding market integration and prerequisites usually identified as reasons for the integration, such as macroeconomic similarities, trade ties, regional proximity and the time zone factor. The section also highlighted the cardinal difference between mature and emerging markets' specificities.

Section 2.3 is examined the findings on cross-market linkages in each of the BRIC countries or several BRIC countries together in a single study. The summary of findings paints an overall portrait of each of the BRIC countries. However, the studies of cross-market linkages of BRIC countries in a single study are not numerous; the studies by Bhar and Nikolova (2009a), Aktan, *et al.* (2009) are rare examples. Because of this it is likely that the examination of the cross-market interactions of BRIC countries together with mature markets might be important in understanding the ties and specificity of “emerging leaders” and this constitutes first research objective (see Chapter 1, page 4) of the thesis.

There are a number of additional issues, that are relevant to the current research and which are proposed for further discussion in subsequent sections.

The first is the issue of possible exposure of the BRIC countries stock markets to the behaviour of the oil price. Wilson and Purushothaman (2003) pointed out the significant increase that has occurred in the share of world consumption of crude oil accounted for by BRIC countries in recent years. This suggests that BRIC countries' stock markets are possibly exposed to the oil price behaviour. This is likely to be confirmed in the case of oil-exporting Russia (Fedorov and Sarkissian, 2000; Anatolyev, 2005; Hayo and Kutan, 2005) and it is possible for oil self-sufficient Brazil, while the level of exposure of the oil-importing India and China is likely to be less pronounced.

Section 0, therefore, is devoted to a discussion of the oil price effect on the economic activity and the stock market indicators, with a summary of the oil price effect on BRIC countries wherever possible.

The second issue is that the different closing time factor. It is one of the issues that authors tend to focus on when examining cross-market linkages. The literature on cross-market linkages of the BRIC countries not only demonstrated the existence of the studies that allude to the non-synchronism problem (Huang, *et al.*, 2000; Bahng and Shin, 2003), but also participated in an active discussion on related issues (Wang and Firth, 2004; Singh, *et al.*, 2010). This fact demonstrates the necessity of research into the specificity of daily data non-synchronism, treatment of this problem and the consequences of ignoring it. Therefore, this is discussed in Section 4.1.

The third issue is the stability of the detected relationships, which is found in the summary of studies of Section 2.3. This could be traced to the testing of the hypothesis of co-integration (Lucey and Voronkova, 2008). Here the authors are concerned with structural breaks inside the sample and where the recursive estimation is applied. The authors also investigate the application of the rolling estimation, in order to discover how parameter (significance) evolves inside the sample (Anatolyev, 2005; Goriaev and Zabotkin, 2006; Yang, *et al.*, 2006; Awokuse, *et al.*, 2009; Diebold and Yilmaz, 2009). Therefore, this issue is discussed in Section 4.2.

3. Oil price effect on economic activity and the stock market

The conclusion of Chapter 2 highlights the significant role that oil price is expected to play in the economic activity of the BRIC countries³⁴. This is particularly relevant to oil exporting countries like Russia, but assuming a rising consumption of the crude oil by the BRIC group of oil importers, it is possible to postulate that the oil price may influence the stock markets as a representative of economic activity and through that influence it may affect the cross-market causal linkages. Therefore, examination of such an effect is a second main research objective.

In order to commence the investigation it is important to examine the sources of the oil price effect on economic activity. Thus, Section 3.1 examines the theoretical foundation of the oil price effect on macroeconomic activity by referring to the findings from previous research.

Section 3.2 provides a summary of findings with respect to the stock market indicators observed at company level, industry level and market level. The market level interaction with the oil price summary is also decomposed with respect to the oil status and economic profile of the country, which this stock market belongs to. Finally, this section also examines the oil price effect on the BRIC countries.

Section 3.3 draws together the findings on the oil price effect and formalises the main research objective. It further sheds light on any additional issues that should be discussed.

³⁴ Goldman Sachs. BRICs AND BEYOND 2007," p. 260.

3.1. Theoretical foundations of the oil price effect on macroeconomic activity

What makes oil different from other commodities is its fundamental capacity to influence the economy. Kilian (2008a) pointed out that a sharp rise and sustained growth in oil price are not typical of other commodities, and such a rise is deemed to be significant since the demand for energy is relatively inelastic. Awerbuch and Sauter (2006, p. 2807) pose the question: *“How can oil price variation produce such dramatic results when crude oil accounts for only 3% of GDP in the US?”* On the face of it, this figure does not really reflect the cardinal importance of oil as a commodity, but its significance for the US economy and world economy as a whole can hardly be over-estimated.

This section briefly describes the principal concepts governing the effect of oil price on economic activity and also dwells, in some detail, on the empirical findings of the oil price effect on economic indicators.

The literature survey by Brown and Yucel (2002) provides a number of reasons for the importance of the oil price to economic activity. The first is a supply-side shock effect which signals a possible energy scarcity in the future. The effect causes a decline in productivity, reduction in real wage growth with further increase in the unemployment rate. This effect also has strong consequences for consumer behaviour, which is different depending on the duration of the effect. If a short-term effect is expected, consumers tend not to reduce the general level of consumption by saving less or borrowing more which leads to an increase in the real interest rate. If a long-term effect is expected, consumers tend to reduce consumption. Both expectations have a significant negative effect on GDP simultaneously increasing the interest rate and inflation. The second area of interest is a redistribution effect of the purchasing power from the oil-importing country to the oil-exporting country which reduces (increases) aggregate demand for the oil-importer (oil-exporter) (Fried and Schulze, 1975; Dohner, 1981; Horwich and Weimer, 1984). The third area of interest is the real balance effect when the oil price increase causes an increase in money demand. Belated attempts to support the growing money demand will force the interest rate to increase, which will have a depressing effect on economic growth (Pierce, *et al.*, 1974; Mork, 1994). Finally, a change in monetary policy (e.g. increase in interest rate) provided by the authorities in response to the oil price shock, can be a reason for a reduction in the GDP growth.

Summary of the oil price effect on macroeconomic indicators are given in separate sections representing results of the measurement of the effect as well as mechanism of its propagation. Thus, the traditional approach in the oil price effect investigations assumes modelling of the oil price

increase shock as an exogenous parameter and, as noted by Kilian (2008b), oil is treated as an intermediate input in domestic production.

Oil price effect on output

Oil price shocks on output are the most intensively researched group of studies. The early studies are represented by GDP regressed with other variables and the oil price (Rasche and Tatom, 1977a; Bruno and Sachs, 1982). The most frequently cited is a study by Hamilton (1983) which established the regularity that a rise in oil prices usually precedes a recession. This does not necessarily mean that the oil price shock is a sufficient condition for recession, since monetary policy and inflation are the other factors that influence GDP. In the sample period from 1949-1972 it was found that a 10% increase in oil price is reflected in a GDP decrease of 0.5%, and possibly more, for several quarters after that. The relationship also remained unchanged in the time period 1961-1982 with respect to the OPEC embargo in 1973 (Gisser and Goodwin, 1986). Furthermore, an investigation of a comparable period by Hooker (1996) demonstrated that a 10% oil price increase precedes a fall in GDP of 0.6%. A further study by Rotemberg and Woodford (1996, p. 555) covering the period 1947-1980 showed that a 10% increase in the oil price reduced the output by 2.5% after 5-7 quarters, which differs significantly from the previous findings. Hooker (1996) and Bernanke, *et al.* (1997) also point to the fact that output responded differently to oil shocks after 1984. For the most recent time period between 2003-2005 Rogoff (2006) found that, on average, an increase in oil price caused a fall of up to 1.5% in output. However, results may change due to different price levels (i.e.: 10% oil price increase from 30\$, 50\$ or 100\$) which, together with oil price asymmetry (Mork, 1989), unexpected innovations attributed to the volatility (Lee, *et al.*, 1995) may suggest that non-linear models (Cuñado and Pérez de Gracia, 2003; Jiménez-Rodríguez and Sánchez, 2005) are more plausible. Nevertheless, it appears that the authors generally accepted a decrease in the oil price effect on the US economy, compared to the period before the eighties (Herrera and Pesavento, 2007; Kilian, 2008b).

Finally, a new branch of the analysis is the investigation of oil price dependence on world output. Barsky and Kilian (2001, 2004) suggest that both the supply and demand are affected by the global macroeconomic indicators, mentioning real economic activity and the interest rate. Kilian (2006) points to the surge in crude oil prices since 2002 which, from the author's point of view, is driven by demand for crude oil, especially when the capacity for the expansion of oil production in the future is limited.

Oil price effect on unemployment

Studies regarding the effect of an oil price rise on the labour market mainly confirm the existence of the inverse effect on employment. These studies can be arranged into three groups regarding the applied model and data applied.

The first group utilises production function based models. Discussion of the mechanism of the oil price effect is usually organised through the input price shock in the production function framework (Rasche and Tatom, 1977a, 1977b; Bruno and Sachs, 1982). As part of the production function framework, the concept of a sectoral-shift effect on aggregate unemployment is examined in the study by Lilien (1982) where it was concluded that labor relocation as a part of the sectoral-shift effect is significantly contributing to aggregate unemployment. A further development in the multi-sector model is performed by Hamilton (1988), where it is suggested that the relative price shock (i.e. energy price shock) may induce workers to remain unemployed in the adversely affected sectors, instead of relocating to sectors that have been positively affected. Having investigated the effect of the appreciation of the US Dollar on wages, Kandil and Mirzaie (2003) found no evidence that energy price fluctuations affect aggregate employment. Moreover, unanticipated energy price fluctuations have a positive effect on nominal wages inflation in the services, transportation and wholesale trade industries and on employment in construction, manufacturing, mining and transportation industries. The anticipated energy price shift effect on employment is found for the mining industry only. This could be explained by the assumption that labour and energy are substitutes in the mining sector (Ewing and Thompson, 2007).

The second group of studies is based on the models that utilise the employment statistics. Keane and Prasad (Keane and Prasad, 1996) applied employment statistics, obtained from the National Longitudinal Survey of Young Men, to represent various sectors in the US economy in to the regression model. The authors found that an oil price increase causes real wages to decline. Besides this, the short-term effect of positive oil price shocks induces an increase in aggregate unemployment. However, in the longer-term aggregate employment is not reduced due to the positive shock of the oil price. Davis and Haltiwanger (2001) analysed job creation and destruction in different sectors of the US economy in the period from 1972 to 1988, confirming that job destruction shows much greater short-term sensitivity compared to job creation. Overall, oil shocks induce unemployment growth to fluctuate by 20-25%.

The third group of studies is an application of the time series econometric models and Granger causality (Granger, 1969) test. Hamilton (1983) applied VAR models to a set of macroeconomic

indicators, including unemployment. He found that the two sample periods (1949:2-1972:4; 1950:2-1972:4), observed quarterly, unambiguously showed that the changes in oil prices caused unemployment to rise in the US. Carruth, *et al.* (1998) applied VAR with ECM and found that the oil price caused unemployment to rise in three sample periods (1954-73; 1973-95; 1954-95) again using US quarterly data. In a contradictory result, a study by Hooker (1996) found that the causality from oil price increases to the US unemployment was confirmed up to 1973, but not the after that point. Regarding Hooker's (1996) results Hamilton (1996) suggests that the use of the net oil price increase instead of logged returns were based on the assumption that most of the individual price increases observed since 1986 were a corrections to earlier falls in prices.

Oil price effect on consumer behaviour

A number of authors highlight that the transmission of wealth from oil importers to oil exporters makes a significant reduction in consumers' income. Edelstein and Kilian (2009) pointed out that: 1) high energy prices reduce discretionary incomes after the payment of energy bills; 2) oil price fluctuations create uncertainty about future trends in energy prices, causing shrinkage of sales of durable goods and irreversible purchases (Bernanke, 1983; Pindyck, 1991; Kuper and Soest, 2003); 3) the instability of the oil price forces rational consumer to increase precautionary savings in the face of rising energy bills or the probability of consumers becoming unemployed. 4) Consumers tend to postpone or decide against purchases of energy-using durables, the effect being especially drastic for vehicles with high petroleum consumption (Hamilton, 1988, p. 594; Bresnahan and Ramey, 1993; Lee and Ni, 2002). Thus, it is pointed out that the price of crude oil products and substitutes has a significant impact on consumer's behaviour, and in the literature it is represented as a transmitter of the oil price shock. The studies by Balke, *et al.* (1998) and Huntington (1998) demonstrated the existence of an asymmetric effect of the various crude oil products and substitutes. Jones, *et al.* (2004, p. 10) points out that asymmetry in crude oil products exists in the speed of responses, while in the oil price to GDP relationship, it is mainly the magnitude of response. Kilian (2008a) highlighted the distinction between retail prices for crude oil products and the crude oil price, suggesting that the crude oil price, supplemented by refining capacity, may better explain the behaviour of gasoline prices. Further, the author emphasises the necessity of focussing on retail energy prices when consumers' response to high oil prices is examined.

Finally, there is an on-going debate on the connection between an increase in the oil price and food prices due to the development of bio-fuel. The mechanism of this effect is demonstrated as follows. During the time of high oil prices, all oil substitutes (e.g. coal, gas, bio ethanol, biodiesel) express an increase in price which, in the long-run, will induce farmers to cultivate energy-rich crops instead of

food crops. Therefore, energy-rich crops, during the period of high energy prices, “crowd out” the crops used for food production. This effect inevitably shrinks the food supply providing a supply-side shock to agricultural production ("World bank. Potential for Biofuels for Transport in Developing Countries 2005," p. 74; McDonald, *et al.*, 2006, p. 263). Thus, consumer’s income may suffer from not only a direct effect from high energy bills, but also from rising prices of food since food, directly or indirectly, is treated as a substitutes for energy, providing an unambiguous nexus to the crude oil price as one of the main energy indicators.

Studies regarding the econometric analysis of a substitutability effect between the oil price and crops used as bio-fuel are not numerous and mainly descriptive (Mitchel, 2008; von Braun, 2008). A study by Chang and Su (2010) investigate the behaviour of corn and soybean³⁵ futures prices in the two sample periods (Jan 4, 2000 - May 10, 2004; May 11, 2004 – July 14, 2008). The purpose of the study was to establish whether corn and soybean futures prices were driven by the crude oil fluctuations or by their own specific agricultural characteristics. For this purpose a bi-variate EGARCH model, with the change in the oil price added as an exogenous variable, was estimated. The study found no evidence of a price spillover effect from the crude oil to corn and the soybean futures in a period of low crude oil prices (before May 11,2004) but the oil price spillover effect was found to be positive and significant over a period of high crude oil prices (after May 11,2004). The study confirms the existence of the substitution effect when oil prices are high, which could be explained by the fact that higher oil prices give the signal that processing of bio ethanol and biodiesel becomes economically viable. The result suggests that future food prices are likely to be volatile, since according to Regnier (2007), “oil prices are highly volatile compared with all products manufactured in the United States”. Thus, all the substitutes of energy commodities are also subject to high volatility.

Oil price effect on Inflation

Despite the output and employment effect, the oil price effect has a strong positive effect on inflation. The measurement of the oil price effect on inflation is performed by means of various models. It is possible to distinguish two approaches – first, measurement through consumer price or wage growth, both by applying regression or VAR models; second, through the Philips curve (Hooker, 2002). Similar to other macroeconomic indicators, the oil price shock of the 1970s made it possible to carry out a number of research studies using the various econometric instruments.

³⁵ Corn and soybean are used in a production of bio ethanol and biodiesel (Chang and Su, 2010).

The earlier studies have mainly established the inverse effect on economic activity in oil importing countries (Rasche and Tatom, 1981; Darby, 1982; Hamilton, 1983; Burbidge and Harrison, 1984; Huntington, 1998), which leads to inflationary concerns through the supply-side shock channel (Brown and Yücel, 2002, p. 195). For example, Hamilton (1983) utilized the VAR model and Granger Causality test in order to examine the effect of the oil price effect on inflation and other economic indicators in the US. It is not specified “to rise” or “to decline” since the decomposition to the negative and positive shock of the oil price (allows response to rise/decline in oil price) is not performed and regression equation in its structure has not allowed asymmetry of the oil price effect. Furthermore, Burbidge and Harrison (1984) provided an investigation of the oil price shock on macroeconomic variables, including inflation, for developed countries. The authors found that oil prices drive consumer prices (CPI) in all countries, but statistics were less significant for oil exporting Canada. Using similar a methodology, but with correction for the asymmetric effect and the use of additional oil variables (“Scaled Oil Price Increases/Decrease” proposed by Lee, *et al.*, 1995), Jime´nez-Rodríguez and Sa´nchez (2005) found that an oil price shock increased the inflation rate in all countries, except Germany. In addition it was found that the GDP growth response of the oil exporting countries (the UK and Norway) was affected differently by the oil price increase which may be explained by the different proportions of oil export revenue and oil industry contribution to the GDP in those countries. Therefore, regarding the oil price effect the activation of the channel of redistribution effect of purchasing power from oil-importer to oil-exporter countries with a large proportion of oil export revenue may express appreciation of the national currency, which may lead to a decrease in oil-exporter’s inflation. Cologni and Manera (2008) applied the VAR model to the oil price shock, GDP and inflation for the G7 countries in a quarterly sample period from 1980:1 to 2003:4. They found that the oil price shock is affected all G7 countries, except the UK and Japan. The study also confirmed the role of interest rates in transmitting the oil price shock. The impulse response analysis confirmed the existence of an instantaneous but temporary effect on the oil price innovation. The study is in line with other studies that find the oil price shock effect is also complemented by the monetary policy³⁶ environment with specificity for each country under investigation.

³⁶ The discussion regarding monetary policy has always accompanied the research regarding oil price effect on output, employment or inflation (see, for instance, Darby, 1982, p. 739; Lilien, 1982; Hamilton, 1983, p. 245). Romer and Romer (1990) suggested that recession was created by the anti-inflationary actions of the Federal Reserve. Despite the methodological shortcomings discussed in the studies by Dotsey and Reid (1992a, pp. 14,15), Hoover and Perez (1994), Bernanke, *et al.* (1997, pp. 96,97). The extensive discussion regarding oil price shock and monetary policy can be found in studies by Bernanke, *et al.* (1997), Leduc and Still (2004).

Measurement of the oil price shock effect on inflation using the Phillips curve³⁷ allowed Hooker (2002) to find evidence of the regime change in the pattern of the oil price shock effect on inflation. The author suggested that, prior to 1980, the oil price shock contributed to core inflation while, after this point, the effect of the oil price shock on core inflation was diminished. Hooker established that structural-break characterisation of the model appears to be robust with a better fit of the asymmetric and nonlinear representation of the oil price. However, Hooker fails to verify the hypothesis that such lessening of the oil price shock effect is performed due to the decline in the energy intensity of the economy. Another probable reason is the change in monetary policy, which possibly organised a regime where the inflation started to be less sensitive to oil price spikes. Applying Hooker's (2002) assumptions, LeBlanc and Chinn (2004) found that the oil price shock has only a modest effect on inflation in the US, Japan and the EU, while Gregorio, *et al.* (2007) showed that an average estimate of the oil price shock pass-through to inflation falls in the developed countries and, to a lesser extent, in the emerging countries. In addition to the factors of the diminishing effect of the oil price shock on inflation, the authors suggest a reduction in the exchange rate pass-through and the strong world demand for crude oil, while Chen (2009) highlights the effect of appreciation of national currency, active monetary policy towards inflation and an increasing degree of trade openness.

³⁷ Hooker (2002) refers to the application of the Phillips curve measurement applied by Fuhrer (1995) and Lown and Rich (1997).

3.2. Oil price impact on stock market

Having established the crucial role of the oil price on economic activity of countries, it is now possible to examine the effect of the oil price on stock market indicators.

Before starting such an examination it is important to emphasise the following: The literature on interdependence demonstrates the existence of a specific nature of behaviour of mature markets and emerging markets. On the other hand the literature on the oil price effect also demonstrates distinguishable groups, which are organised with respect to their oil exporting/importing status. Therefore, it is necessary to analyse the oil price effect with respect to the given parameters of the countries (oil-status and economic profile).

Section 3.2.1 gives a summary of the literature regarding the company and industry level responses to the oil price effect, which may be treated as the main drivers of the market index behaviour.

Section 3.2.2, 3.2.3, 3.2.4, 3.2.5 summarize the findings of the studies with respect to the oil status (exporting/importing) and economic profiles (developed/emerging) of the countries in question.

Section 3.2.6 gives a summary of the oil price effect on the BRIC countries.

3.2.1. Response to Oil price changes on industries' and companies' levels.

There is a large volume of published studies describing the role of the oil price shock in influencing stock markets indicators. The authors are mainly interested in the sign, magnitude and significance of the oil price (or its proxies) estimates in explaining behaviour of market indicators.

The first extensive discussions and analyses of the oil price effect on industries emerged with studies focussing mainly on the Oil & Gas industries, with further expansion to the construction and mining industries. These studies confirmed the existence of a positive response from the given industries to oil price fluctuations. Manning (1991) utilised a regression model in order to test the hypothesis of a positive impact of the oil price effect on oil production in related sub-sectors: Oil extraction sector, Exploration, Integrated oil producers. The author found no evidence against the given hypothesis. Moreover, the market estimates represented by SE100 (Stock-Exchange-Financial times index) index returns were substantially smaller compared to estimates of oil price changes. Al-Mudhaf and Goodwin (1993) using the APT model found evidence that the oil price shock raises returns for firms with a substantial part of their assets in domestic crude oil production. Huang, *et al.* (1996) utilising the daily closing price of NYMEX Oil futures, S&P500 index and Treasury bill for the period from 1983 to 1990, provided a Granger Causality test using the VAR framework. The S&P500 stock index was observed on three levels: 1) stock market index as it is 2) petroleum industry index 3) stock prices of

three individual oil companies. Strongly significant results of Granger causality were found for the petroleum industry and all individual stocks under investigation. However, the oil futures did not demonstrate any statistical significance in the leading S&P500 index. No statistical significance was found in the case where Treasury bills and the S&P500 index attempted to cause the oil price. This study contradicts others that underline the importance of oil price for the economy. Also, the fact that returns of the Petroleum industry index and Individual oil company shares depend on Crude oil futures might justify the significance of the influence of oil futures on stock indices where oil companies' dominate.

Since around the end of the 90s, authors started to concentrate on the response from stock market indicators of other sectors and they attempted to make comparisons. The oil & gas and related industries continued to have a positive response with respect to the oil price shocks, while other industries usually demonstrate a negative response to shocks conditioned on the energy intensity of the industry and shocks on consumer behaviour. Faff and Brailsford (1999) utilised the two-factor CAPM in order to investigate sensitivity of the Australian sectoral index returns on oil price changes treated as a factor. The sample period spans from 1983 to 1996. The authors found that the oil price had a positive and significant effect on the Oil & Gas industry and Diversified resource industries, while for the Paper and Packaging, Transportation and Banking industries the oil price impact is found to be negative. Hammoudeh, *et al.* (2004) utilised a daily data series of the oil spot/NYMEX futures and five S&P oil sector stock indices in the VECM model for the period from July 17, 1995 to October 10, 2001. The findings suggest that the oil industry indices show bidirectional causality with all observed Oil futures except 3-month future price, while these particular futures can explain the stock price movements of independent companies engaged in exploration, refining and marketing. El-Sharif, *et al.* (2005) utilise the data of Brent Crude oil in the analysis of its impact on the daily market portfolio excessive returns (return of FTSE All shares subtracted for 1-month UK Treasury Bills). Also, additional variables were contributed to the study e.g. daily excessive returns for the London Oil & Gas sectors index, the daily change in the US \$/UK £ exchange rate and the daily change in the difference between 3- and 1- month UK Treasury Bills. The data were daily observations in half-year sub-periods for the sample starting from January 1, 1989 to June 30, 2001. Two and four factor regression models with (White, 1980) heteroscedasticity correction were used to explain the returns of the London Oil and Gas index. The daily shares return and oil price movements show a positive sign of the estimate in all sub-samples. The daily shares return estimates were significant in all sub-samples. However, oil price estimates were significant in 9 out of 25 sub-samples. In contrast, the oil price showed variability in the sign of the estimate, but the estimate was mostly insignificant in the Mining, Transport, Banking, Software/Computer service sectors.

Recent research papers provide a more thorough analysis, expanding the scope of the analysed countries. Nandtha and Faff (2008) examined the effect of oil price changes on 35 industries in a period from April 1983 to September 2005 using monthly data. A regression model is used with World market returns and WTI oil price. The World market index is preliminarily exempt from oil price shocks using a univariate regression model. The oil price is modelled as unanticipated change, which is derived by the difference between real value at time (t) and expected value model in one step ahead forecast of AR(1) process. The study also investigates the asymmetric responses on oil price innovations. The result on the Mining and Oil & Gas industries stays in line with the other studies, confirming the positive response to oil price change, while all other participating industries demonstrated a negative sign. Agusman and Deriantino (2008) applied OLS regression for 9 industrial sectors of Indonesia together with WTI Crude oil price in a time period from January 1996 to June 2008, observed on a monthly basis. The model was constructed assuming a contemporaneous relation between the sector index and oil price, and the asymmetric effect as a special model. The paper in particular emphasises the liberalisation of domestic oil price due to the fact that, after the year 2003, Indonesia had technically become a net oil importer state. Relying on the time period following the liberalisation the authors found that the impact of the oil price effect is positive for the Mining sector and negative for the Trading sector, Consumption and Infrastructure sectors. The authors also documented that a decrease in oil price does not improve investor activity. Barkoulas, *et al.* (2008) applied the Multi-beta CAPM in the form of a regression model to examine responses of the oil extracting related companies to changes in the oil price. The system of equations is solved using a Seemingly Unrelated Regression method with oil commodity price changes, MSCI world index and risk associated with geopolitical events, (represented by date: 09/11/2001), which during the estimation is restricted by a set of dummies. The lack of significance of the oil price beta for each participating oil-related company led the authors to make a decision that oil-related companies are not the best opportunity for hedging during the geopolitical events.

McSweeney and Worthington (2008) examine the oil price as a pricing factor for the excess returns of the Australian industries in the time period from January 1980 to August 2006 on a monthly basis. WTI oil price is used in a regression model together with other macroeconomic factors (Market returns, Exchange rate, Term premium) following the studies by predecessors (Faff and Brailsford, 1999; Sadorsky, 2001). The changes in oil price are found to be positive and significant for Energy and Materials sectors in contemporaneous time, while a significant and negative effect is shown in the Banking and Transportation sectors and at lag 1 for the Retail sector. Gogineni (2009) shows that since the main customers of the industry (demand side) and the industries' own oil price dependence (cost dependence) are affected by the oil price, then the index of that particular

industry is sensitive to oil price changes. The oil price returns beta from the regression model with a set of other economic indicators is estimated in the time period from January 1998 to December 2006. The positive and significant oil price beta is found not only for the Oil & Gas and related industries, but also for Primary metals, Management of companies and enterprises. A negative relationship is found for the Air transportation, Financial sector (Federal reserve banks, credit intermediation, and related activities; Insurance carriers and related activities), Accommodation, Food service and drink places. Özkan (n.a.) utilising a sample period from 2000 to 2008, observed on a daily basis, used 19 industrial stock indices from the Istanbul stock exchange in order to examine the impact of Brent Crude oil price. On the basis of a regression analysis, it was found that Defence and Energy industries returns are strongly affected by oil price changes. However, Non-metal, Food and Beverages industries are the least affected. A negative relationship is found for the Tourism and Transportation industries. Swaray and Hammad (n.a.) investigated 36 non-integrated oil-related firms from the following sectors: Drilling and exploration, Equipment and services, Pipeline owners and operators, Refining and marketing. The GARCH(1,1), TGARCH(1,1) model was applied in order to investigate the oil price return volatility in a conditional variance equation for all participating companies in the time period from January 1997 to January 1999, observed on a monthly basis. The highest rate of volatility is found for the Refining and Marketing sectors. Malik and Ewing (2009) applied a bi-variate BEKK-GARCH (1,1) model for WTI oil price and five US industrial indices (Financial, Technology, Consumer services, Health care, Industrials) obtained from Dow Jones in the time period from January 1, 1992 to April 30, 2008 and observed on a monthly basis. The author reported the conditional variance equations where the oil price is allowed to be affected by volatility and squared innovations of the corresponding industrial sector. The indirect significant effect of oil price is found only for the Technological sector, which is explained by the fact that unexpected changes in the oil price make technology firms more risky in terms of volatility. Oil price return volatility spillover was found for the Consumer service and Health care sectors, which explains the fact that an increase in oil price or risk factor of supply affects the demand for goods and services.

3.2.2. Oil price effect on the developed oil-importing countries' stock market

The initial research studies concentrated on the linkage between the stock market and the price of oil as part of research on the influence of oil prices on the economic activity of a country. The markets of developed nations have proved to be obvious leaders, the US market in particular, due to the ease of access to data, availability of econometric tools and interest on the part of investors and policy makers. In this connection it is worth mentioning again the research study by Hamilton (1983) where the multivariate VAR model was constructed and the Granger Causality test confirmed that the US stock market was led by the oil price. The idea of investigating the oil price effect on the stock

market indicators was further developed by Kling (1985) who also tested the non-causality hypothesis. He pointed to the delayed effect of the oil price rise on stock market behaviour with a further decline in economic activity. The oil price effect in the time period from 1973 to 1982 was found to be significant in industries where oil is used as an input factor.

Use of CAPM and APT models

Further research relating to the interaction of oil prices with the stock market was conducted as part of Capital Asset Pricing Model (CAPM). The development of CAPM presupposes a search for economic indicators which could assist in portfolio optimisation and improve on the results of forecasts. Herewith, it is necessary to single out the study by Chen, *et al.* (1986), where the factor loading is represented as a list of economic indicators which represents economic state variables, these are related to the economic factors that explain pricing of the asset on the stock market (see, for instance, Fama and MacBeth, 1973; Chen, *et al.*, 1986, p. 394). The oil beta was found to be significant in the overall period and two out of four sub-periods. Inclusion of the oil price into the model induced fall in the significance in other factors (e.g. industrial production) simultaneously rising the risk-premium variable and term-structure variable. By comparison with the model without oil price inclusion, the authors concluded that oil price was not priced properly in the period from 1968 to 1977 when the OPEC cartel became important. Hamao (1988) applied the same method with respect to the Japanese stock market, with the focus on international factors due to the importance of international trade to Japan. The author also concluded that the price of oil was not priced in a model in the sample period from 1975 to 1984. Kaneko and Li (1995), by applying the VAR model, confirmed that the oil price was found to be significant in its effect on the Japanese stock returns and innovations in the oil prices explain 8.2-8.8% of the forecast error variance.

Further analysis is concentrated on a lead-lag relationship, which is similar to the investigation of market linkages discussed in the previous chapter, since it utilises similar econometric models. Similar to the Chen, *et al.* (1986) comparison, Jones and Kaul (1996) estimated a regression model with stock market and cash flow variables, with and without oil price inclusion. The rationale of this procedure was to determine whether stock price overreacts to new information, which inevitably has consequences for economic activity. Stock price behaviour might depend on the oil price volatility shock impact on cash flow. In order to confirm the existence of the effect, the study utilises Granger causality test. The main findings of the Jones and Kaul (1996) study was that the oil price in the post war period had a significant detrimental effect on the stock market returns in the US, the UK and Japan.

VAR, VECM and volatility modelling

Sadorsky (1999) applied the GARCH (1,1), VAR model with the application of variance decomposition and impulse response function. The data was represented by a set of economic variables: industrial production, interest rate, real oil price and real stock return. The monthly data covers a period from 1947:1-1996:4 which is split into two sub-periods, by treating the year 1986 as a point of regime switch. Variance decomposition demonstrated that the oil price shock effect rose in magnitude in the second period compared to the previous period. The study also examines the asymmetric effect of real oil price and real oil price volatility shock, which is derived by the extraction of standardised errors from the GARCH (1,1) model. In the first sub-sample, the positive shock explained more in real stock returns compared to the negative shock, while in the second period the positive and negative shocks demonstrated the same effect on real stock market returns. Application of the real oil price volatility demonstrated that positive volatility shocks explain a large proportion of forecasting error variance of real stock returns compared to the negative ones. Both return and return volatility shocks of the oil price have a significant effect on economic activity, while economic activity has a small effect on oil prices, which can be interpreted as the exogenous nature of the oil price. Ciner (2001) applied Granger causality based on the VAR and Hiemstra and Jones (1994) non-linear causality test. The data set is represented by the S&P500 index, crude oil and heating oil from NYMEX in a time period which start from 1979 and 1983, respectively, and end in the year 1990. The VAR model failed to detect Granger Causality. Residuals were exempt from serial correlation extracted from the VAR model and then applied to the Hiemstra and Jones (1994) test. The Hiemstra and Jones (1994) test confirmed the existence of non-linear causality from crude oil futures returns to stock index returns, while no non-linear causality was detected from heating oil returns to stock index returns. After the application of standardized residuals extracted from the VAR corrected for the 1990 dummy variable which assumed the Iraq invasion of Kuwait, it demonstrated the existence of bidirectional causality between both pairs of indices. The author ascribed this relationship to the existence of a feedback effect and suggested that oil price might be endogenous to the economic activity represented by the stock market (Barsky and Kilian, 2001) and represented by the non-linear specification which is in line with Hamilton (2003). Further, Ågren (2006), by applying the VAR(2)-BEKK model with parameter restrictions, also assumed that oil price is an exogenous factor in the model. The sample period spans 1989 to 2005 utilising data on a weekly basis. Evidence was found regarding the oil price volatility spillover to Japan and the US. Moreover, Japan and the US responded asymmetrically to the oil price shock, while the UK responded symmetrically. O'Neill, *et al.* (2008) confirmed the evidence that higher oil prices adversely affected the stock markets of the US and France in the time period from 2003 to 2006. The authors interpreted this finding by the fact

that these countries are significant energy consuming countries. Park and Ratti (2008) analysed 13 European countries together with the US stock market indices which were observed in relationship with the UK Brent Crude Oil index. The sample ran from 1986 to 2005, observed monthly. The authors found that the impact of the oil price on stock market returns were statistically significant within the same month and one month horizon in the VAR model. All oil importers had a negative response to the various proxies of the oil price change. Chiou, *et al.* (2008) applied the threshold autoregressive model (TAR) suggested by Enders and Granger (1998) and its modification momentum-threshold autoregressive model (M-TAR). The data was represented by the S&P500 index WTI oil price in the sample period from 1992-2000, observed daily. The authors confirmed the existence of unidirectional causality in the event of negative shocks on the error correction term, which is in line with findings regarding exogeneity of the oil price with regard to stock market behaviour suggested by Sadorsky (1999). Sariannidis, *et al.* (2009) applied the multifactor univariate GARCH(1,1) and I-GARCH (1,1) models, where the oil price was included as an exogenous variable to the conditional mean equation. The authors found evidence that oil price negatively affected the US stock markets, while the US 10-years bonds had a positive effect. The Miller and Ratti (2009) multivariate co-integration model, together with VECM on the OECD countries stock market index, interest rate and industrial production was observed on monthly bases from 1971 to 2008. The break points were allowed in the estimation, and Camarero and Tamarit's (2002) rolling likelihood ratio technique based on the Hansen and Johansen (1993) approach was applied to detect them. Three structural breaks were detected during the estimation phase. The authors found a co-integrating coefficient with a positive sign for two periods (1971-1980 and 1988-1998), which the author interpreted as evidence of a clear long-run relationship between OECD stock markets and oil price. No statistically significant relationship was confirmed in the period 1980-1988, while in the last period (1999-2008) the authors interpreted it as the existence of a substantial break since some coefficients expressed sign reversal behaviour, which can indicate the existence of a change in the relationship between the oil price and the stock price.

Exogeneity vs. endogeneity of oil price.

Contrary to this, Kilian and Park (2009) provide a critique of the assumption of the exogenous nature of the oil price effect. The study is based on previous papers by Barsky and Kilian (2001, 2004) and Hamilton (2003). The crucial point is that a rise in the oil price should be decomposed due to its source. The authors distinguish the following sources of the oil price increase: supply-side shock due to the shortfalls in oil production, demand side shock due to rapid development of the world economy; precautionary demand for crude oil due to the expectations regarding future oil supply

shortfalls. For this purpose a structural VAR model is applied for the period starting from 1973.1-2006.12, observed monthly. The authors concluded that the joint demand and supply shock explained one fifth of the long-term variation in the US real stock returns. The authors stress the finding that shocks to the production of crude oil are less important compared to shocks of the booming world economy that cause a rise in the aggregate demand for industrial commodities, or shocks to the precautionary demand. The latter has a significant impact due to the political instability in the Middle East region, which may cause an immediate rise in the precautionary demand with a spillover to the oil price and fall in stock prices.

Apergis and Miller (2009), by modifying the Kilian and Park (2009) procedure, applied VECM with a decomposition of oil price change into the following components: oil-supply shock, global aggregate demand shocks, global oil-demand shock (precautionary demand). The analysis was performed on a set of developed countries. The temporal causality test showed that only in the case of Australia, the lagged variable of the oil supply shock caused stock returns. Germany, Italy, the UK and the US demonstrated a consistent pattern with causality from the variables of global aggregate demand for oil and global oil-demand. Japan, together with Canada, revealed no causality effect for each of the sources of the oil shock. Finally, the authors confirmed that the overall strength of causality is low, which indicates a low predictability of stock returns which, in its turn, leads to the conclusion of a high level of stock market efficiency.

Application of regime switching models

A special class of studies are empirical investigations into whether the reaction to the oil price from the stock market is more rapid and strong compared to the reaction from the industrial production side. Cobo-Reyes and Quiros (2005) modified Hamilton's (1989) model of industrial production by the inclusion of an ARCH specification and a model developed by Raymond and Rich (1997) for the analysis of the oil price effect on GDP growth in the framework of the Markov switching model. The sample period runs from 1963 to 2004 and is observed on a monthly basis. The main conclusion of the study is that the US stock market responds faster to the oil price increase than to industrial production. However, the long term effect is found to be stronger for industrial production. The overall effect of the oil price on both variables is negative. Aloui and Jammazi (2009) applied the two-regime switching EGARCH model to analyse the relationship between the oil price shock and the stock market. The investigation of the Japanese, French and UK stock markets is performed on the sample period from 1998 to 2007. Two regimes are identified: the first one captures the behaviour during a "bear market" with low expected returns and high variance, which is likely to appear during a recession state; the second regime is a "bull market" which is represented by higher expected

returns and low variance. Both regimes are detected in the observed sample period. The authors found evidence that recession is associated with a low mean/high variance regime. Overall, the finding is that the oil price increase has a significant explanatory power for both the volatility of stock returns and the probability of transitions across regimes. Chiou and Lee (2009) applied the Autoregressive Conditional Jump Intensity (ARJI) model with structural changes on the S&P500 index and WTI oil price (spot and futures) in a time period from 1992 to 2006, observed daily. The result confirmed the existence of a negative impact of the oil price shock on stock index returns, emphasising that the asymmetric effect is found to be statistically significant only in the high-fluctuation states. Chen (2010) applied the time varying transition probability Markov switching model using S&P500 and world average crude oil price index. The time period is represented by the interval from 1957 to 2009, observed on monthly basis. The author concluded that a higher oil price increases the probability of switching from a bull market to a bear market. Moreover, a higher oil price induces the stock market to stay in the “bear” regime.

3.2.3. Oil price effect on emerging oil-importing countries’ stock market

Considering the growing interest in the emerging markets in recent years, researchers started paying greater attention to the oil price impact on the dynamics of the stock markets of developing economies. Research studies which compare the effect of oil prices on oil importers with mature and emerging stock markets are fairly few in number. The majority of such studies are conducted on large groups of countries with no division into oil importers and oil exporters. In view of this, an attempt has been made to summarise the relevant research articles dealing with the response of stock markets of developed and emerging economies to changes in oil price, taking into consideration the fact that most countries in the designated categories could be regarded as oil importers.

In the study by Maghyereh (2004), 22 emerging markets (excluding Russia) were observed utilising the VAR model and generalised decomposition of forecast error in response to a day closing price of Brent Crude Oil. The period under investigation stretched from January 1, 1998 to April 31, 2004, observed daily. The conclusion of the research is that the generalized decomposition analysis showed that the Brent Crude oil price had no significant influence on the emerging markets under investigation. It explained less than 2% of forecast errors, and in 16 out of 22 emerging markets the ratio fell to less than 1%. The impact of oil price was found to be higher in the countries which have energy-intensive consumption. Moreover, the author found evidence that the oil price shocks are highest in the largest Asian and Emerging European countries, emphasising the factor of energy intensity of consumption. Regarding the difference in response between oil price and stock markets of emerging and developed countries, the author stated that the results provided weak evidence of

the existence of the relationship. Innovations from the oil market are slowly transmitted to the stock market, which the author ascribed to the inefficiency of emerging economies. The author tentatively suggested that the role of the oil price for the emerging economies is overestimated.

Driesprong, *et al.* (2008) examined the predictability of the developed and emerging markets with respect to different oil price indicators by the means of a regression model, using both weekly and monthly data. Developed markets are found to have a more pronounced relationship with the oil price, since the author rejected the null hypothesis of no oil price effect. The emerging markets show different responses to different oil price indicators, e.g. the null hypothesis cannot be rejected for the West Taxes, Brent and oil futures, while for Arab light oil the null hypothesis is rejected at the 10% level of significance. The inclusion of the world market index as an additional regressor intensifies the significance of oil estimates, while for emerging markets the estimates becomes insignificant. Similar to Maghyreh (2004) the authors also found delayed responses to oil price fluctuations. Both the developed and emerging economies respond in a similar way when the higher lags of oil prices are included, while the developed market demonstrated better predictability.

Ramos and Veiga (2009) examined the exposure of the oil and gas industry of 34 countries to oil prices fluctuations. The sample spans the period from 1998:05 to 2009:06. A multifactor panel model is used with a set of additional explanatory variables representing the World factor (world market portfolio excess return), the Local factor (Local market portfolio excess return), oil price and oil price volatility³⁸ with and without asymmetric decomposition and the Exchange rate. The same factors were also used in the earlier studies by Chen, *et al.* (1986) and Ferson and Harvey (1997). The sector indices are rearranged into mature and emerging markets groups. The author found evidence that the effect of change in the oil prices is large and positive for the developed countries, compared to the emerging markets. The oil price volatility was significant in all cases for the developed countries, while for the emerging markets it was found to be insignificant. The authors found the existence of the asymmetric effect, when a positive shock had a greater impact compared to a negative one. A subsequent study by, Ramos and Veiga (2010) demonstrated additional evidence of the existence of a different response to the spot and future oil price fluctuations from developed and emerging markets. The same APT model is applied to the data set of 43 countries grouped into the developed and emerging markets. Each group investigated for the existence of possible effects in a given set of options: 1) examination of oil price return asymmetric effect; 2) examination of simultaneous oil price return and oil price volatility³⁹ effects; 3) application of previous two options

³⁸ Oil price volatility is obtained using moving average used on standardized residuals obtained by fitting the AR(1) model to oil returns (Gallant and Tauchen, 1998).

³⁹ Oil price volatility is represented by the absolute returns of oil price changes (Kogan, *et al.*, 2009).

in quintile regression form, which allows the effect to be observed depending on different levels of oil price return and volatility. Regarding the first option, the authors highlighted that developed markets are likely to have a higher magnitude and significance of oil return asymmetric parameter estimates. The estimates of emerging markets are usually small in magnitude and insignificant, with a positive response to the oil price increase, which is cautiously ascribed to the mix of emerging oil-importers and oil-exporters in the data set. In the case of developed countries, the hypothesis of no oil price return effect and hypothesis of symmetrical effect of oil price return was rejected, while the emerging markets case demonstrated a lack of rejections. The outcome in the second option demonstrated that the developed markets' returns fall when oil price becomes more volatile, while the emerging markets do not express any significant exposure to the oil price risk. The third option uncovers a potential difference in factors across quintiles. Developed markets demonstrate a higher stability of the sign across quintiles, both in the case of asymmetric oil returns and in the case of oil price volatility. The significance of developed markets is likely to exist on smaller quintiles, whilst in the case of emerging markets; the results of the parameter significance are mixed. Overall, the authors documented this effect by highlighting the difference between developed and emerging markets in response to the oil price fluctuations which the authors ascribe to the two groups of separate asset class behaviour. This finding is in line with the research work by Bekaert (1995) who stated that emerging markets are likely to be driven by countries' specific factors. Nevertheless, it should be noted that both groups represent a mixture of countries with the oil-importing and oil-exporting status. A specific response from the Oil & Gas industries of the net-oil-exporting and net-oil-importing countries may possibly occur. Therefore, arguably, the mixture of countries with a different oil status may provide a potential distortion in estimates, since the net-oil-exporters usually express high export revenues which, in its turn, may boost the economy and, indirectly, stock market growth and development.

3.2.4. Oil price effect on developed oil-exporting countries' stock market.

This section makes a summary of main findings regarding developed oil exporting countries. The studies interrogated focus on Norway, the UK and Canada.

Norway

Gjerde and Sættem (1999) provided an empirical analysis of dependencies among the macroeconomic parameters of Norway. The relationships between the oil price and the stock market were analysed. The authors concluded that there was a substantial positive effect of the oil price on the stock market behaviour. Hammoudeh and Li (2005) examined the effect of the NYMEX 3-month oil futures price on the Mexico and Norway stock market indices, and additionally the MSCI

World index, the US Amex Oil Index, and the US NYSE Transportation Index. Johansen (1988) and Johansen and Juselius (1990) used co-integration to examine the existence of a long-term relationship in multivariate form among the participating time series with further investigation in VECM form and VAR form. The authors concluded that the oil industries in Mexico, Norway and the US positively respond to rise in the oil price, while the US NYSE transportation index demonstrates a negative response. Further findings show that the Norway equity market has a positive one day lead relationship, while the MSCI World index has a negative one day lead relationship. The authors also concluded that the systematic risk represented by the MSCI World index has a greater impact compared to the growth of Oil price. Ågren (2006) applied asymmetric BEKK (1,1) and the oil shock is assumed to be exogenous by applying the parameter restriction. The research concentrated on a set of 5 countries, including Norway and the UK, in the time period from 1989 to 2005 using a weekly frequency. Two models were used in the analysis assuming the effect of oil price at lag 1 and lag 0. For the lag 1 case Norway and the UK are not affected by the oil price in the conditional mean equation, while in the case of lag 0 Norway is positively affected by changes in the oil price. The conditional volatility of Norway is affected by oil price volatility in the case of lag 1, while no evidence is found in the case of lag 0. The oil price had a significant symmetric effect only on the UK conditional stock price volatility. A joint test for volatility spillover was significant for both countries in the model with a lag 1 assumption of oil price effect in mean equation. Finally, the author concluded that the market's own shocks are found to be more prominent compared to the oil price shock. The author also ascribes the issue of the importance of contemporaneous structure when measuring dependencies among time series. O'Neill, *et al.* (2008) confirmed the evidence that higher oil prices positively affect the stock markets of Canada, while it was adversely affected in the UK. The sample period spans from 2003 to 2006. This result is contradictory since, according to estimates based on the BP Energy report data (Source: BP. Energy report 2008, data file), the oil production/consumption ratio is higher in the UK (2003: 1.32; 2006: 0.92) compared to Australia (2003: 0.73; 2006: 0.60). Also puzzling is the high ratio of a net oil-exporting Canada (2003: 1.41; 2006: 1.43), which makes a clear contrast to the UK which expresses unusual behaviour in response to the oil price. Bjørnland (2009) applied the regression and VAR models in order to investigate the effect of oil price changes on the Norwegian equity market. The monthly sample period represented by the span of time from 1993 to 2005 is applied. The author concluded that Oil price changes have a positive effect on the Norwegian equity market. The author found that a 10% increase in oil prices causes an immediate 2-3% increase in stock returns, assuming that energy companies held more than half of market capitalisation in the Norwegian equity market in the year 2005. As for the effect on the macroeconomy, the author found that an increase in oil price had a stimulating effect on the

Norwegian economy. The important issue of the study is the division of the oil price series into different bands based on the assumption that the economy responds differently to oil price changes in different bands. Park and Ratti (2008) studied 13 European countries together with the US stock market indices which were observed in relationship with the UK Brent Crude Oil index. The sample ran from 1986 to 2005, observed monthly. The authors found that the impact of oil price on stock market returns was statistically significant within the same month and one month horizon in the VAR model. A positive response of the Norway stock market index on the oil price changes and scaled oil price (SOP) was confirmed, but the estimate was statistically significant at 10% level only. In the case of the UK, only SOP of world real oil price was confirmed at 10% level of significance with a negative sign of estimate. Therefore, this finding can lead to the conclusion that there is no clear pattern in oil price effect on UK stock market indices, which would not allow a researcher to ascribe the UK to the prominent oil-exporters or oil-importers behaviour in response to the oil price effect. However, the inclusion of US returns into the VAR model changes the results of the orthogonal impulse response function, where the UK responds clearly negative to the oil price changes.

The UK

In addition to the aforementioned Manning (1991) who found the positive relationship between stock prices of the UK oil-related companies (see Section 3.2.1.), the findings of other authors are mixed. Jones and Kaul (1996) analysed a set of four countries, including the UK and Canada, in the post war period. The main conclusion was that an increase in the oil price has a detrimental effect on the economy and, thus, on stock market behaviour. It is important to note that the lagged oil price effect on stock market behaviour is reported only in the form of a summation of lags 1(0)-4 estimates derived from the estimated regression. This fact makes it difficult to observe lag 0, lag 1 oil price effect on stock market behaviour and distinguish between responses of net oil-importers and net oil-exporters. All reported summations are found to be negative, with the least value represented by Canada (-0.992), which is followed by the US (-1.009), the UK (-1.107) and Japan (-1.531). Thus, the summation of coefficients for the US is smaller in absolute terms compared to the UK, meaning that a detrimental effect on the US (net oil-importer) is smaller compared to the UK (net oil-exporter). In order to explain such a conclusion, one should take notice of the approximate date when the UK acquired the status of a net oil-exporter. According to the BP energy report⁴⁰ ("BP. Energy report 2008"), the UK held net oil exporter status from approximately 1980 to 2005 and oil production was significantly smaller than consumption until the year 1975. The change in the status may also lead to a change in the response to the oil price behaviour. Therefore, it is possible

⁴⁰ Microsoft Excel data file is supplied together with BP Energy Report 2008 (Source: BP. Energy report 2008, data file).

to expect that a structural break may occur in the period of the oil status change and, consequently, a mix of the two different regimes. Therefore, in the period from 1962 to 1991 utilised in the study by the study by Jones and Kaul (1996) one would expect the regime switch in the oil price effect on the stock market behaviour. Therefore, the UK case contrasts with the stable net oil-importer and net oil-exporter status of the US and Canada.

However, the findings of the UK to responses to the oil price behaviour with application of the recent periods are also conflict with the UK oil-exporting status. This could be traced in study of afore mentioned Ågren's (2006), where non-rejection of the asymmetry hypothesis for the UK is confirmed, which shows the absence of the prominent positive response of the UK's market to the oil price fluctuations. Moreover, in study O'Neill, *et al.* (2008, p. 297) the UK response to the oil price is found to be negative in a period starting from March, 2003 to September, 2006, which may be address to the clear oil-importing status of the country. From the study by Apegis and Miller (2009) on the UK and Canada response to the oil price, it is possible to conclude the following: the UK demonstrated behaviour which was consistent with the behaviour of oil-importing countries, while for the Canadian stock market there was no detected causality found from the oil-supply, global aggregate-demand and precautionary demand shocks.

Canada

Sadorsky (2001) examined the effect of oil prices on the Toronto Stock Exchange (TSE) Oil & Gas industry in the period between 1983-1999, via monthly observations. The multifactor regression model was applied with the WTI crude oil 1 month futures price, TSE-300 value weighted stock market index and additionally, the Interest rate and Exchange rate variables. The inclusion of the oil price into the single factor (CAPM) regression model in order to explain the behaviour of the Oil & Gas index has a considerably high explanatory power in terms of R^2 compared to the one factor model. The main findings are that the market and oil price have a positive effect on the Oil & Gas index, while the interest rate and the exchange rate have a negative effect. The structural stability of the model is performed using recursive estimation. Boyer and Filion (2007) examined 105 Canadian Oil & Gas corporations, which represent 99 producer and 6 integrated companies. Quarterly data is used over the time period 1995–2004. The stock returns of the companies in question are explained by the price of oil and gas, and industry specific factors. The authors made a comparison of the ways these factors vary depending on the type of companies involved. They also confirmed that stock return determinants are different for integrated firms compared to producer firms.

The summary of the oil price effect on stock markets of developed countries demonstrates that the proposition of a positive effect on stock market index behaviour is mostly confirmed.

3.2.5. Oil price effect on emerging oil-exporting countries' stock markets.

The study of the oil price effect on emerging oil-exporters mainly focuses on large oil production volumes. In this regard the whole GCC oil exporters' stock market indices were the focus of recent studies on the oil price effect.

GCC countries

Hammoudeh and Aleisa (2004) used Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates together with WTI spot and futures prices observed daily in the period from February 15, 1994 to December 25, 2001. Lead-lag relationships were observed using a VECM framework. The Saudi Arabian stock market has causality links with all other countries under investigation, except Oman. It is also found that a bidirectional link exists between the Saudi Arabian stock market and the NYMEX future price at the 5% level of significance. Other investigated markets have no direct link with the Oil price and, thus, have no predictive power for changes in the oil price. The models were corrected with respect to the different time zones of stock markets' trading hours.

Hammoudeh and Choi (2006) analysed GCC countries in relation to three global factors: oil price, US S&P 500 and US Treasury bill rate. The sample period ran from February 15, 1994 to December 28, 2004. Johansen (1988), Johansen and Juselius (1990) co-integration test, VECM and IRF were used. The existence of co-integration among GCC countries and other participating series is confirmed, but the relationship is not stable over time. When applied to the VECM model, the Oil price (WTI) and S&P 500 are found not to be good predictors of GCC market dynamics in the short-run when observed at a weekly frequency. Moreover, the oil price effect on Bahrain and Saudi Arabia was found to be negative.

Malik and Hammoudeh (2007) investigated the equity markets of the US, Saudi Arabia, Kuwait and Bahrain, observed in a daily frequency over a time period starting from 14 February 1994 to 25 December 2001. Evidence was found that volatility from the US equity markets and the WTI oil price significantly affect the dynamics of participating Middle East markets, while only in the case of Saudi Arabia was the volatility spillover found from the WTI oil price on its own.

Arouri and Fouquau (2009) used the traditional co-integration technique (Engle and Granger, 1987) and asymmetric co-integration technique (Schorderet, 2003) in order to investigate the effect of oil price on Bahrain, Kuwait, Oman, Saudi Arabia, UAE and Qatar. Monthly data from the Arab Monetary Fund in the period starting from January, 1996 to December, 2007 and weekly MSCI

indices in the period starting from June, 2005 to October, 2008 is applied. The OPEC spot price is used as a representative of the oil price dynamics. By conducting a Johansen (1991) co-integration test and ADF, PP test performed on the residuals, the authors found evidence of asymmetric co-integration between these countries and the oil price. The authors pointed out that the coefficient was higher (lower) for the negative (positive) returns of oil price, which points to the asymmetric nature of the oil price effect.

Rault and Arouri (2009) applied the Seemingly Unrelated regression (SUR) method to examine long-run relationship between the oil price and GCC countries in the sub-samples: 7 June 2005 to 21 October 2008, and from January 1996 to December 2007. The sub-samples are observed on a weekly and monthly basis. The authors found evidence of co-integration between the oil price and GCC countries. Furthermore, for the same data set and periods, Arouri and Rault (2010) applied seemingly unrelated regression for Granger Causality testing suggested by Konya (2006). It is shown that Saudi Arabia has a bi-directional causal relationship with the oil price, while for other GCC countries the oil price has a unidirectional causal effect on equity market returns.

For other countries it is possible to highlight the study for Nigeria, where Adebisi, *et al.* (n.a.) found an instant and significant negative effect on the Nigerian stock market returns in the sample period 1985:1 to 2008:4, observed quarterly. This result is unusual, since a positive impact from the oil price was expected. The result may be partly explained by the use of quarterly data assuming that low frequency market fluctuations fail to capture high frequency market fluctuations⁴¹. The application of the Granger causality test revealed that the oil price leads stock market returns, which is also confirmed in the sub-samples 1999:1 - 2008:4 and 2004:1 - 2008:4.

The summary on the oil price effect on stock market behaviour documents prominent linkages between the behaviour of the oil price and national stock market indices. At the same time, the summary is mainly represented in the studies conducted on the Middle East region this is due to the lack of studies on other emerging countries. However, it is possible to expect a similar response from other oil rich regions such as Mexico, Venezuela, Columbia, Iran, and Kazakhstan.

3.2.6. Response to oil price shock from BRIC countries' stock market indices

The review of the literature below contains studies dedicated to the BRIC group of countries. At this stage it is important to emphasise that research studies which examine all BRIC countries as a whole with respect to the oil price shock are still quite rare.

⁴¹ In this regard Basher and Sadorsky (2006) pointed out that the exact relationship depending on data frequency is being used.

Driesprong, *et al.* (2008) observed the lead-lag relationship of eighteen countries with the world index and oil price indicators, including: Brent, WTI and Dubai, Arab Light and Brent/WTI futures. The data is a series observed monthly for the period from the October, 1973 to April, 2003. In heteroscedasticity consistent regression all major countries (except Japan) showed significant dependence on most observed oil price series at lag 1. However, for the emerging markets of Russia and China none of the oil price parameters were significant. India was dependent on the Arab Light and Dubai movements, and Brazil was dependent on the Arab Light, Dubai, Brent and Brent futures. For no lags and 5 lags, results for emerging markets movements of the WTI oil price were insignificant. In contrast, all major countries' stock markets showed dependence on the WTI for the same lag parameters. The study demonstrates evidence that different oil price indices have different relationships with stock market indices.

A study by Nandha and Hammoudeh (2007) analyses fifteen Asia-Pacific region countries and the OPEC oil price, observed weekly, covering a period from May 4, 1994 to June 30, 2004. The regression model represented a dependence test for the countries' stock markets with respect to oil price, additional risk factor beta generated on a 13-week rolling regression estimation and Asia crisis dummy variable. Further, the regression model was extended for the asymmetric effect of changes in oil price and risk factor beta variables. The findings of the study suggest, as expected, that oil exporting and importing countries respond differently to a change in oil price. The positive change in the oil price has a positive effect on oil exporters but negatively affects oil importers and vice versa for a negative change in the oil price. The oil price increase estimate is found to be negative and insignificant for the stock markets of India and China.

Hosseini, *et al.* (n.a.) investigated the effect of oil price, money supply, industrial production and inflation on the stock market indices of Russia, India and China. The sample period from 1999.I to 2009.I is used in a monthly frequency. Multivariate co-integration by Johansen and Juselius (1990), Johansen (1991) and VECM are applied. One co-integration vector is found among the participating time series for China, confirming the existence of long-term relationship. Further, VECM with three lags is conducted, where the oil returns at all lags are insignificant and estimates of the first two lags are high and negative, while the lag 3 is smaller and positive. In the case of Russia the oil price is found to be positive and significant at lag 1 and, negative and significant at lag 3. The result is interpreted by the oil-exporter status of Russia. In the case of India, oil price variables are found to be positive and significant at lag 1. The authors ascribe the existence of a positive relationship to the increase in speculation in mining and oil related indices, as suggested by Cong, *et al.* (2008) and Davis and Aliaga-Diaz (2008, p. 9).

The first and probably the most comprehensive study of the BRIC countries' mean and variance dependencies on the oil price is a study by Bhar and Nikolova (2009b). The authors applied a bivariate EGARCH model in order to investigate the effect of WTI oil price on the BRIC countries' equity market indices in the time period from January 1995 to February 2007 weekly observations were employed.

The effect of the Oil price on the Russian market is found to be highly significant and positive, while its own past returns have a greater impact on the Russian equity market dynamics. For other BRIC countries the oil price effect is found to be insignificant, positive and much smaller compared to the Russia-WTI returns relationship. The authors also found evidence that the effects of a one lag return innovation of the BRIC countries was higher compared to the oil price. The authors attribute this to the previous study by Bhar and Nikolova (2007), where they discovered that, to a large extent, the BRIC countries are driven by the regional indices returns compared to world index returns.

The effect of one lag own standard innovations on conditional volatility is found to be significant for all BRIC countries and the oil price. The coefficient of BRIC countries standardized innovations is found to be higher compared to the oil price. The asymmetric response to volatility shocks is found to be significant for Brazil and China, demonstrating the existence of symmetry for Brazil and asymmetry for China.

The impact of return standardized innovations of oil price in the conditional variance equation is significant and positive for Russia and insignificant and positive for China and Brazil, while it is insignificant and negative for India. The authors ascribe Russia's case to the historical net-exporter position of Russia, while China and India are mainly net-importers. The estimated value of Brazil oil price innovation in the conditional variance equation is second highest after Russia for all of the BRIC countries. The authors conclude that this value would probably rise in future as a result of increasing export revenues from Brazilian oil. The Russian case shows that an oil price increase causes a rise in oil export revenues which, in its turn, causes an increase in the stock price of oil companies. In addition to this, it is suggested that rising oil export revenues generate higher export duties, which are also beneficial for Russian economy. Thus, non-Oil & Gas stock prices on the Russian market also benefit from a rise in the oil price due to an increase of export cash flow for the Russian economy.

Finally, the Brazilian time-varying conditional correlation is relatively stable and statistically insignificant which, in the study, is explained by the ability of Brazil to substitute world oil with domestic oil and ethanol production. On the other hand Russia demonstrated statistically significant and the most volatile conditional correlation out of all BRIC countries, which is explained by the net-

exporting position of Russia and its position as a reliable supplier of oil. The authors explained the rise in the conditional correlation by the chain of events that increased the risk uncertainty of oil supply from the Middle East region (e.g. War in Iraq 2003). Similar events could be ascribed to the statistically significant time-varying conditional correlation for India, which is less volatile compared to the Russian case, and often negative. China's time-varying conditional correlation is insignificant, stable and positive, which is explained by the relatively closed nature of the Chinese financial system. The overall conclusion of the study is that the effect of oil price and volatility in the BRIC countries, to a major extent, depend on the historically established role as net-exporter or net-importer. On the other side, the volatility of stock returns in the BRIC countries does not provide any significant impact on world oil prices, despite the significant economic growth of the BRIC countries over the last few decades.

A number of other studies, which examine the BRIC countries' equity market indices or Oil & Gas stocks, found no prominent trend in the relationship. Gay and Nova (2008) examined the BRIC countries in relation to macroeconomic factors including the oil price. Monthly data was used through the period from 1999:03 to 2006:06. The Box and Jenkins ARIMA model was used with the Moving Average parameter at lags 1, 3, 6 and 12⁴², with the oil price and exchange rate. The resulting relationship between stock market returns and oil price was inconclusive. A strong positive and significant relationship for MA(1) was found for India, while for Russia the oil price is not significant; for China the relationship is negative. Moreover, in the case of India the MA(1) model R^2 reached 0.31, while in all other models for each country the R^2 is below 0.07. The authors ascribe this fact to the absence of the countries' specific macroeconomic variables which may improve the specification of the model. However, it may also be a problem of data frequency and model misspecification. Chang, *et al.* (2009) applied a VARMA-GARCH model suggested by Ling and McAleer (2003), for the WTI oil price and 10 large oil and gas companies, including Brazil (Petrobras), two Russian companies (Lukoil, Surgutneftegas). The sample period ran from 14 November 1996 to 20 February 2009 and is observed on a daily basis. Like Bhar and Nikolova (2009b), the authors concluded that each pair of the oil price and stock market returns are affected by their own ARCH and GARCH components. In both the VARMA-GARCH and VARMA-AGARCH models no evidence is found for spillover effects between the oil price and returns series.

Studies conducted separately for each of the BRIC countries are disproportionally distributed. Thus, no separate studies are available for India, while only one master degree thesis by Davey (2007) is to be found for Brazil, which involves an examination of the relationship between the oil price and the

⁴² Henceforth referred to as MA(1), MA(3), MA(6) and MA(12)

stock market over the time period from the start of January 2002 through to the end of June 2007. The regression model is combined with recursive estimation in order to investigate the coefficient stability. The “all-in-one” regression which involves returns of US the S&P 500 index, Mexican Bolsa index, Exchange rate and the oil price, found no evidence of a significant effect from the oil price returns to the Brazilian market. The application of CUSUM⁴³ demonstrated that there are two periods within the sample where oil price is found to be highly significant, but this finding not used to draw a plausible conclusion on the nature of the relationship.

A number of studies are found for Russia and China, and the summary of findings from these studies is provided below.

Russia

Rautava (2004) applied VAR, co-integration and VECM to investigate the oil price effect on the following set of parameters: GDP, fiscal revenues, real exchange rate and the oil price variable. Oil price is treated as an exogenous variable. The exchange rate and the oil price play a significant role in the Russian economy. To be more precise, the author concluded: *“a 10% permanent increase (decrease) in international oil prices is associated with a 2.2% growth (decline) in the level of Russian GDP. In addition, a 10% real appreciation (depreciation) of the Ruble is associated with a 2.7% decrease (increase) in the level of GDP in the long run”* (Rautava, 2004, p. 326). Hayo and Kutan (2005) applied the GARCH(1,1) model in order to investigate the effect of the US stock and bond markets and the oil price on Russian equity market returns in the time period from September 1995 to November 2001. All explanatory variables, including 1998 crisis dummies and energy news dummies, are combined in the conditional mean equation of the model. The energy news dummies are found to be insignificant, while the daily percentage growth rate of oil price was found to be significant and positive but lower compared to the influence from the S&P 500 index. Anatolyev (2005) examined two periods: the first, from January 1995 to January 2005; the second, from October 1999 to January 2005. A rolling regression was used for the analysis. Results demonstrate that a large proportion of Russian market movements are explained by the US equity market behaviour and the Crude Oil price. In the second period the author found a diminishing influence of Oil price in the Russian equity market. Gorjaev and Zabotkin (2006) used single and multi-factor CAPM together with the rolling window approach in order to investigate variability of Russian stock market indicators with respect to a set of systematic risk factors, including the Brent crude oil price indicator. The authors concluded that the sensitivity of the Russian stock market to the oil price is fairly modest. Oil’s factor beta was significant and positive in 29% of the regressions, mostly in the

⁴³ CUSUM is a sequential analysis technique suggested by Page (1954).

period between 2003 and 2006, which could be ascribed to the oil price level effect, given the high predisposition of the Russian economy to the oil export revenue. The study also confirms the high sensitivity of the Russian Oil & Gas sector to fluctuations in the oil price. Saleem and Vaihekoski (2010) applied the international asset pricing model with a set of global and country specific risk factors to weekly data over the period 1999 to 2009. The oil price is used as an additional variable, since it is expected that it influences the Russian market, as it is one of the worlds' main oil exporters. The multivariate GARCH-M framework of De Santis and Gérard (1998) is utilised in the form of a three-factor model for excessive returns. The authors did not investigate the relationship between the Russian stock market and the oil price. Their main finding are that the Russian risk premium is mostly explained by the local and currency risk components. The latter is time-varying and affected by the oil price, to be more precise: *"higher oil prices tend to lower the price of currency risk"* (Saleem and Vaihekoski, 2010).

Bhar and Nikolova (2010) applied the multivariate EGARCH model in order to investigate the linkages between the Russian AK&M index and WTI oil price. Besides traditional advantages of the multivariate models, the specification is assumed to restrict the AK&M index return effect on the oil price fluctuation, relying on the proposition of exogeneity of the oil price fluctuation discussed in the studies by Hamilton (1983) with certain contradictions by a group of authors who assume that oil price is endogenous with respect to global macroeconomic conditions (Barsky and Kilian, 2001, 2004). Nevertheless, the model is specified to allow the examination of the bidirectional volatility spillover effect in a conditional variance equation. The authors found evidence that the Russian stock market is determined by its own past values and, to the lesser extent, by the past values of the oil price return, which positively affect the dynamics of the Russian market. Regarding the cross-market standardized innovations, the Russian market is found to be affected by innovations from the oil price changes, but not vice versa. These findings confirm the exogenous nature of the oil price fluctuations. The study demonstrates that oil has a significant impact on the Russian stock market, and it is the main contributor to the booming Russian economy.

Some indirect evidence of the oil price shock on the stock market is found in the study by Kwon and Spilimbergo (2009). The authors used a set of panel regressions utilising data from 76 regions during the time period 1993-2002, observed annually. Oil price return and oil price shock is used in the study. The oil price shock is estimated as an *oil share in a regional income* multiplied by *oil price returns*. The overall result is that the oil price shock is significant and the parameter estimate has a positive sign (Kwon and Spilimbergo, 2009, p. 108).

China

Regarding the response of the Chinese market with respect to the oil price fluctuations it is possible to summarise the findings of the following research papers. Jiao, *et al.* (2007) confirmed the existence of bi-directional causality between the Chinese national economic production and the safety stock. The variation of the Chinese market is substantially smaller compared to the oil price. The authors found evidence that the oil price effect on the stock market is rapid and high in magnitude, while the Chinese market effect is small and slow. Cong, *et al.* (2008) utilised monthly data from the time period 1996:1 to 2007:12 to analyse Chinese stock market sectoral indices and oil companies with a set of Chinese macroeconomic indicators and the oil price. The Oil price is represented by the world oil price (Brent Crude oil price) and the Chinese oil price (Brent Crude oil price adjusted by the exchange rate). The VAR model applied for each of the stock markets and a set of macroeconomic variables, including the oil price, demonstrated that the manufacturing index and oil companies have a positive response to oil price shocks. Moreover, the use of the Chinese oil price demonstrated a more statistically significant impact. The study also demonstrates that there is no evidence for supporting the asymmetric effect hypothesis. An increase in oil volatility in the Andersen and Bollerslev (2003) framework does not affect most of the indices, while it may increase speculation on the mining and petrochemical index, which is also supported by Davis and Aliaga-Diaz (2008, p. 9). Finally, the authors concluded that the oil price can explain more than the interest rate and manufacturing index. This may suggest the oil price, as one of the global shocks, may be suitable for inclusion in equations to explain the behaviour of stock market returns.

3.3. Concluding remarks and proposition of the research objectives

This chapter has presented a summary of findings on the oil price effect on various economic indicators. It has attempted to trace the genesis of the oil price effect starting from studies examining the oil price effect on the economic activity (mainly output, employment, inflation), with a further expansion into studies regarding the oil price effect on stock market behaviour.

In this regard, it began by examined the oil price effect at company and industry level. The findings suggest that in general the positive effect is likely to occur for oil related companies and companies involved in the Mining and Construction sectors. If the first is likely to be explained by the increasing revenue in a period of high oil prices, then the later is associated with rising aggregate demand. These industries treated the oil price increase as an indicator of the development of the Global economy. Despite the positive effect stated above, there is clear evidence of a negative effect on energy intensive industries. Being the most traded commodity in the World, oil price is used in setting the prices of other energy commodities⁴⁴. Energy-intensive industries tend to increase price of production to compensate for the energy-commodity shock (e.g. transportation industry), which, in its turn, reflects on the price of products and their consumption. The evidence of this summary suggests that assets traded on the stock market are inhomogeneous in their response to oil price, and the compound structure of stock market indices inevitably provides a mixture of the various trends of assets with different specificity of behaviour. The problem, together with technical aspects of index construction⁴⁵, should be treated as a potential source of hardly avoidable bias rarely mentioned by other authors.

Nevertheless, a considerable amount of literature has been published on the oil price effect on stock market indices. In order to investigate the effect on specific countries, countries analysed in literature have been arranged with respect to their oil status (oil-importer, oil-exporter) and the profile of the countries' economies (developed or mature market economy, emerging economy). The findings by the authors demonstrate a clear split in outcomes regarding the countries' profile, for example:

⁴⁴ Various energy commodities are connected because of the substitutability effect. There are studies that documented the existence of the long-run relationship between: crude oil and gas prices (Panagiotidis and Rutledge, 2007); crude oil and coal (Shafiee and Topal, 2010); crude oil and bio-fuel (Du, *et al.*, 2009; Chang and Su, 2010; Zhang, *et al.*, 2010).

⁴⁵ The problem is associated with the adjustment which is applied to stock used in the estimation of the stock market composite index (Roll, 1992). Two parameters are usually included in the formula: the adjustment coefficient reflecting the number of outstanding stocks available on the open market and the coefficient restricting the share of the stock in total market capitalisation.

First, the discussion in Section 2.2 demonstrated a prominent difference between the behaviour of developed and emerging market, which is seen in the descriptive characteristics of the returns (Bekaert and Harvey, 1995; Bekaert, *et al.*, 1998; Levich, 1998, p. 209), low correlation with developed markets (Bekaert and Harvey, 1995; Bekaert, *et al.*, 2003), a greater predictability of characteristics compared to developed markets and the substantial role of the local and regional factors, compared to global factors (Bekaert and Harvey, 1995; Carrieri and Majerbi, 2006; Bhar and Nikolova, 2009a) and lesser magnitude of a causality pattern compared to the developed markets (Levich, 1998, p. 233; Gebka and Serwa, 2007; Hashmi and Tay, 2007).

Second, Ramos and Veiga (2009) demonstrated that the effect of the change in oil prices on the Oil & Gas industry is positive and larger for developed countries, compared to the emerging markets. Oil price volatility was significant in all cases for the developed countries, while for the emerging markets, it was found to be insignificant. Ramos and Veiga (2010) demonstrated that the effect of a change in the oil price in developed markets is likely to have a higher magnitude and the significance of oil return asymmetric parameter estimates, whilst estimates for emerging markets are usually small in magnitude and insignificant. Also, developed markets' returns fall when the oil price becomes more volatile, while the emerging markets do not express any significant exposure to the oil price risk. Finally, developed markets demonstrate a higher stability of the sign across quintiles, both in the case of asymmetric oil returns and in the case of oil price volatility.

A prominent split is also found regarding the oil-status, for example:

The studies of market indicators at company and industry levels demonstrated a different response to the oil price, to the extent of exposure to the oil price fluctuations on particular industry. Oil and Gas and related industries are likely to have positive relationship with the oil price. In particular, the study by Jones, *et al.* (2004, p. 24), which pointed out that asset prices are, to some extent, synchronised with oil price dynamics, since asset prices are the present discounted value of the future net earnings of the oil firm. Therefore, as suggested by Nandha and Faff (2008), oil price impacts should be quickly reflected in the dynamics of the stocks, and this should be true both for the short and long term behaviour of the oil price. Positive effects of the oil price on stocks of oil related companies and oil related industries are largely confirmed in Section 3.2.1 (Manning, 1991; Al-Mudhaf and Goodwin, 1993; Huang, *et al.*, 1996; Hammoudeh, *et al.*, 2004). Moreover, comparison with other industries demonstrates a drastic difference in sign (positive/negative) of the response to the oil price (Faff and Brailsford, 1999; El-Sharif, *et al.*, 2005; Agusman and Deriantino, 2008; McSweeney and Worthington, 2008; Nandha and Faff, 2008; Gogineni, 2009; Özkan, n.a.).

In addition, stock market indices in developed countries with a large proportion of industries which are exposed to the positive oil price effect as suggested in Section 3.2.4 (Gjerde and Sættem, 1999; Sadorsky, 2001; Hammoudeh and Li, 2005; O'Neill, *et al.*, 2008; Park and Ratti, 2008; Bjørnland, 2009). A similar pattern can be found in the emerging market response to the oil price summary (Section 3.2.5) where studies demonstrate prominent connections between behaviour of stock market indices and the oil price (Hammoudeh and Aleisa, 2004; Malik and Hammoudeh, 2007; Arouri and Fouquau, 2009; Rault and Arouri, 2009; Arouri and Rault, 2010).

Finally, as for the difference between oil-importing and oil exporting countries, it is possible to highlight the findings by Driesprong, *et al.* (2008). They confirmed that the reaction to the oil price from energy exporting countries is positive. However, the average estimates of the oil price parameter (treated as a response of the index to the oil price fluctuation) for the group of energy exporting countries is equal to 0.0134, compared to the average reaction of energy importing countries which is equal to -0.047. In both cases, the hypothesis that all coefficients are equal to zero is rejected.

In this regard it is important to carry out an analysis with respect to these separate groups, and the empirical results with respect to these countries' criteria. It is also important to highlight that there are two countries which have reached approximate self-sufficiency: developed UK and the emerging Brazil. As is highlighted in the summary of the developed oil-exporting countries regarding UK behaviour, it is important to underline the following: Jones and Kaul (1996) who found a detrimental effect from the oil price shocks to a group of developed countries, including the UK, with the coefficient magnitude higher than the oil-importing US; Ågren's (2006) found that the UK responds symmetrically to the oil price fluctuations, which may signal that the UK expresses neither oil-exporting nor oil-importing behaviour; O'Neill, *et al.* (2008) estimations suggest that the UK is likely to express oil-importing behaviour due to the negative sign of the oil estimates; Apegis and Miller (2009) demonstrated that the behaviour of the UK stock market is consistent with the response of an oil-importing country. As indicated in the listed studies, the UK fails to express clear oil-exporting behaviour in response to the oil price shock. Regarding Brazil the lack of studies on this country does it to be treated as an oil-exporting nation. However, relying on the statistical data it can be deduced that Brazil cannot be treated either as an oil-importer or as an oil-exporter⁴⁶ in the sample under investigation. Therefore it was decided to organise a special group that represent the countries with self-sufficiency in oil.

⁴⁶ Brazil reached its self-sufficiency approximately in the year 2006-2007 ("BP. Energy report 2009").

The rising significance of the BRIC countries as new economic powers, as suggested by Wilson and Purushothaman (2003), indicates the importance of research into various dimensions of their interactions with world economic indicators. Evidence of the rising role of the BRIC countries as energy consumers necessitates a more thorough analysis of the regularities of oil price shock spillovers, both in conditional first and second moments. A summary of the findings has demonstrated the scarcity of existing research on the BRIC countries, especially for Brazil and India.

Recognising that cross-market linkages could also be dependent on the oil price shock, a decision was taken to examine such a relationship using classical techniques with modifications applied in the literature, already discussed. Nearly all the studies investigate the oil price effect by adding the oil price returns or their proxies into the model as a common factor, whilst few studies pay attention to the oil price effect on the relationships between stock markets. Chen, *et al.* (1986, p. 401) applied the CAPM model with and without adjustment for the oil price and found that oil price inclusion decreased industrial production coefficients, whilst risk-premium and term-structure variables increased in magnitude and significance. The application of oil as an exogenous variable for BRIC countries is found in a study by Hayo and Kutan (2005), where the oil price is added to the conditional mean equation of multifactor GARCH (1,1) model and found to be significant in explaining the RTS index. By applying rolling regression Anatolyev (2005) found the oil price and the US S&P500 index useful in predicting Russian RTS. Jalilov and Miyakoshi (2005) applied the multifactor EGARCH (1,1) model, in order to examine effect of German and the US markets on the Russian RTS index where the oil price is added as an exogenous variable together with natural gas prices.

All of the listed studies mentioned above investigated the oil price effect for one or two pairs of indices. Therefore, it is clear that there is a gap in the research into the oil price effect on a large group of countries and this therefore constitutes the second research objective (see Chapter 1, page 4).

As discussed in the literature, there is obvious interest in how the oil price affects stock market behaviour, particularly in respect to countries with different oil importer/exporter/self-sufficient status or how economies with different profiles (developed/emerging) react to changes in the oil price. This classification is also applied in this thesis. The comparative results, as part of the second research objective are further sub-divided into possible combinations of pairs regarding the countries' oil-status and economy profile. The examination of these combinations and the question of whether there is a pattern in the oil price effect on cross market linkages determined by

the oil status and economic profile characteristics, constitutes the third research objective (see Chapter 1, page 5).

In addition to research objectives 1-3, it is possible to examine the more traditional research question discussed in a Section 3.2, where the oil price effect and stock market performance are examined in their relationships with each other. This examination is performed as a part of the fourth research objective (see Chapter 1, page 5).

The scheme of estimation used in this thesis assumes the use of the CCF GARCH Cheung and Ng (1996) causality test in order to examine mean and variance causality between the oil price and the stock market. An attempt is made to distinguish the difference in response to the oil price effect with respect to oil-status and economy profile of participating countries. It is worth noting that the CCF GARCH method is used by: Bhar and Hamori (2002) in order to investigate crude oil price and trading volume relation; Hanabusa (2009), who examines relationships between the price of diesel fuel and the industry activity index in Japan; Chen and Hamori (2009), who applied the IMF World energy price index in relation to real effective exchange rate as a proxy for China's international competitiveness. However, as far as is discernable this study is the first attempt to examine the relationship between oil price and stock market behaviour.

Having discussed the rationale for the first group of research objectives it is important to make a summary of the additional issues which are often integrated into research on the linkages between the stock market and the oil price effect on stock market behaviour. Therefore, it is important to discuss these issues in Section 4.

4. Additional issues in examination of dependencies of financial time series.

This chapter concentrates on the issues, which may affect the estimation and interpretation of results.

The first issue is the non-synchronism problem, which is well discussed in the literature on stock market linkages. The studies on international equity indices linkages and the oil price effect on indices are likely to use data of weekly, monthly or quarterly frequency when multivariate models are used. Difficulties arise, however, when an attempt is made to implement daily data. Since the international indices are distributed over different time zones, the problem of non-synchronism arises. In which case, multivariate models, (e.g. VAR model introduced by Sims, 1980) are an obvious example of asynchronous daily data application problems⁴⁷.

Since VAR is symmetric in the specification of parameters, and the lag structure cannot be modified for each particular series, it presents an insurmountable problem in matching a parameters' lag with respect to the contemporaneous interactions⁴⁸ among global indices. The early opening markets are therefore likely to be in a less beneficial position. For example, in the Japan to US causality case, lag 1 for Japan means that 38 hours⁴⁹ pass after market closing in Japan to the next day's closing value of the US market. However, the US market closing value is ready to cause Japanese market closing value after 9 hours.

Besides this example, the summary of the literature on stock market linkages demonstrated that some studies may possibly be exposed to the non-synchronism problem. In the case of India the important fact is the questionable use of the US effect at lag 0 (Wang, *et al.*, 2005a; Aktan, *et al.*, 2009), while other studies apply a more plausible lag 1 (Mukherjee and Mishra, 2010; Singh, *et al.*, 2010). Estimation of multivariate GARCH family model with lag 1 in a study by Yoshida (2010) may have a JP-to-US case mentioned above.

Studies of the oil price effect on stock markets are also not exempt from this problem. Potential underestimation of the effect may occur in oil price effect studies by Chang, *et al.* (2009, p. 8), where use of multivariate VARMA-GARCH model is used without allowing for the same day effect from the Russian Lukoil (LKOH, Russia), Surgutneftegas (SNGS, Russia). Previous discussions of the study by Ågren (2006) of the Norwegian market, where asymmetric BEKK(1,1) is applied, demonstrate better

⁴⁷ See Gjerde and Settem (1995), Singh, *et al.* (2010) for instance.

⁴⁸ Granger (1969) proposed testing for the instantaneous causality in a regression form.

⁴⁹ Number of hours calculated as a time interval between closing time of Japanese market in previous day and closing time of the US market in current day and vice versa.

performance of lag 0 compared to lag 1, at least for the returns in a conditional mean equation. Other studies of the contemporaneous cross equity market dependencies, Wang and Firth (2004); Singh, *et al.* (2010), are also of used in this thesis.

The problem is likely to appear when daily data is used together with multivariate models. Therefore, Section 4.1 provides an insight into the problem and suggests a way of treating it.

The second issue regards the application of the unit root test as a routine procedure before the application of the recursive co-integration test. Various studies apply the co-integration test together with the recursive co-integration test, for example, through the Hansen and Johansen (1993, 1999) framework. It is possible to suggest that the application of the co-integration test may already contain an error in itself, in cases when preliminary assumption $I(1)$ for the participating series is not met. In other words, when recursive estimation is used together with a co-integration test, all recursive sub-samples should also be tested for the $I(1)$ condition.

Most research (for instance a study by Yang, *et al.*, 2004) in this area usually applies various recursive or rolling co-integration tests generating chains of recursive and rolling sub-samples, which are not proved to be non-stationary. The problem may have unpredictable consequences when some recursive (rolling) sub-samples meet $I(0)$ condition instead of $I(1)$. In this case, the application of the co-integration test on a sub-sample, which is proved to be stationary $I(0)$, looks meaningless. However, since most of the co-integration test are relative to a unit root test (Banerjee and Lumsdaine, 1990, p. 2) estimated on the log of the series, they can be easily implemented to confirm that all sub-samples are not $I(0)$.

The third issue is a potential problem with the overall analysis where breaks are known or expected inside the sample. Thus, it is quite difficult to guess how stable the estimated coefficients are. The stability issue is discussed in studies by Smith, *et al.* (1993), Fujii (2005), and it can be concluded that there is a rising interest in the parameter (significance) stability within the literature. Panton, *et al.* (1976, p. 415) emphasised the crucial role of stability testing, since the instability of market co-movements may cause limitations in investor's ability to understand the nature of the process. However, Shawky, *et al.* (1997, p. 319) questioned whether if the lead-lag relationships are stable over time then an investor may increase the predictability price behaviour on a lagged market, by looking at the leading market stock return dynamics. In this regard, stability of the lead-lag relationship between two markets breaks the main postulate of the concept of market efficiency, which implies that the investor should not be able to earn an abnormal profit.

The second and the third issues are discussed in Section 4.2 since parameter (significance) stability is a significant part of the modern co-integration techniques.

4.1. Non-synchronism problem and contemporaneous causality.

The non-synchronism problem appears when indices located in different time zones without trading time overlap are observed in daily frequency. The non-synchronism problem is thoroughly discussed in the literature that analyses mean causality. Discussions with respect to the mean causality testing can be found in the studies by Koch and Koch (1991), Malliaris and Urrutia (1992a) and Bessler and Yang (2003).

Explanation of the problem originates in the causality concept. Humes' Causality principle states that "cause necessarily precedes effect" (Hume, 1739–1740/1999, pp. 58,83). That principle lies in the foundation of causality testing and it is true for Granger's "Instantaneous causality"⁵⁰.

Most authors agree that the use of daily data on worldwide spread indicators with different closing times within one trading day may lead to potential misspecification of the model, which is utilised in causality testing. The day closing price is the most common way of recording stock market indicators. However, day closing values of all indices are recorded at the certain calendar point (e.g. 01/12/1998), where the trading time of indices has taken place. The exact Greenwich Mean Time⁵¹ (GMT) stock market indices closing time is not commonly reported in data sources. This creates an illusion that indices are fully synchronised, and the direct implication of the daily data into standard models looks absolutely normal. Regarding causality in economics, Chendroyaperumal (2008) suggested: *"A date in the calendar is nothing but a name to identify a particular quantum of time"*. Thus, the main problem is how the researcher treats that quantum as a moment or as a time period. Since the "quantum" is treated as a moment, the research assumes full synchronisation among the series, and all the non-synchronisation is admitted as an insignificant divergence. If it is treated as a period, then the researcher admits, or knows, that a series in that period is not synchronised. Using this proposition as a basis, the researcher decides to use daily data and reformulate the model with

⁵⁰ Granger (1969) has suggested the possibility of 'instantaneous causality' and provided an approach for testing it. The definition of Instantaneous Causality is also provided in the work: "If $\sigma^2(X | \bar{U}, \bar{Y}) < \sigma^2(X | \bar{U})$, we say that instantaneous causality $Y_t \Rightarrow X_t$ is occurring. In other words, the current value of X_t is better "predicted" if the present value of Y_t is included in the "prediction" than if it is not" (Granger, 1969, p. 429).

⁵¹ The following description of GMT is given in Encyclopaedia Britannica (2006, p. 802) : "Greenwich Mean Time (GMT) Former name for mean solar time of the longitude (0°) of the former Royal Observatory at Greenwich, England, or Greenwich Meridian. GMT was used to avoid potentially confusing references to local time systems (zones). In accordance with tradition, 0000 GMT (denotes the start of a solar day) occurred at noon. In 1925 the numbering system for GMT was changed so that the day (like the civil day) began at midnight. Some confusion resulted, and in 1928 the International Astronomical Union changed the designation of the standard time of the Zero Meridian, to UNIVERSAL TIME, which remains in general use. The term GMT is still used for some purposes (including navigation) in English-speaking countries."

respect to the non-synchronism (Koch and Koch, 1991; Gebka and Serwa, 2007) for the model reformulation, or use data with lower frequencies (e.g. Theodossiou and Lee, 1993; Masih and Masih, 1997a) for lower frequency application. Hence, if it is known that the series are fully synchronised then Granger Causality could be used in standard form, where the hypothesis of non-causality is tested between Y_t and the preceding X_{t-1} . If it is known that the series is not synchronised in time, but all closing time values are recorded at a certain point of time line (“quantum” treated as a period), then the investigation of the stock markets’ closing time sequence is needed with further data or model correction, where for overlapped indices the causality is tested for the Y_t and preceding X_t and vice versa.

This particular case has wide prevalence in the lag correction method for the single equation model (e.g. Regression), or univariate models with a set of exogenous variables (e.g. Multifactor univariate GARCH). At the same time, such a technique imposes limits on the application of such corrections in multivariate VAR model (Sims, 1980). The non-synchronism corrected simultaneous equations, proposed by Koch and Koch (1991), together with Gjerde and Sættem’s (1995) warnings, contribute to the point of view that classic VAR cannot be used, since the lag matching in standard form of VAR⁵² looks problematic. Gjerde and Sættem (1995) stated the following (p. 166): *“The VAR technique treats all variables in a system without imposing a priori restrictions on the relations among them”*, and further they concluded (p. 169): *“In a bi-variate test approach, the problem of non-synchronous data due to different time zones may be explicitly incorporated in the test formulation. However, in the VAR approach a pair-wise matching is impossible, and the empirical results must be interpreted on the basis of this fact”*. Singh, *et al.* (2010) also confirmed the problem of applying the so called “same day effect” to the VAR model, which forced them to switch open/close data structure.

Any “one day shifting in series” for the previous observation in order to correct the daily data non-synchronism in bi-variate (multivariate) VAR, VECM and standard bi-variate (multivariate) GARCH family models will fail to provide any corrections, since non-synchronism correction cannot be incorporated in standard model formulation without rebuilding the equation structures. Thus, most authors who utilise daily data for standard VAR, VECM⁵³ and multivariate GARCH family models in

⁵² Critique (Singh, *et al.*, 2010) and model extension is given in VAR model propositions (e.g. asymmetric VAR by Keating, 2000; structural VAR by Waggoner and Zha, 2003; Rubio-Ramírez, *et al.*, 2010).

⁵³ It is important to note that Granger Causality could be tested using other methods e.g. in VAR, VECM form. This particular issue is discussed in Engle and Granger (1987), Sims, *et al.* (1990), Toda and Phillips (1993), Toda and Yamamoto (1995). In the first technique the assumption is made that the series are possibly co-integrated. Thus, it assumes careful examination of the unit-root, usually using the Johansen (1988) unit-root test with further application of the VAR or VECM. The other technique is MWALD provided by Toda and

most cases use trading hours overlapped series⁵⁴ where the pair wise matching of the lag is possible, or use lower frequency financial data (weekly, monthly). It is also worth noting, that users of VAR and VECM models, if they use lower frequency data, try to justify such a choice by claiming that daily data contains additional noise (Table 4.1-1 summarises the controversy around daily data usage).

Table 4.1-1

Brief summary of arguments for and against usage of daily frequency in the analysis

Arguments against the use of daily data	Arguments for the use of daily data
Bailey and Stulz (1990): <i>“daily data is deemed to contain “too much noise”;</i> Smith, et al. (1993, p. 55): <i>“Daily data exist, but contain a great deal of noise”.</i> Sharma (2007, p. 159): <i>“But generally daily data is suffered by ‘noise’ content. Noise plays a big role in high frequency volatility persistence. At less frequent observation, the noise content dies away. Monthly data series is ideal for the volatility analysis”.</i>	Eun and Shim (1989, p. 242): <i>“it captures potential interactions, since a month or even a week may be long enough to obscure interactions that may last only for a few days”</i> Elyasiani, et al. (1998, p. 94): <i>“the daily return data is preferred to the lower frequency data such as weekly and monthly returns because longer horizon returns can obscure transient responses to innovations which may last for a few days only”</i> Martens and Poon (2001, p. 1806): <i>“The use of low frequency data leads to small samples, which is inefficient for multivariate modelling especially when parameters are time varying. Moreover, monthly and weekly data cannot capture daily correlation dynamics.”</i>

Most researchers are usually less likely to move to the single equation models AR or AR with ECM. Masih and Masih (2002, p. 65) commenting on the VAR, VECM approach in co-integration adjusted techniques pointed out that *“examinations of bi-variate relationships (single equation is meant) may provide additional insight, they are not entirely useful for purposes of policy and serve at best as a prerequisite for a more thorough analysis of relationships amongst stock markets in a multivariate setting”*. However, since daily data is in most cases exposed to the problem of non-synchronism, then the use of bi-variate regression form is more preferable since data non-synchronism could be corrected in the equations. Moreover, the use of bi-variate regression might be the only alternative to a Granger Causality test based on daily data for the worldwide spread indices. Finally, simultaneous equations with a block-recursive structure proposed by Koch and Koch (1991) is an obvious example of application of non-synchronism correction.

Examination of the consequences of ignoring the non-synchronism problem constitutes the fifth research objective (see Chapter 1, page 5). In order to achieve this research objective, the decision

Yamamoto (1995). The beneficial side of its application is the fact that it does not require co-integration pre-testing.

⁵⁴ The application of the model usually involves analysis of intraregional linkages. The analysis by In, et al. (2001) for the Asia region and by Antoniou, et al. (2003) for three markets of EU can be mentioned as an example of multivariate model application. In both cases VAR-EGARCH model was applied to daily data. Thus, non-synchronism problem is avoided by application of overlapped indices.

was made to estimate the regression model both for classic and non-synchronism corrected forms, for further investigation of the consequences of ignoring non-synchronism problem. The discussion on the non-synchronism correction technique is given in a Section 5.1. as part of the methodology discussion.

Continuing with the non-synchronism issue, it is important to note that research papers that utilise non-synchronism correction mainly refer to the contemporaneous form⁵⁵ of cross-market interactions, while higher lag interactions⁵⁶ are mainly omitted. This issue have been discussed in a small number of papers while analysing the non-synchronism problem and it could be termed as a factor of earlier/later closing markets. This factor was mentioned in a study by Furstenberg, *et al.* (1989), since then, with rare exclusions (Malliaris and Urrutia, 1992a; Peiró, *et al.*, 1993, 1995), this issue has been neglected in other papers which discuss the non-synchronism problem.

Furstenberg, *et al.* (1989, p. 32) examined the propagation of information of external events through international markets by the means of technical analysis. The authors stated that: *"Clearly, the latter explanatory variable (meaning later closing market effects) would be expected to be the strongest for ΔA (meaning US logged returns), while the "earlier" ones, though increasingly freighted with used-up information as one goes back in time, would be partly collinear with it"*.

The problem is also mentioned without discussion in other studies. The study by Malliaris and Urrutia (1992a, p. 357) is relevant in this regard since the authors attempted to regress Japanese returns ($t+1$) with respect to US returns ($t-1$), which may be reformulated to Japanese return (t) with respect to US ($t-2$). Overall, the study demonstrated that the Granger causality which was conducted using a joint test at lag 2 and higher for the later closing markets and at lag 1 and higher for the early closing markets was found to be insignificant during the 1987 pre-crash and post crash period, while it is found to be significant during the period of the crash, including the US-Japan case.

Peiró, *et al.* (1993, 1995) also examined the effect of US ($t-2$) on Japan (t) in correlation and regression form. They found evidence that lag 1 of the US corresponds to the lag 0 of Japan.

The non-synchronism problem is directly referred to in the traditionally established GMT timeline. This time ruler gives us strict intervals, which allows recording of the time of particular events. The

⁵⁵ Lag 0 for early closing markets and lag 1 for the later closing markets (see Gebka and Serwa, 2007).

⁵⁶ Higher lag interaction, for example, lag 1 for the earlier closing market and lag 2 for the later closing market (see Furstenberg, *et al.*, 1989; Malliaris and Urrutia, 1992b) with omission of the lag 0 for the earlier closing market and lag 1 for the later closing market.

market in the time ruler, called earlier/later⁵⁷ closing, is due to the allocation of its trading time and closing values at the beginning or at the end of the day (close to the borders of the time quantum). The GMT time ruler puts Japan at the beginning of the day (quantum) and puts the US at the end of the day (quantum). However, some changes in the time ruler should affect the placement of the trading and closing value of indices inside the quantum of the GMT time ruler. It is expected that some changes in the GMT time ruler may also have a reverse effect, when an early closing market becomes a later closing one and the later closing one becomes an early closing one. After such a swap, exposure to the non-synchronism problem for two markets is also swapped.

Therefore, during the measurement of interdependence between two markets, the existence of earlier/later market closing bias may be anticipated, associated with the traditionally established GMT timeline and that part of the interactions where a later closing market is found to be dominant may be attributed to the aforementioned bias. This task constitutes the sixth research objective (see Chapter 1, page 6), which will investigate the particular effect of the later closing markets, when they are virtually placed in early closing markets conditions.

4.2. Parameter (significance) stability issues

The current research is also interested in stability issues regarding stock market linkages. Therefore, it has been decided to devote a section of the discussion to stationarity/non-stationarity issues, where the stability issues are sharper compared to other fields. As a result it may be possible to identify the most optimal parameter stability examination technique in integration, for further examination of non-stationarity characteristics of the dataset, as well as the application of techniques in other models used in this thesis.

4.2.1. Methods of stability investigation. Case of Integration and Co-integration.

The growing body of the literature on unit root testing and co-integration raises concerns about stationarity testing and refers to the point that full sample testing cannot be treated as a sufficient condition, especially when the sample size is large (Banerjee and Lumsdaine, 1990; Leybourne, *et al.*, 1998; Pascual, 2003) or breaks are expected.

Since the introduction of the Dickey and Fuller (1979) unit root test authors have posed questions about the validity of the test. Perron (1989) shows that if a break exists under the non-stationarity assumption, the test often fails to reject the null hypothesis. Campos, *et al.* (1996, p. 190) suggests that $I(1)$ process with the break is likely to express $I(2)$. In contrast to this phenomena, Leybourne, *et al.* (1998, p. 192), by conducting the DF test on different combinations of break allocation, that: " $I(1)$

⁵⁷ The discussion of the two markets interactions does not necessarily need a time ruler, since it is possible to state that market A closes before market B opens, as made in the Bessler and Yang (2003, p. 269) restriction.

process with a break can 'appear to be' $I(0)$ when the Dickey-Fuller test is routinely applied" and, further, emphasizing the fact "that null hypothesis can be rejected very frequently, leading to the spurious conclusion of trend stationarity". Besides this the authors focussed on the case, where a monotonic trend or drift is assumed to be absent and the application of the Dickey Fuller test "can produce many rejections of the null (hypothesis), when the break occurs very early in the series". Further, articles by Leybourne and Newbold (2000), Kim, *et al.* (2003) provide a deeper understanding of the subject and disclose more and more possible combinations of the existence of breaks and their effect on stationarity.

Further approaches are introduced in order to avoid the typical problems of the popular test. The following authors: Banerjee, *et al.* (1990), Zivot and Andrews (1990); Perron and Vogelsang (1992); Gregory and Hansen (1996); Perron (2006), Cook (2002), Sen (2008) provide solutions for various preliminary propositions of the break structure which complicate the testing procedures. However, the absence of an ultimate unit root test forces researchers to use several tests simultaneously. In this regard the work by Carrera, *et al.* (2003) should be highlighted, where based on the principal of methodological triangulation an investigation of macro-variables of Argentine was performed using eleven unit root test.

Since the integration test is a preliminary test in time series analysis, then the question of parameter stability (constancy) arises (Brown, *et al.*, 1975; Panton, *et al.*, 1976). Thus, it is suggested that recursive and rolling window approaches be applied together with standard test (e.g. Yan, 1999; Pascuale (2003) for co-integration). Besides the popularity of both approaches the authors usually find the rolling window is more favourable. Given Thoma's (1994) discussion on the application of recursive approach, Swanson (1998, p. 456,) concluded that: "*Thoma (1994) uses a growing window of data, as he is not concerned with tracking a possibly evolving system in the sense of time-varying parameters, but rather assumes that the system is evolving to some final form*". In regard to this suggestion Awokuse, *et al.* (2009, p. 550) states that: "*Specifically, if there is (at least) a structural break, parameter estimates after the break are based on the data mixed with two (or more) different regimes and, thus, may be imprecise or even invalid*".

The discussion in a study by Pacuale (2003, pp. 197,198), with respect to the Rangvid's (2001) findings, shows that recursive estimation may provide potential misguidance when a sample size sensitive test is applied. The application of the recursive co-integration test (Hansen and Johansen, 1993, 1999) in Rangvid (2001), demonstrated the increased statistics of co-integration vectors, which is interpreted as an indication of increased convergence among European stock markets. Conversely, Pacuale (2003), by comparison of recursive and rolling estimations, found no support for the

increasing convergence in the case of rolling estimation, which gave him ground for the conclusion that recursive estimation in some tests may have significant drawbacks when the test is sample size sensitive.

This point of view is also supported in a study by Basher and Sadorsky (2006, pp. 231-232), where it was concluded: *"One advantage of using a rolling regression approach is that structural shocks work through the data set by the length of the fixed window and do not have lasting impacts over the entire data range."*

The application of rolling integration is also proposed by Banerjee, *et al.* (1990). The discussion in that study raises intriguing questions of validity of standard stationarity testing based on full sample. The main contribution of that work is the development of a model and statistics to test the stationarity hypothesis when the break dates are unknown inside the sample. The rolling window approach was proposed as one of the most promising methods for the detection of breaks and investigation of stationarity stability. As a complement to the rolling approach the author suggested: *"Rolling statistics are computed using sample that are a constant fraction δ_0 of the full sample, rolling through the sample."* (p. 3) and further in the text of the article the author stated: *"... rolling statistics might better be able to detect some breaks, because ... any break will be excluded from at least one part of the rolling sample and included in another"* (p. 9).

In addition to this phenomena, analysis by Elyasiani and Kocagil (2001, pp. 1171,1172) and Awokuse, *et al.* (2009, p. 550) concluded: *"By contrast, rolling co-integration analysis with a fixed-length window can ensure that the effects of regime shifts are isolated and restricted to the event period, rather than being allowed to cloud the overall picture"*.

Taking into account the potential problem of co-integration analysis regarding instability of the hypothesis rejection, it would be useful to raise a question regarding the preliminary condition of the co-integration test, which, in our opinion, might be neglected in full testing. As mentioned above, the authors apply different co-integration techniques, including their binding with recursive and rolling estimation. Most of those studies on co-integration apply integration tests based on full sample estimation only, while co-integration tests in recursive and rolling scheme are likely to apply the co-integration test on all sub-samples in estimation chain, simultaneously omitting the unit root test for each of sub-samples under investigation. Such omission may critically violate the preliminary assumption that the sample under investigation should be integrated at order 1. Investigation of this anomaly is performed as a part of the seventh research objective (see Chapter 1, page 6).

This task is performed by checking the stability of the unit root of the series before the application of the co-integration technique by the algorithm of the rolling window technique. If stationary cases are detected, then the application of co-integration test will be problematic, since the sub-sample is confirmed to be integrated at order 0 ($I(0)$) instead of $I(1)$ forces the co-integration test to violate the preliminary condition that the analysed sub-sample should be integrated at order 1 (Engle and Granger, 1987, p. 253; Johansen, 1991, p. 1559; Gregory and Hansen, 1996, p. 100).

Moreover, taking into account the parameter instability and possible regime shift inside the sample it is worth making a sensitivity analysis of the lead-lag linkages, which in the case of Granger Causality stability means rejecting the stability of a non-causality hypothesis in a sensitivity testing technique. This task constitutes the eighth research objective (see Chapter 1, page 7).

This objective assumes that the thesis will examine the stability of significance of the Granger Causality test, as applied in the GARCH model suggested by Cheung and Ng (1996) and used for the result confirmation of the outcome from CCF GARCH causality test.

The arguments of authors (Pascual, 2003; Basher and Sadorsky, 2006; Awokuse, *et al.*, 2009) in support of rolling estimation technique and its advantages compared to recursive estimation suggest performing the rolling estimation technique in the two research objectives mentioned above.

5. Methodology chapter

Similarities in methodology can be found in both the interdependence between stock indices and the stock index to Oil price interdependence groups of studies. The Granger Causality testing procedure is one of the most widely used methods of measuring the dependencies between series and its testing procedures are usually applied to different models. Therefore, Chapter 5 provides the model specification⁵⁸ which is used in this study. The priority in choosing the models for the study was their ability to be corrected for the trading time non-synchronism as discussed in Section 4.1. Section 5.1 is devoted to the non-synchronism problem and its correction.

Discussion on Granger Causality starts from the original model as suggested by Granger (1969) with further modification with respect to the integration/co-integration characteristics of data and correction for the non-synchronism.

Further, the methodology chapter discusses the CCF GARCH model proposed by Cheung and Ng (1996). The model is presented in standard form and non-synchronism corrected form.

Sensitivity analysis is discussed in Section 5.3 concentrating on a discussion of the application of multiple window sizes, with further consolidation to the hypothesis rejection frequency statistics as given in Swanson (1998).

⁵⁸ GARCH family model made a significant breakthrough to the multivariate structure, but like a VAR model they also exhibit the non-synchronism problem. Closing time non-synchronism is a significant barrier of using the multivariate GARCH (BEKK, VEC, DCC etc.) models for the worldwide spread non-overlapping markets observed daily. Thus, due to the daily data non-synchronism this thesis avoids using multivariate models linear VAR, VEC and multivariate non-linear GARCH (BEKK, VEC, CCC, DCC etc.) models, knowing that lag matching of variables in the models structure is problematic (Gjerde and Sættem, 1995).

5.1. Non-synchronism correction

It is possible to summarise from the literature several ways of solving, or avoiding, the non-synchronism problem. The first, most typical and simplest among them is the application of monthly (weekly) data, obtained by aggregation, this was used in studies by Longin and Solnik (1995), Ramchand and Susmel (1998), Brocato (1994) or, in the use of aggregation of average two-day returns, which becomes useful within the analysis of contagion effect following the study by Forbes and Rigobon (2002) (also used in studies by Billio and Pelizzon, 2003; Serwa and Bohl, 2005). The second solution was the use of Wednesday (Thursday) closing price, besides solving the non-synchronism problem, it is suggested that this is a fairly frequently used method of avoiding the weekend effect and minimizing holidays within the sample. (e.g. Godfrey, *et al.*, 1964; Lo and Craig Mackinlay, 1990; Hodgson and Nicholls, 1991; Smith, *et al.*, 1993). The third application uses synchronous instead of synchronised data to correctly measure stock market co-movements (Martens and Poon, 2001; Kleimeier, *et al.*, 2003). The fourth method is the use of indices which partly or fully overlap each other. In this case the problem of non-synchronism vanishes (Chaudhuri, 1997; Bekiros and Diks, 2008). Fifth, the use of open-to-close, close-to-open returns, also used to manage the problem of data non-synchronism. Authors, who utilised this approach, also mention that the use of daily closing price only causes the loss of relevant return fluctuations inside the day (Hamao, *et al.*, 1990; Koutmos and Booth, 1995). The sixth is a calculation of synchronised correlation on the basis of non-synchronised data as proposed by Burns, *et al.* (1998). Seventh, the use of a non-synchronism restriction in the model output interpretation. After the VAR model calculation Eun and Shim (1989) used information on stock market's operating hours for the purpose of interpreting the empirical results. Last, the use of a causality restriction to formulate the model⁵⁹. This application can be found in studies by Koch and Koch (1991), Malliaris and Urrutia (1992a), Liu, *et al.* (1998), Bracker, *et al.* (1999), Bessler and Yang (2003) and, to some extent, for the cross-correlation matrix correction by Gjerde and Sættem (1995) and correlation of returns of non-contemporaneous stock markets by Kahya (1997).

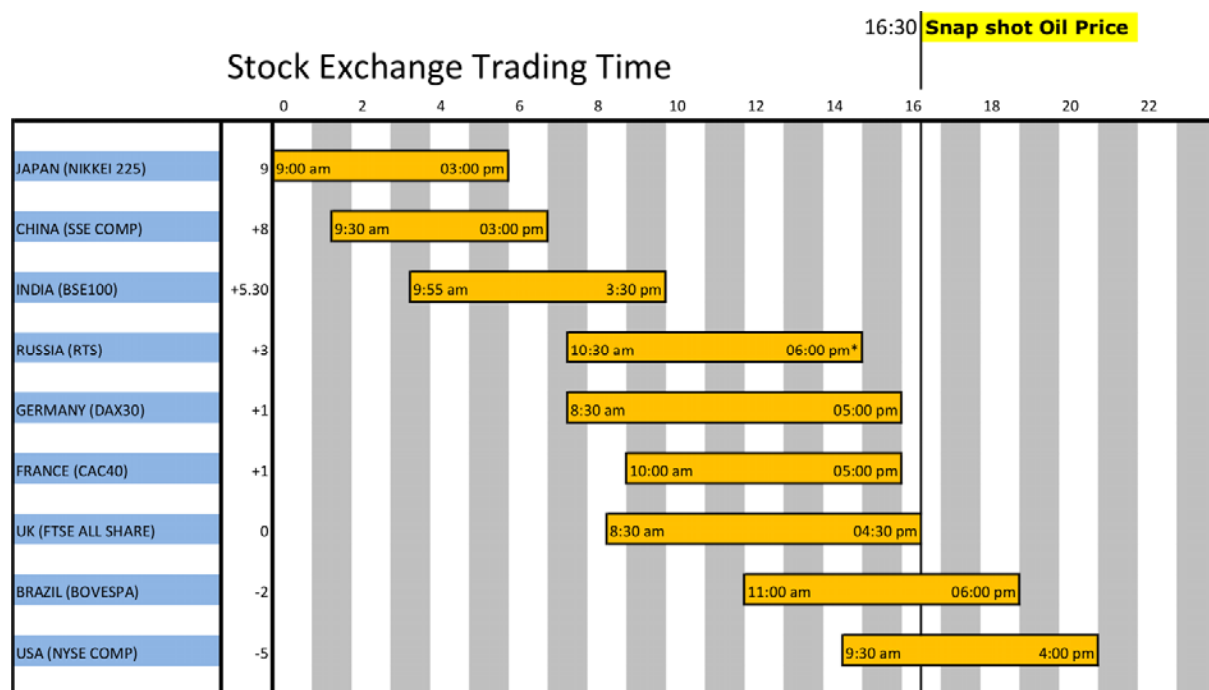
The fact that BRIC countries and major stock market indices are spread worldwide imposes modifications on the model specification. Thus, before giving the model specification it is important

⁵⁹ Most common way of non-synchronism corrected equations is by changing the starting values of lag orders from $(t-1)$ to (t) . This transformation prepares the model to be tested in "Contemporaneous Causality" (Hicks, 1979) or Granger's (1969) "Instantaneous Causality" frameworks as discussed in Chendroyaperumal (2008, p. 25). This assumes testing of causality between the stock market indices within the same day, based on a sequence of stock market indices' closing time. See, for instance, Koch and Koch (1991), Malliaris and Urrutia (1992a, p. 357).

to focus on the problem of non-synchronism (asynchronism) of daily data, since the trading times of the stock market indices are distributed in different time zones.

This thesis utilises the time zone scheme shown in Bessler and Yang (2003, p. 269) for the stock index under investigation to reveal a contemporaneous structure of the market's working hours. The use of the correction technique in the current study is stipulated by the fact that some of the indices' trading times do not have any overlaps.

Figure 5.1-1
Trading hours participating equity markets.



Notes: Stock market open and closing times collected on December 01, 2008.

* Russian market closing time during the period 25/07/2005 to 23/03/2007 was 45 minutes later. This fact is not taken into account during the estimation.

Figure 5.1-1 represents the trading time of markets under analysis. It is clear that markets' trading time is spread within the time zones throughout the working day. Moreover, a more or less precise overlapping of trading hours of different indices can be organized into groups, e.g. Asian group (China, Japan, India), European group (Russia, Germany, France, Germany) and South-North America Group (Brazil, US). There are some overlaps between indices from each group. A similar grouping is found in a study by Gebka and Serwa (2007) for 12 emerging markets.

Previous studies such as Eun and Shim (1989) used the time difference in trading hours in the interpretation of the results of the VAR estimation. Furthermore, Bessler and Yang (2003) used the

studies by Eun and Shim (1989), and Koch and Koch (1991) as a basis for imposing the restriction in order to fix the problem of non-synchronism. In this study the restriction is used to correct the Granger Causality equations in order to solve the problem of non-synchronism.

Table 5.1-1
No correction. (Regular matrix, classic Granger causality)⁶⁰

	JP	CH	IN	RU	GE	FR	UK	BR	US	OIL
JP	NA	1	1	1	1	1	1	1	1	1
CH	1	NA	1	1	1	1	1	1	1	1
IN	1	1	NA	1	1	1	1	1	1	1
RU	1	1	1	NA	1	1	1	1	1	1
GE	1	1	1	1	NA	1	1	1	1	1
FR	1	1	1	1	1	NA	1	1	1	1
UK	1	1	1	1	1	1	NA	1	1	1
BR	1	1	1	1	1	1	1	NA	1	1
US	1	1	1	1	1	1	1	1	NA	1
OIL	1	1	1	1	1	1	1	1	1	NA

Notes: Classic form of Granger Causality equation assumes test:

Table 5.1-1: index of Japan in column causes index of the US in row at lag 1, i.e., previous day ($l_{JP,US}=1$).

Table 5.1-1: index of the US in column causes index of JAPAN in row at lag 1, i.e., previous day ($l_{US,JP}=1$).

Table 5.1-2
Non-synchronism correction matrix.

	JP	CH	IN	RU	GE	FR	UK	BR	US	OIL ⁶¹
JP	NA	0	0	1	1	1	1	1	1	0
CH	0	NA	0	1	1	1	1	1	1	0
IN	0	0	NA	0	0	0	0	1	1	0
RU	0	0	0	NA	0	0	0	0	1	0
GE	0	0	0	0	NA	0	0	0	0	0
FR	0	0	0	0	0	NA	0	0	0	0
UK	0	0	0	0	0	0	NA	0	0	0
BR	0	0	0	0	0	0	0	NA	0	0
US	0	0	0	0	0	0	0	0	NA	0
OIL	0	0	0	0	0	0	0	0	0	NA

Notes: Corrected form of Granger Causality equation assumes correction of the equation. Thus, to determine the appropriate value for the lag correction, it is assumed that country in column attempts to cause country in row. For example:

Table 5.1-2: index of Japan in column attempts to cause index of the US in row at lag 0, i.e., same day ($l_{JP,US}=0$).

Table 5.1-2: index of the US in column attempts to cause index of JAPAN in row at lag 1, i.e., previous day ($l_{US,JP}=1$).

*- UK closing time in interaction with closing time of France and Germany in the analysis takes same day effect.

Restriction: "Market A cannot influence market B in contemporaneous time, if the latter (B) is closed before the former (A) opens (on the same calendar day)".

On the basis of this rule, all the equations should be reformulated in order to provide the appropriate causality structure. Therefore, it was decided to provide an equation correction matrix

⁶⁰ The regular matrix is based on the classic form of Granger Causality where testing assumes that the previous day of one particular index causes current day of another index and vice versa. Thus, the matrix will be filled by (1) representing lag 1 effect.

⁶¹ Crude Oil price is tested on the assumption that Crude Oil price affects indices on the same day.

for further use in the model specification. The regular matrix⁶² is displayed in Table 5.1-1 and non-synchronism correction matrix is given in Table 5.1-2.

Having established the daily data non-synchronism corrected rule, it is possible to start from the model specification part of the methodology, starting from the specification of the Granger Causality test with its further application within the framework of co-integration and CCF GARCH Cheung and Ng (1996) causality test. For all participating models, after the solution of theoretical issues, the non-synchronism correction procedure will be introduced.

5.2. Granger causality method

5.2.1. Classic form of Granger causality

Granger Causality has become one of the classical techniques for identifying the level of interdependence between time series. The basis of the test implies the following: time series X causes another time series Y , if X can better explain Y . Smith, *et al.* (1993) in his study defines the Granger Causality test as follows:

$$\sigma^2(Y|I) < \sigma^2(Y|I - X)$$

If X provides additional information to help explain Y , then the inclusion of X in the information set, I , will reduce the variance of Y . Granger Causality test is conducted using equation (1):

$y_t = \delta_0 + \sum_{q=1}^k \alpha_q y_{t-q} + \sum_{z=1}^k \beta_z x_{t-z} + \varepsilon_t$	(1)
---	-----

where the series y_t and x_t are the returns for the markets tested, δ_0 is constant, α_q and β_z are parameters, ε_t uncorrelated disturbance with zero mean and finite variance. Hypothesis:

$$H_0: \beta_z = 0, \quad z = 1, 2, \dots, k,$$

is tested. If the β_z are jointly significantly different from zero (H_0 is rejected), then X is said to Granger-cause Y .

The hypothesis testing procedure of the Granger Causality test is used in various models, in order to examine causal effect between series. Since, the test is applied in various models in the present thesis the application of the test is applied with respect to integration/co-integration characteristics

of the data (Engle and Granger, 1987; Kleimeier and Sander, 2002) and to trading time non-synchronism (Gjerde and Sættem, 1995).

5.2.1.1. *Granger causality and integrational/co-integrational characteristic of data*

The recent developments of Granger Causality testing theory have been the subject of considerable research. Besides the benefits of simplicity in the application of the Granger Causality test, the method has undergone changes due to the development of the co-integration concept (Granger, 1988a, 1988b). The application of the Granger Causality test should take into account the order of integration⁶³ of the series and existence of co-integration⁶⁴. Such a condition modifies the original Granger Causality test proposed by Granger (1969), due to the fact that it can be exposed to potential bias due to the nature of data. To perform a Granger Causality test with respect to these issues the present thesis utilised the sequence of testing and pretesting procedures suggested by Kleimeier and Sander (2002), where this starts from a Granger Causality model constructed for log levels of the series, knowing that the series are found to be $I(0)$ ⁶⁵. However, due to the fact that most financial series are found to be $I(1)$, such equations are omitted from the analysis of their paper. In other words, the assumption is made that all series and their subsamples are $I(1)$.

Testing of Granger Causality for $I(1)$ series assumes testing for the existence of co-integration. Engle and Granger (1987) showed that if two series are individually $I(1)$ and co-integrated, then a causal relationship would exist in at least one direction. Such occurrences need to be taken into account in Causality testing.

The co-integration definition says that two $I(1)$ series are co-integrated when the residuals derived from the linear combination of levels of that series are integrated at order $I(0)$. This particular test can be organised in bi-variate regression form:

$$Y_t = \gamma_{Y,0}X_t + u_{Y,t}; \quad \hat{u}_{Y,t} = Y_t - \hat{\gamma}_{Y,0}X_t \quad (2)$$

$$X_t = \gamma_{X,0}Y_t + u_{X,t}; \quad \hat{u}_{X,t} = X_t - \hat{\gamma}_{X,0}Y_t \quad (3)$$

with further testing of the residuals $(\hat{u}_{Y,t})$ and $(\hat{u}_{X,t})$ for the order of integration using Augmented Dickey-Fuller test (Dickey and Fuller, 1979; Said and Dickey, 1984). Therefore, if residuals are $I(1)$

⁶³ The test for order of integration can be provided by unit root test (e.g. Dickey and Fuller, 1979).

⁶⁴ One should mention the studies by Engle and Granger (1987), Sims, *et al.* (1990), Toda and Phillips (1993), Toda and Yamamoto (1995), who devised the methods of Granger Causality testing with respect to integration level of the series and existence of co-integration between them.

⁶⁵ If the series is $I(0)$ then the F-test and Wald test is valid for testing Granger Causality, where Y and X represented in levels of data. The equations are represented in a form: $Y_t = \delta_{Y,0} + \sum_{q=1}^k \alpha_{Y,q} Y_{t-q} + \sum_{z=1}^k \beta_{Y,z} X_{t-z} + \varepsilon_{Y,t}$, and vice versa where Y tries to explain X .

then Granger Causality should be tested using the first difference of the series. Since the series are not co-integrated then the original Granger Causality equation could be presented in bi-variate regression form (4) and (5) for the returns of series, which is exactly the same as in the Smith *et al.* (1993) technique.

$$\Delta Y_t = \delta_{Y,0} + \sum_{q=1}^k \alpha_{Y,q} \Delta Y_{t-q} + \sum_{z=1}^k \beta_{Y,z} \Delta X_{t-z} + \varepsilon_{Y,t} \quad (4)$$

$$\Delta X_t = \delta_{X,0} + \sum_{j=1}^k \alpha_{X,j} \Delta X_{t-j} + \sum_{i=1}^k \beta_{X,i} \Delta Y_{t-i} + \varepsilon_{X,t} \quad (5)$$

Testing Granger causality for returns is traditionally referred to ‘temporal’ or short term Grange Causality (Masih and Masih, 1997a, p. 60; Masih and Masih, 2001, p. 564).

If residuals of linear combination of Y against X are $I(0)$, then Granger Causality should be tested using the first difference of the series and error correction term. Thus, potential bias due to the existence of co-integration could be avoided if Granger causality equation includes the error term inside. This could be presented using the Granger two step method framework, as shown below:

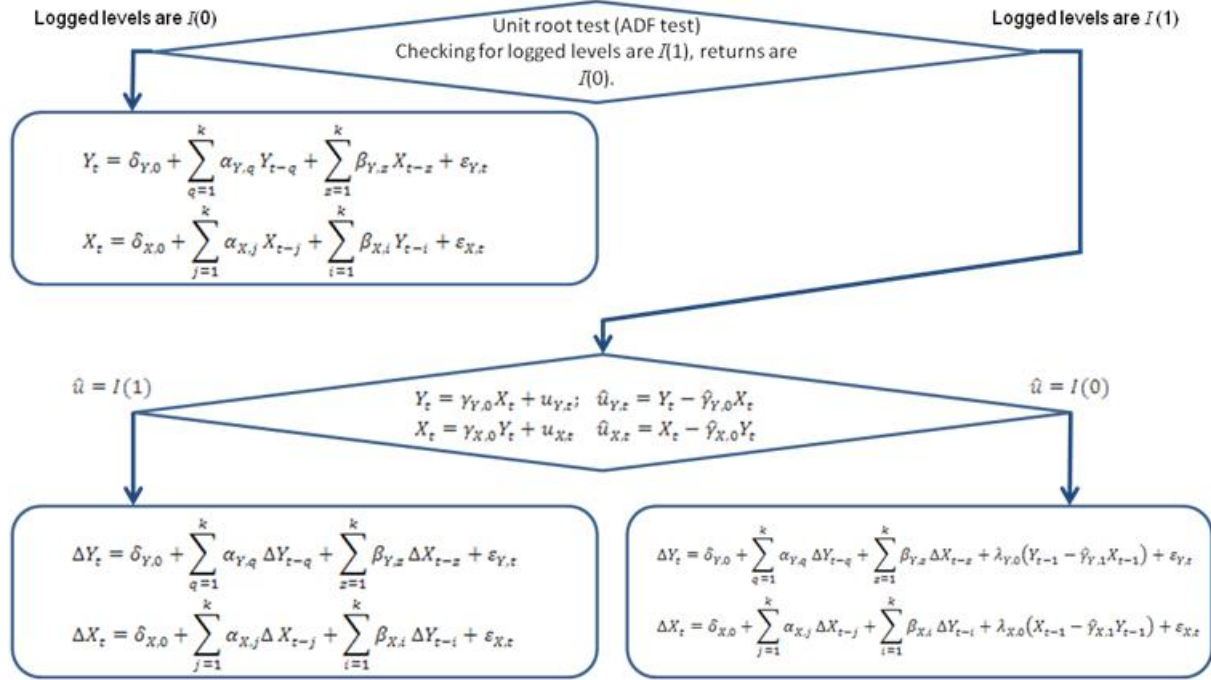
$$\Delta Y_t = \delta_{Y,0} + \sum_{q=1}^k \alpha_{Y,q} \Delta Y_{t-q} + \sum_{z=1}^k \beta_{Y,z} \Delta X_{t-z} + \lambda_{Y,0} (Y_{t-1} - \hat{\gamma}_{Y,1} X_{t-1}) + \varepsilon_{Y,t} \quad (6)$$

$$\Delta X_t = \delta_{X,0} + \sum_{j=1}^k \alpha_{X,j} \Delta X_{t-j} + \sum_{i=1}^k \beta_{X,i} \Delta Y_{t-i} + \lambda_{X,0} (X_{t-1} - \hat{\gamma}_{X,1} Y_{t-1}) + \varepsilon_{X,t} \quad (7)$$

In which case, it is possible to test both short term causality, the existence of which is observed on significance of $\beta_{Y,z}$ ($\beta_{X,i}$), and long-term causality, the existence of which is observed on significance of $\lambda_{Y,0}$ ($\lambda_{X,0}$), as advocated by Masih and Masih (1997a; 2001). To present the sequence of procedures more clearly it is important to show the listed steps in a scheme form see Figure 5.2-1.

Figure 5.2-1

Granger causality testing procedures assuming that series are possibly co-integrated.



5.2.1.2. Proposition of non-synchronism corrected form

By applying this rule it is possible to reconstruct equations (2)-(7) in order to correct for the problem of non-synchronism. In its classical form, the application of the Granger Causality test on stock market pairs is based on the assumption that the previous day of one particular index causes the current day of another index and vice versa. The difference between classical bi-variate Granger Causality and its corrected form can be illustrated in the US-Japan example. Since the Japan stock market closes earlier compared to the US one, it affects the US market on the same day. To derive this structure⁶⁶ one needs to replace $\beta_{US,z}$ estimators' counting in summation from $(z=1, \dots, k)$ to $(z=0, \dots, k-1)$. The same procedure could be applied to equations (4) which, in updated form, could be written as:

$$\Delta JP_t = \delta_{JP,0} + \sum_{q=1}^k \alpha_{JP,q} \Delta JP_{t-q} + \sum_{z=l_{US,JP}}^{k-1+l_{US,JP}} \beta_{JP,z} \Delta US_{t-z} + \varepsilon_{JP,t} \quad (8)$$

$$\Delta US_t = \delta_{US,0} + \sum_{j=1}^k \alpha_{US,j} \Delta US_{t-j} + \sum_{i=l_{JP,US}}^{k-1+l_{JP,US}} \beta_{US,i} \Delta JP_{t-i} + \varepsilon_{US,t} \quad (9)$$

Where $l_{US,JP}$ and $l_{JP,US}$ are time subscripts with values 1 and 0 respectively, regarding the value in the corresponding cell in the non-synchronism correction matrix in Table 5.1-2.

⁶⁶ Correction for other pairs of indices can be found in Table 5.1-2

Equations (2), which participate in the co-integration test, are also subject to modification since their residuals remain as an error term in equations (6). The corrected form could be presented as:

$$JP_t = \gamma_{JP,0} US_{t-l_{US,JP}} + u_{JP,t}; \quad \hat{u}_{JP,t} = JP_t - \hat{\gamma}_{JP,0} US_{t-l_{US,JP}} \quad (10)$$

$$US_t = \gamma_{US,0} JP_{t-l_{JP,US}} + u_{US,t}; \quad \hat{u}_{US,t} = US_t - \hat{\gamma}_{US,0} JP_{t-l_{JP,US}} \quad (11)$$

Since in equation (3) the regression, where the US market tries to explain the Japanese market in the same day is meaningless, when in equation (11) US market is delayed for 1 lag denoted by the time subscript $l_{US,JP}=1$ as given in Table 5.1-2. Thus, knowing that $l_{JP,US}=0$ and $l_{US,JP}=1$ the equation is given as follows:

$$JP_t = \gamma_{JP,0} US_{t-1} + u_{JP,t}; \quad \hat{u}_{JP,t} = JP_t - \hat{\gamma}_{JP,0} US_{t-1}$$

$$US_t = \gamma_{US,0} JP_t + u_{US,t}; \quad \hat{u}_{US,t} = US_t - \hat{\gamma}_{US,0} JP_t$$

Since all the components needed for correction of equations (6) are collected, it is possible to perform an update. Equations (12) and (13) represent equations (6) updated for non-synchronism:

$$\Delta JP_t = \delta_{JP,0} + \sum_{q=1}^k \alpha_{JP,q} \Delta JP_{t-q} + \sum_{z=l_{US,JP}}^{k-1+l_{US,JP}} \beta_{JP,z} \Delta US_{t-z} + \lambda_{JP,0} (JP_{t-1} - \hat{\gamma}_{JP,0} US_{t-1-l_{US,JP}}) + \varepsilon_{JP,t} \quad (12)$$

$$\Delta US_t = \delta_{US,0} + \sum_{j=1}^k \alpha_{US,j} \Delta US_{t-j} + \sum_{i=l_{JP,US}}^{k-1+l_{JP,US}} \beta_{US,i} \Delta JP_{t-i} + \lambda_{US,0} (US_{t-1} - \hat{\gamma}_{US,0} JP_{t-1-l_{JP,US}}) + \varepsilon_{US,t} \quad (13)$$

By applying the $l_{US,JP}=1$ and $l_{JP,US}=0$ time subscript values taken from Table 5.1-2 it is possible to present equations in a finalised form:

$$\Delta JP_t = \delta_{JP,0} + \sum_{q=1}^k \alpha_{JP,q} \Delta JP_{t-q} + \sum_{z=1}^k \beta_{JP,z} \Delta US_{t-z} + \lambda_{JP,0} (JP_{t-1} - \hat{\gamma}_{JP,0} US_{t-2}) + \varepsilon_{JP,t}$$

$$\Delta US_t = \delta_{US,0} + \sum_{j=1}^k \alpha_{US,j} \Delta US_{t-j} + \sum_{i=0}^{k-1} \beta_{US,i} \Delta JP_{t-i} + \lambda_{US,0} (US_{t-1} - \hat{\gamma}_{US,0} JP_{t-1}) + \varepsilon_{US,t}$$

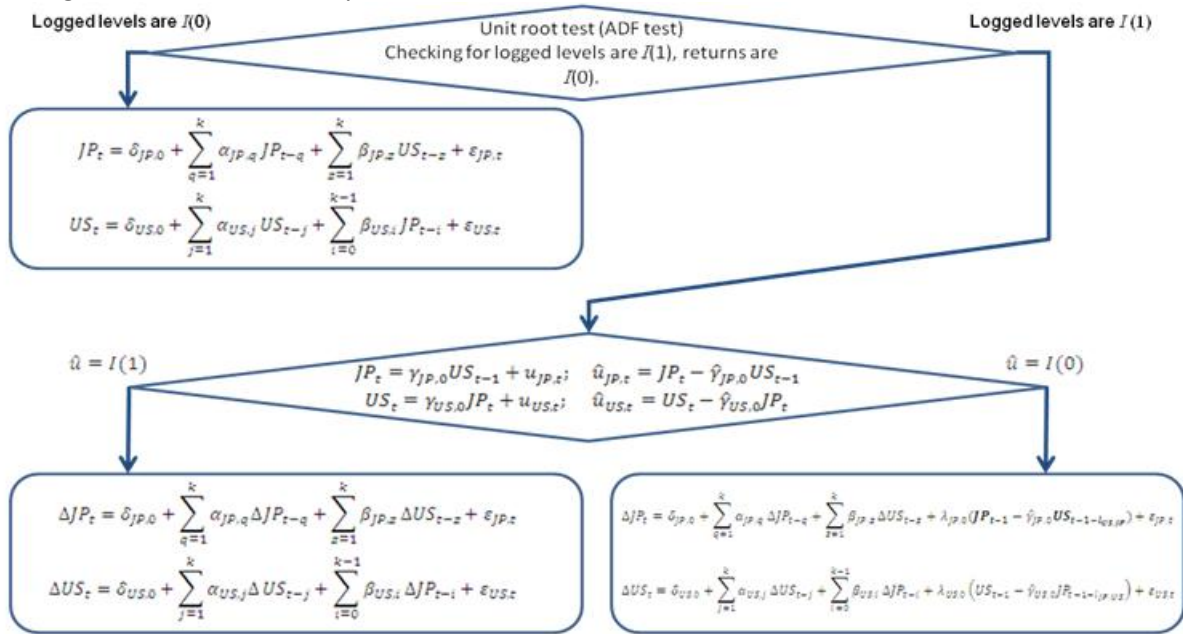
Therefore, the equation represents the regression based ECM model, which is different from the classic ECM model (Engle and Granger, 1987) by adding non-synchronism correction parameters. Each equation should be updated separately in respect of the information criterion. This analysis

utilises the (Schwarz, 1978) information Criterion⁶⁷ (SIC), which is an alternative to AIC (Akaike, 1974) and Akaike's (1969) Final Prediction Error (FPE). SIC tends to decrease the complexity of the model, in terms of the number of parameters.

The full scheme of US-Japan Granger Causality pretesting and testing procedures with correction for the non-synchronism problem can be found in Figure 5.2-2.

Figure 5.2-2

Granger causality testing procedures assuming that series are possibly co-integrated, allowing correction from non-synchronism.



All the reconstructed equations are organised for each combination of the pairs of series under investigation. Then this regression model is tested using Breusch and Pagan (1980) and Godfrey (1978) test for existence of heteroscedasticity in residuals. If the existence of heteroscedasticity is not confirmed, then the regression model is kept for further procedures. If the existence of heteroscedasticity is confirmed, then the regression model is re-estimated with a Newey and West (1987) heteroscedasticity and autocorrelation coefficient consistent covariance matrix. Finally, for each rolling sub-sample we conduct Wald test for Granger Causality for the given β restrictions⁶⁸.

⁶⁷ Schwarz information Criterion (SIC) is defined as: $SIC = -\frac{2l}{T} * \frac{(k \cdot \log T)}{T}$, where l is a log likelihood, which is computed: $l = -\frac{T}{2} * (1 + \log(2\pi) + (\log \hat{e}'\hat{e} / T))$

⁶⁸ $H_0: \beta_z = 0$, z -interval depends on non-synchronism correction in each equation. Thus, test for same day causality $z=0, 1, \dots, k-1$; test for previous day $z=1, 2, \dots, k$ and vice versa with l variable in reversed equations.

5.2.2. Cheung and Ng (1996) CCF-GARCH causality test

The CCF method was developed by Cheung and Ng (1996) based on the Granger, *et al.* (1986) method. The method represents a two-stage procedure to perform the test for causality in mean and causality in variance. In the first stage, it begins with the estimation of a univariate model for both series that allows time variation for conditional mean and conditional variance. In the second stage, standardized residuals are derived from both equations. Further, a cross-correlation function is constructed separately for the standardised and squared standardised residuals, which represent data for further testing for the causality in mean and causality in variance respectively using *s*-statistics proposed by Cheung and Ng (1996).

Use of the GARCH family model in the first stage is explained by its ability to tackle serial correlation and heteroscedasticity presented in the raw data. A brief summary of the literature that utilises CCF together with GARCH family models shows, that GARCH first proposed by Bollerslev (1986) and EGARCH extended by Nelson (1991) are the most frequently used models (Table 5.2-1).

Table 5.2-1
Summary of CCF application in interdependence studies.

Study	Data type	Model specification
Cheung and Ng (1996)	Stock market indices, daily	ARMA(m, n)-GARCH(p, q). ARCH-in-mean is allowed.
Hu, <i>et al.</i> (1997)	Stock market indices, daily	MA(n)-GARCH(1,1)-M model
Hong (2001)	Exchange rate, weekly	AR(m)-GARCH model
Speight and McMillan (2001)	“Black” exchange rate, monthly	ARMA(m, n)-GARCH(p, q). ARCH-in-mean is allowed.
Bhar and Hamori (2002)	Crude oil price and trading volume, daily	AR(m)-GARCH.
Huang and Yang (2002)	Exchange rate data, daily	ARMA(m, n)-GARCH(p, q).
Kanas (2002)	Exchange rate, monthly	AR(m)-EGARCH-M, asymmetric model.
Alaganar and Bhar (2003)	Stock market index; financial, banking and insurance indices	AR(m)-GARCH(1,1) model
Constantinou, <i>et al.</i> (2005)	Stock market indices, daily	AR(m)-EGARCH-M, asymmetric model.
Fulii (2005)	Stock market indices Morgan Stanley Capital International, daily	AR(m)-GARCH model
Hamori, <i>et al.</i> (2006)	Industrial product index, monthly	AR(m)-EGARCH model
Neaime (2006)	Stock market indices, weekly	AR(m)-GARCH model. Threshold ARCH (1,1) and ARCH-in-mean is allowed.
Alba and Park (2007)	Exchange rate, daily	MA(n)-GARCH-M model
Gebka and Serwa (2007)	National equity indices MSCI index	AR(m)-GARCH model (Globe Shocks Error correction variable; Global Shocks variance equation adjustment). Variance causality observed on standardized errors adjusted for mean-causality.
Inoue (2008)	Stock market Index and Foreign Institutional Investments, monthly	AR(m)-EGARCH, asymmetric model
Boubaker and Sebai (2009)	Stock market, daily data. (1992-2006)	AR(m)-GARCH model
Chen and Hamori (2009)	IMF World energy price index, real effective exchange rate as a proxy for China’s international competitiveness	AR(m)-ARCH(p) model
Hanabusa (2009)	Price of diesel fuel and the industry activity index in Japan, monthly	AR(m)-EGARCH model
Zwinkels (2009, p. 74)	Exchange rate, daily	AR(m)-GARCH model with exogenous variable in conditional mean on residual extracting phase

The users of GARCH family models are more likely to justify their choice by the simplicity of the model. However, the most common justification for the EGARCH model is its ability to avoid a widely known GARCH problem, where the summation of ARCH and GARCH term estimates in the variance equation is equal to unity or greater than unity. Most authors who prefer the EGARCH model point out that the latter has no parameter restrictions to keep positive variance (Hamao, *et al.*, 1990; Koutmos and Booth, 1995).

Regarding the CCF test Hamori (2003, p. 37) points to the possibility of EGARCH to capture an asymmetric effect. It allows different responses to the lagged error with respect to their sign. Thus, positive and negative residuals from the regression are allowed to have different responses to the variance. The asymmetric framework in EGARCH is found to be significant in most cases in the study by Inoue (2008) and insignificant in all cases in the study by Constantinou, *et al.* (2005).

In this thesis Nelson's (1991)⁶⁹ EGARCH model is applied, which is an exponential extension of Bollerslev's (1986) GARCH. The stock return is modelled as follows:

$$Y_t = \alpha_0 + \sum_{z=1}^m a_z Y_{t-z} + \sum_{s=1}^n \varphi_s \zeta_{t-s} + \zeta_t, \quad \zeta_t / \Omega_{t-1} \quad (14)$$

$$\log(\sigma_t^2) = \omega_0 + \sum_{d=1}^q \omega_d \left| \frac{\zeta_{t-d}}{\sigma_{t-d}} \right| + \gamma \frac{\zeta_{t-1}}{\sigma_{t-1}} + \sum_{b=1}^p \beta_b \log(\sigma_{t-b}^2).$$

The variables are denoted as follows: Y_t are returns, ζ_t is the stochastic error which is assumed to follow Generalized Error Distribution (G.E.D.), Ω_{t-1} is the information set at time $(t-1)$ and σ_t^2 is the conditional (time varying) variance. The same model (14) should be estimated for country X_t . In the second stage, the squared residuals standardized, corrected by conditional variance, are obtained from both models (for Y_t and X_t). The residuals are given as:

$$U_t = (X_t - \hat{X}_t)^2 / \hat{h}_{X,t} = e_t^2 \quad (15)$$

$$V_t = (Y_t - \hat{Y}_t)^2 / \hat{h}_{Y,t} = \zeta_t^2 \quad (16)$$

where ε_t and ζ_t are standardized residuals. $r_{UV}(k)$ is defined by Cheung and Ng (1996) as a sample cross-correlation function of the squared standardized residuals at time lag (k) . The same procedure is applied to $r_{\varepsilon\zeta}(k)$ as sample cross-correlation of the standardized residual series at time lag k .

⁶⁹ Note that E-views internal command for the estimation of the EGARCH is different compared to original Nelson's (1991) proposition, but can still utilise the G.E.D. as well as other distributions ("Eviews 7. User's Guide II," pp. 198,209).

$$r_{UV}(k) = \frac{c_{UV}(k)}{c_{UU}(0)c_{VV}(0)} \text{ and } r_{\varepsilon\zeta}(k) = \frac{c_{\varepsilon\zeta}(k)}{c_{\varepsilon\varepsilon}(0)c_{\zeta\zeta}(0)} \quad (17)$$

R_{UV} is a sample cross-correlation at lag k , where $c_{UU}(0)$ and $c_{VV}(0)$ are sample variances of U and V , respectively, and $c_{UV}(k)$ is the k -th lag sample cross covariance given by:

$$c_{UV}(k) = T^{-1} \sum_{t=1}^{T-k} (U_t - \bar{U})(V_{t+k} - \bar{V}) \quad k = \pm 0, \pm 1, \pm 2, \dots$$

The quantities $r_{UV}(k)$ and $r_{\varepsilon\zeta}(k)$ are used to test for causality-in-variance and causality-in-mean respectively within the framework offered by the CCF testing methodology. Further, the cross correlation is used in estimation of the S-statistics. According to Cheung and Ng (1996) it is possible to use the asymptotic Chi-square distribution. It has been possible to test two independent hypotheses⁷⁰. First, we can test the null hypothesis of non-causality in mean against the alternative hypothesis of causality at time lag k . To this end the appropriate CCF-statistic is given by

$$S_{\mu} = T \sum_{i=j}^k (r_{\varepsilon\zeta}(i))^2 \quad (18)$$

Second, we can test the null hypothesis of non-causality in variance against the alternative hypothesis of causality at time lag k , the CCF-statistic is given by

$$S_{\mu} = T \sum_{i=j}^k (r_{UV}(i))^2 \quad (19)$$

Based on statistics, calculated either for the separate lag (checking causality from a certain lag) or for the minimum lag to the certain lag (checking causality from a set of lags on joint hypothesis basis), it is possible to derive causality in mean and/or in variance. The null hypothesis that X_t does not cause Y_t from lag j to k could be tested with $(k - j + 1)$ degrees of freedom. Thus, testing for the non-causality hypothesis at a specific lag is found at condition $k = j$, when both of them represent the order number of that particular lag.

⁷⁰ Cheung and Ng (1996) causality test relies on a study by Granger, *et al.* (1986). Chung and Ng (1996, p. 36) gives the following description regarding the testing of the causality-in-variance: "In their illustrative example, these authors focus on the relationship between $h_{x,t}$ and lagged Y^2 's. Under the no-causality-in-variance assumption, the squared innovation of X , $h_{x,t}\varepsilon_t^2$ and $h_{y,t}\zeta_t^2$ are not correlated. Similarly, the hypothesis that X does not cause Y in variance implies zero correlation between $h_{x,s}\varepsilon_s^2$ and $h_{y,t}\zeta_t^2$, $t > s$. Thus, the null hypothesis that X and Y are independent implies zero cross-correlation between $h_{x,s}\varepsilon_s^2$ and $h_{y,t}\zeta_t^2$ for all s and t ".

The research in this thesis involves an investigation into the influence of the oil price on linkages between stock market indices as a part of the second and third research objectives. This investigation can be performed on the comparison on change in CCF coefficients estimated on oil price unadjusted and adjusted standardized residuals for observing both causality-in-mean and causality-in-variance. It is worth noting that the application of the oil price in order to see its influence on the relationships between other variables has a number of examples in the literature as discussed in Section 3.3. for example Chen, *et al.* (1986, p. 401), Jones and Kaul (1996), Hayo and Kutan (2005), Anatolyev (2005) and Jalilov and Miyakoshi(2005). This study will also add the oil price as an exogenous variable in the mean equation into model (14). The model thus becomes:

$$Y_t = \alpha_0 + \theta_1 Oil_t + \sum_{z=1}^m \alpha_z Y_{t-z} + \sum_{s=1}^n \varphi_s \zeta_{t-s} + \zeta_t, \quad \zeta_t / \Omega_{t-1}$$

$$\log(\sigma^2_t) = \omega_0 + \sum_{d=1}^q \omega_d \left| \frac{\zeta_{t-d}}{\sigma_{t-d}} \right| + \gamma \frac{\zeta_{t-1}}{\sigma_{t-1}} + \sum_{b=1}^p \beta_b \log(\sigma^2_{t-b}), \quad (20)$$

θ_1 is a parameter of the oil price⁷¹ variable (Oil_t). The extracted standardized and squared standardized residuals take the same procedure as suggested above for model (14).

There are a number of issues that should be taken into account while testing for causality using the Cheung and Ng (1996) CCF test. According to the Cheung and Ng (1996) the serial correlation should be tackled with the GARCH family model with the optimally detected lags (e.g. using SIC). For the checking for the existence of serial correlation Cheung and Ng (1996) suggest using a portmanteau test (Box, 1976; McLeod and Li, 1983) for the levels and squares of levels of the standardized residuals. In the present thesis the Ljung and Box (1978) Q-statistics⁷² are applied together with LM-test (Breusch and Pagan, 1980).

Concern also arises about possible bias while estimating variance causality. Cheung and Ng (1996, pp. 38,39) raised the question of independence conditions of return and variance causality testing. They emphasised that the bias of mean and variance causality depends on model specification. Giving the GARCH model example, Cheung and Ng (1996) suggest that testing for the variance causality may be affected by the existence of causality in mean. Conversely, in the GARCH-in-mean model potential concern may arise when testing for causality in mean, in the presence of causality in

⁷¹ Oil price returns were also included in the mean equation of the GARCH model in studies by Hayo and Kutan (2005), Sariannidis, *et al.* (2009).

⁷² The test is performed using Ljung and Box (1978) notation: $Q_{LB} = T(T+2) \sum_{j=1}^k \frac{\tau_j^2}{T-j}$, where T is a number of observations and τ_j^2 is an autocorrelation estimated using $\tau_j = \sum_{t=k+1}^n a_t a_{t-k} / \sum_{t=1}^n a_t^2$. Q-statistics at lag k is tested with null hypothesis of no autocorrelation and has asymptotic χ^2 distribution with a number of autocorrelations taken as degrees of freedom.

variance. The problem is avoided by applying a new augmented model that includes the exogenous variable in mean (variance) equation to avoid bias in causality testing in variance (mean). This correction is applied in the study by Gebka and Serwa (2007, p. 214) to avoid bias in variance causality testing. In the GARCH-in-mean model checking for the existence of this problem was attempted in a study by Constantinou, *et al.* (2005, pp. 17,18), where the authors' findings suggest that mean causality is mostly due to variance causality. Thus, the procedure for mean causality (if it exists) bias correction suggested by Gebka and Serwa (2007), is applied before the extraction of standardized residuals for further testing for causality in variance. Finally, as a possible limit of the model Cheung and Ng (1996, pp. 36,37) accepted that a CCF based test may not detect the non-linear variance causality effect.

Having established a theoretical framework, it is possible to switch the discussion to non-synchronism correction and confirmation of the results in ARMA (m,n)-EGARCH(p,q) with other stock markets as exogenous variables.

5.2.2.1. Non-synchronism corrected form and causality testing in ARMA(m,n)-EGARCH(p,q).

Cheung and Ng (1996, p. 43-44) suggest a daily data non-synchronism corrected form of CCF. It is assumed that the researchers derive CCF coefficients and their statistics with respect to market closing time for each index, in observed pairs.

This is performed through the multifactor GARCH in Cheung and Ng (1996, p. 43), where they give an equation correction approach. Thus, in the example the S&P500 index is assumed to be explained by Nikkei225, and in the GARCH (1, 1) model this allows the case, where Nikkei225 is causing S&P500 using a same day effect.

$$R_t = \phi_0 + u_t + \xi_1 R_t^*$$

$$h_t = \varphi_0 + \varphi_1 h_{t-1} + \varphi_2 u_{t-1}^2$$

Source: Cheung and Ng (1996, p. 43).

Notes: ϕ_0 and φ_0 is a constant terms in mean and variance equations respectively. R_t and R_t^* are the returns on daily S&P500 and Nikkei225 indices respectively; ξ_1 is an estimator of R_t^* ; ϕ_1 is a GARCH term and ϕ_2 is a ARCH term.

The following example of correction is used in the estimation procedure and for each pair of indices the correction is performed with respect to the corresponding value in a non-synchronism correction matrix⁷³ (Table 5.1-2). A similar correction is given in Cheung and Ng (1996, p. 43) in the conditional variance equation. Thus, additional squared returns of the exogenous index are added to the

⁷³ The correction procedure is integrated in the program code of EViews7 software through the analogue of Table 5.1-2 matrix.

conditional variance equation at minimum⁷⁴ and maximum lags detected in the CCF test for squared residuals as suggested in Cheung and Ng (1996):

$$R_t^* = \phi_0 + u_t + \xi_1 R_t + \xi_2 R_{t-1}$$

$$h_t = \varphi_0 + \varphi_1 h_{t-1} + \varphi_2 u_{t-1}^2 + \delta_1 R_t^2$$

Source: Cheung and Ng (1996, p. 44).

Notes: ϕ_0 and ϕ_0 is a constant terms in mean and variance equations respectively. R_t and R_t^* are the 15-minutes returns from the spot and futures index series respectively; ξ_1 is an estimator of R_t ; ϕ_1 is a GARCH term and ϕ_2 is a ARCH term and δ_1 is an estimator of R_t^2 .

By establishing the augmented model, it is possible to test causality from one index to another in the Granger (1969) sense from the minimum detected lag to the maximum detected lag in a joint test (e.g. $\xi_t=0$ and $\xi_{t-1}=0$ for return spillover from R_t to R_t^*).

Thus, introducing rigor into the research, both detected CCF mean and variance causalities are subject to the tests in a multifactor EGARCH model. This assumes that to test mean (variance) causality using EGARCH model, where it is necessary to include a lagged return (squared lagged return) of another market into the conditional mean (variance) equation. In this case the augmented model can be written as follows:

$$Y_t = \alpha_0 + \sum_{g=l_{X,Y}}^c \lambda_g X_{t-g} + \sum_{z=1}^m \alpha_z Y_{t-z} + \sum_{s=1}^n \varphi_s \zeta_{t-s} + \zeta_t, \quad \zeta_t / \Omega_{t-1}$$

$$\log(\sigma_t^2) = \omega_0 + \sum_{d=1}^q \omega_d \left| \frac{\zeta_{t-d}}{\sigma_{t-d}} \right| + \gamma \frac{\zeta_{t-1}}{\sigma_{t-1}} + \sum_{b=1}^p \beta_b \log(\sigma_{t-b}^2) + \sum_{w=l_{X,Y}}^f \mu_w X_{t-w}^2, \quad (21)$$

where m, n, q, p remain the same as detected at stage one for model (14), and X_{t-g} and X_{t-g}^2 lagged exogenous returns are added to the model to perform causality testing from X to Y for causality in mean and causality in variance respectively. Lag detection is performed using the CCF Cheung and Ng (1996) approach, where c and f are the maximum lag for the mean and variance causality detected separately. The time subscript $l_{X,Y}$ is a starting lag value for g and w and this is found in Table 5.1-2 (non-synchronism correction matrix), where the starting lag value is located in a cell with causing country in column and caused country in row. Both λ_g and μ_w are tested for causality in the Granger (1969) sense, by applying the condition that lag parameters are jointly equal to zero, regarding non-causality in mean ($\lambda_{l_{X,Y}}=\dots=\lambda_g=0$) and non-causality in variance ($\mu_{l_{X,Y}}=\dots=\mu_w=0$) null hypothesis.

Model (20) with oil price inclusion is represented as follows:

⁷⁴ Minimum lag in Cheung and Ng (1996) is determined by contemporaneous structure of indices' trading time. In this thesis the minimum lag is obtained from Table 5.1-2.

$$\begin{aligned}
Y_t &= \alpha_0 + \theta_1 Oil_t + \sum_{g=l_{X,Y}}^c \lambda_g X_{t-g} + \sum_{z=1}^m \alpha_z Y_{t-z} + \sum_{s=1}^n \varphi_s \zeta_{t-s} + \zeta_t, & \zeta_t / \Omega_{t-1} \\
\log(\sigma_t^2) &= \omega_0 + \sum_{d=1}^q \omega_d \left| \frac{\zeta_{t-d}}{\sigma_{t-d}} \right| + \gamma \frac{\zeta_{t-1}}{\sigma_{t-1}} + \sum_{b=1}^p \beta_b \log(\sigma_{t-b}^2) + \sum_{w=l_{X,Y}}^f \mu_w X_{t-w}^2,
\end{aligned} \tag{22}$$

where m, n, q, p remain the same as detected at stage one for model (20), and the other parameters are the same as discussed for model (21).

Having built an augmented EGARCH model with exogenous returns and squared returns for other markets, it is possible to investigate the robustness of the causal linkages found in the Cheung and Ng (1996) CCF test.

5.3. Examination of test significance stability for the applied models

The examination of the stationarity characteristics of series (Section 4.2.1) demonstrated that authors pay attention to the stability of the obtained results of the unit root tests and the critique of the recursive estimation (Pascual, 2003; Basher and Sadorsky, 2006; Awokuse, *et al.*, 2009) this makes the rolling window approach a good technique for the investigation of that stability.

The rolling window approach is a widely used technique. The generalised explanation of the rolling (moving) window approach is presented in studies by Brown, *et al.* (1975) and Banerjee, *et al.* (1990). The application of the rolling window technique together with the Granger (1969) Causality enabled Smith, *et al.* (1993) to discover the exact period, where the non-causality hypothesis was rejected, and compare causality in the pre-crash and post-crash period with the precise identification of causality effect duration. Surprisingly, the Smith, *et al.* (1993) technique has been neglected in the literature of the market linkages for the later period. Hence, it is difficult to avoid the impression that this method is somewhat sidelined from the general tendency in Interdependence studies of stock market indices. Since the publication of the article, the technique has also been applied to the research by Aaltonen and Östermark (1997) and (1999), where it is used in the analysis of relationships between the Finnish and Japanese stock markets⁷⁵. It appears that no

⁷⁵ Lag length determination for the equation (1) in Smith, *et al.* (1993) and Aaltonen and Östermark (1997) was based on the findings of (Akaike, 1969) minimum Final Prediction Error (FPE) for each autoregression. Smith *et al.*, initially estimated the Granger causality for the first 150 observations. They then dropped one observation, while adding another and re-estimating the relationship. This was done throughout the sample. Thus, the Granger causality test became a rolling regression. By employing this method, they were not only able to detect changes in the Granger causality relationships, but these changes indicated structural breaks that may occur in any linkages. Interestingly, despite the fact that Smith, *et al.* (1993) and Aaltonen-Östermark used the same window size, they utilised different data frequencies, weekly and daily respectively. Also, in reference to

other research papers, which utilise the Smith *et al.* technique, have been published thus far. The application of the rolling window technique together with CCF can be found in a study by Fujii (2005), where significance stability is subject to investigation.

There are a number of advantages in this technique which are worth noting. The first is that the use of the rolling window technique enables relationship to be observed in dynamics. Secondly, it assumes the flexibility of sample break points are overcome, as discussed in Section 4.2.1. Thirdly, it provides an opportunity to observe coefficient and significance stability in a given period. Besides this the technique usually suffers from the window size justification problem, and it appears this fact has not been mentioned by other authors.

Table 5.3-1

Total number of rolling subsamples with respect to the different window sizes.

Window sizes in sample for the levels	3131	2731	1931	1131	331	250	150
Total number of rolling subsamples for the levels	1	401	1201	2001	2801	2882	2982
						Total number of subsamples:	12269
Window sizes in sample for the returns	3130	2730	1930	1130	330	250	150
Total number of rolling subsamples for the returns	1	401	1201	2001	2801	2881	2981
						Total number of subsamples:	12267

The application of the one window size⁷⁶ (150 observations) raises a question, because usually there are no grounds for the choice of the exact window size. It appears that the use of different window sizes in a rolling technique can be partly substantiated, ideally from the maximum (full sample) to the "minimal reasonable"⁷⁷ (10-15 observations) with the step of 1 observation. The application of bandwidth (window size) changing step equal to 1 is problematic at the current stage of information system development. Thus, in order to speed up the calculation process, it has been decided to

the non-synchronism problem it was suggested in Smith *et al.*, who did not use daily data, that this was explained by extra noise. Instead, in his research weekly data, which is represented as a trading day closing value of Wednesday, was applied. This method was also applied, for example, in Godfrey, Granger and Morgenstern (1964), Lo and Mackinlay (1990). No reference for non-synchronism problem is given in Aaltonen and Östermark (1997).

⁷⁶ Smith, *et al.* (1993) applied the rolling window technique for window size equal to 150 observations. Fujii (2005) applied the rolling window test for window size equal to 240 observations assuming approximately a one year sub-sample.

⁷⁷ 'Minimum reasonable' window size can be defined by the researcher, based on the aims of the study. One can check 20 or 125 observations assuming approximately 4 weeks and 6 months patterns respectively for 5 days a week data.

utilise the following window sizes⁷⁸: 3130, 2730, 1930, 1130, 330, 250, and 150. The corresponding total number of rolling subsamples to each of the presented window sizes is given in Table 5.3-1.

This window size structure assumes a total number of 12267 sub-samples for the given set of window sizes. Moreover, the total number of equations will rise significantly when the rolling window is applied to the estimation for all participating series (e.g. pair wise form⁷⁹). Therefore, the testing of the hypothesis for a large number of equations requires the solution of new objectives: 1) overall statistics of Granger Causality tests for each window size; 2) new form of results presentation.

5.3.1. Application of hypothesis rejection frequency and results representation diagrams in measuring of the stability.

There have been a number of research articles where the authors, due to the large number of estimated equations, apply the ratios that represent the overall result of appearance of a particular event (e.g. significance of parameter, rejection of the non-causality null hypothesis). In this thesis term consolidating statistics refers to the given ratios. Authors utilise such statistics in order to derive the overall conclusion or to distinguish the general trend. For example: Swanson (1998) by applying the rolling window method used Granger Causality test *rejection rate*; Hwang and Satchel (2005) performed the testing procedure for the GARCH-X model, where the rolling window approach is used and a hypothesis rejection rate for the group of tests (Percent of Significant Coefficients, Portmanteau Tests Q-stats); Gorjaev and Zobotkin (2006) applies rolling single-factor and multi-factor CAPM reporting the average value of the estimated beta coefficients and percentage number of coefficients with the same sign and significance at the 5% level; Wang and Lee (2009), by analysing pair wise Granger Causality testing for the countries from the Asia-Pacific region, utilised percentage and frequency ratio analysis of the lead-lag relationship of the stock returns and stock returns' volatilities.

Following the Swanson's (1998) procedure the consolidating statistic is applied for each window size in order to examine the frequency of rejection of null hypothesis (e.g. non-causality hypothesis).

⁷⁸ At a preliminary stage of simulation a set of 14 window sizes was used starting from the full sample and ending at 50 observations. Knowing that there is a trade off between the number of window sizes to be estimated and the time needed for that estimation, the decision was taken to reduce the total number of window sizes in order to increase the speed of estimation. But, as mentioned above, the most detailed estimation could be performed using one observation step between the nearest window size (E.g. Window sizes with 1 observation step difference are: 3130, 3129, 3128 ... 151, 150) and each of these should be applied in the rolling window estimation. It is thought that this estimation is necessary for a more thorough analysis in future studies.

⁷⁹ This notion is used to describe a pair of series, where bi-directional causality is tested from one series to another and vice versa.

Thus, there is perceived to be considerable interest in attributing the percentage number of tests for each window size where the hypothesis of Granger non-causality⁸⁰ was rejected. For example: for window with size Q (*observations*) it was made N number of rolling Granger Causality tests, where M is the number of tests where non-causality hypothesis is rejected. This can be found using the following formula:

$$\text{Rejection Frequency} = \frac{M}{N} * 100\% \quad (23)$$

Consequently, the given statistics for the definite pair of time-series allows observation of how the decrease of the window size (Q) affects the parameter of non-causality hypothesis Rejection Frequency (*non-causality HRF*). The representation of Q and *non-causality HRF* on the diagram for each pair of time series in a bidirectional test makes it possible to analyse changes in *non-causality HRF* of one pair compared to *non-causality HRF* of other pairs of indices. At the same time, this misses the opportunity to trace the exact location of structural breaks since within the overall statistics they are hidden.

For interpretation purposes it is important to distinguish possible cases of *non-causality HRF* behaviour with respect to the specified windows sizes, all solved using the Smith, *et al.* (1993) technique. These are shown in Table 5.3-2 on the following page.

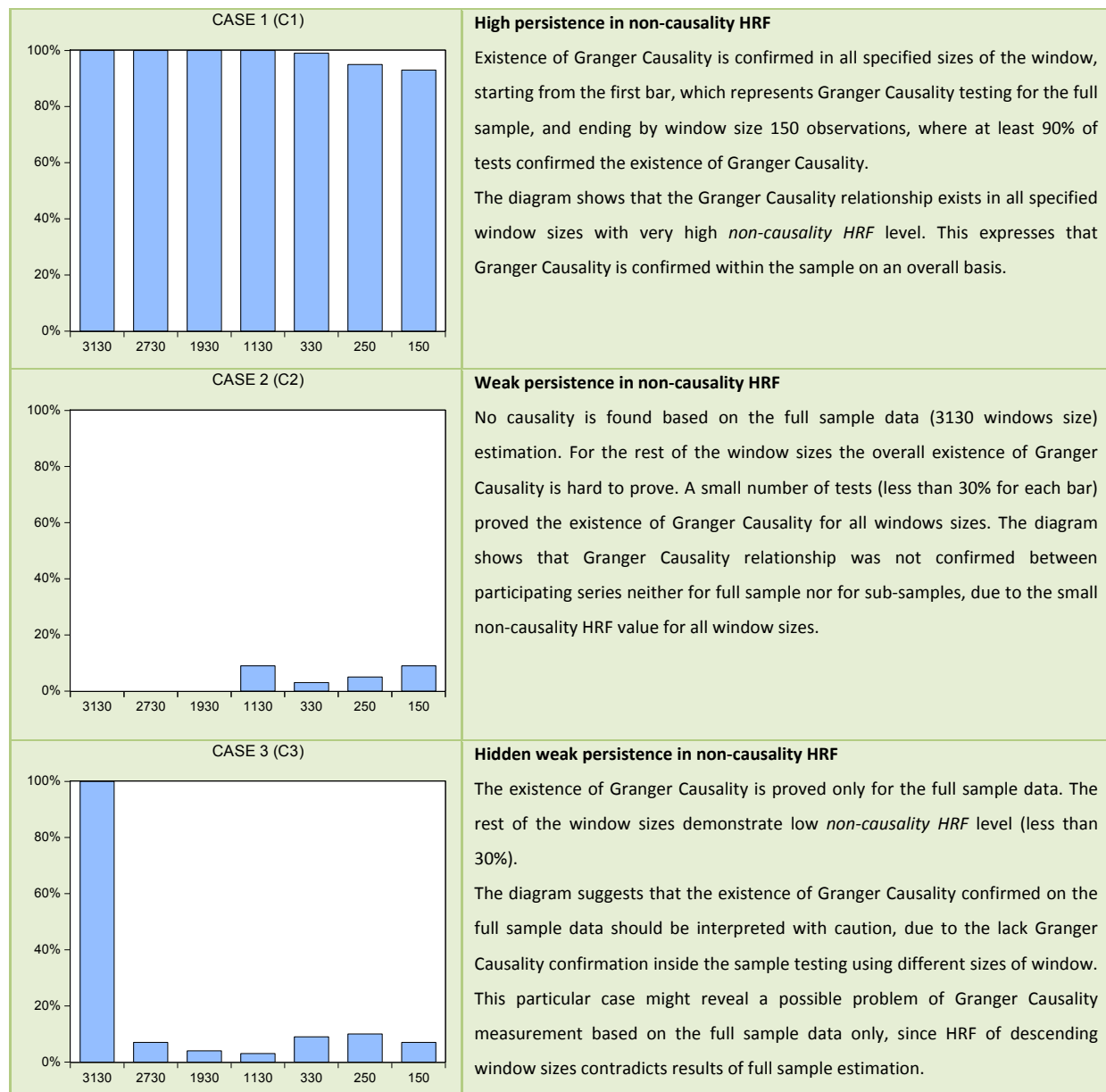
All the given sets of Granger Causality interpretation give a better understanding of what happens inside the analysed pairs of series. One should not assume that transitory cases between suggested ones (cases 1-4) might also occur.

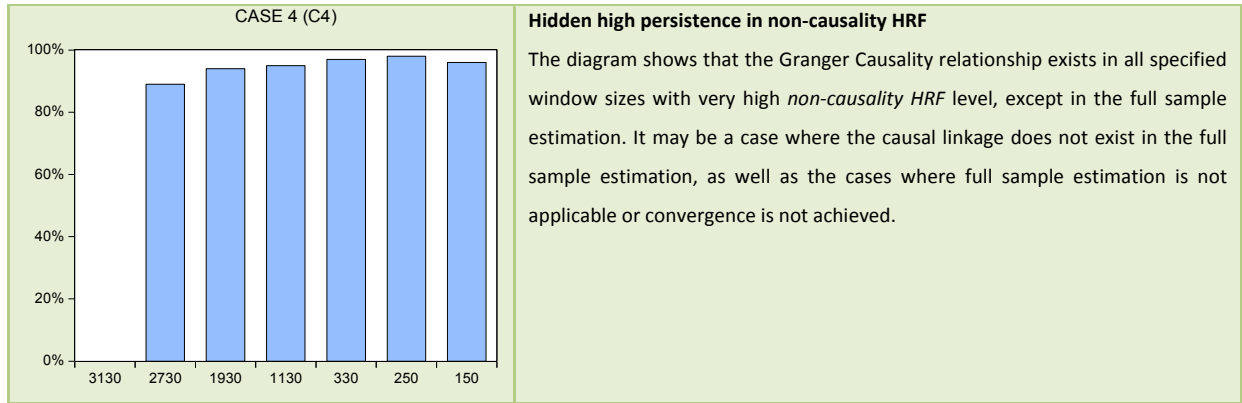
The non-causality HRF persistence diagrams are useful when comparing different pairs of series. First of all, based on the non-causality HRF parameter, it allows researchers to distinguishing a pair with the strongest causality relationships out of two highly persistent ones (assuming high percentage values of HRF) in non-causality HRF diagrams, since it is possible to observe how the non-causality HRF parameter declines with respect to descending window sizes as applied in the Smith *et al.* (1993) technique.

⁸⁰ At this point, the discussion is focused on the consolidated statistics in respect of the Granger non-causality test, which is the main test applied in the current study. However, due to the universality of the rolling window approach and consolidated statistic estimation, the same procedures are also applied to other tests (e.g. Augmented Dickey and Fuller (1979) test), as well as to the detection of the percentage change sign prevalence, when the difference in the CCF causality is observed in oil unadjusted and adjusted cases (Section 5.2.2 discussion of oil unadjusted and adjusted models; Section 7.3.4 p. 158 discussion of the comparison procedures and Sign Prevalence; Appendix A.4 gives the verdict regarding cross-correlation coefficient percentage change Sign Prevalence at a certain lag observed in mean and variance). The frequency of the sign appearance is used in the study by Gorjaev and Zabolkin (2006, p. 393) where the authors used a percentage of rolling "betas having the same sign as the average coefficients and significant at 5% level". Consolidating statistics is derived using code developed in studies by Grigoryev (2005, 2006).

Secondly, it enables the question of intraregional interdependence to be examined, since stock markets, which have partly or fully overlapped trading time, could be exposed to the existence of contemporaneous Granger Causality. This particular group of countries is more likely to have High persistence in non-causality HRF compared to the countries located in different time zones.

Table 5.3-2
Possible patterns of *non-causality HRF* vs. *rolling window size* diagram.





The thesis assumes the models in Section 5.2.2.1 to be estimated both in the full sample and rolling window approaches. Moreover, the non-stationarity hypothesis of returns is also tested using descending window size solved in the rolling approach. For these purposes the rolling ADF test is applied. The discussion on application of rolling integration is given in Sections 4.2.1 of the present thesis. Therefore, this section is devoted to the rolling estimation as well as its shortcomings. The perception is that the use of multiple window sizes (descending window sizes) could show how the non-causality HRF and other tests evolve with respect to change in the window size.

6. Data and descriptive statistics

6.1. Data set

The full data set consists of the BRIC countries' stock market indices: RTS index (Russia), SHANGHAI SE Composite (China), BSE 100 National (India), BOVESPA (Brazil), following stock market indices of major countries: NYSE Composite (US), NIKKEI 225 Stock Average (Japan), DAX 30 performance (Germany), CAC 40 (France), FTSE All Share (UK) and the oil price, represented by ICE Brent Crude Oil price. All series represent daily data (5 days a week daily closing price). Crude Oil is represented by Brent⁸¹ Crude Oil weighted on the current bid/ask offers and completed deals of the futures market (DataStream abbreviation: "Dtd Brent UK Close U\$/BBL") recorded at 16.30 London time daily from Intercontinental Exchange (ICE) (DataStream data supplier: ICIS pricing. www.icispricing.com). Knowing the exact time of the Crude Oil daily record it should be possible to apply the Crude Oil price value to interdependence analysis.

All data have been downloaded from DataStream. The series covers the time period from 01/01/1996 to 31/12/2007. The starting period is taken due to the fact that it is a first full year of the Russian stock market (RTS), while the ending point of the sample is taken as a last full year before the year where the sub-prime crisis has started. The total number of observations levels being: 3131.

Comparable sample sizes but for a different sets of indices and time periods were used in the application of the GARCH family model by Hwang (2005), Fang, *et al.* (2006), Bhar and Nikolova (2009a). The series used in this thesis contains two "crisis" (Asian 1997 and Russian 1998). However, according to Smith, *et al.* (1993, pp. 55,57) and Basher and Sadorsky (2006, pp. 231,232), the rolling window method will flexibly overcome outliers and possible structural changes will be isolated (restricted) by the group of sub-samples.

In addition to possible bias in index analysis, Roll (1992) highlights two factors that might affect stock index behaviour. The first factor is the technical aspects of index construction⁸² and the second is exchange rate behaviour. To fulfil the requirements of comparability, transformation of one currency should occur. The most precise transformation to the dollar value can be performed as suggested in Bessler and Yang (2003, p. 268). According to them, the most appropriate transformation is the use of the exchange rate for each of the non-US dollar countries with the timing of the exchange rate closely matched to the local stock market closing time. However, it was

⁸¹ Brent Crude Oil is traded throughout the day. It opens at 01:00 London local time and closes at 23:00 London local time, with the BST time seasonal switch (ICE Brent Crude Futures, Contract Specifications 2010).

⁸² It should be noted that the research utilises composite indices that are assumed to be estimated with the variable weights for some shares, adjustment for the number of outstanding shares (free-float coefficient) and changing list of shares for index estimation. These adjustments may affect the real dynamics of the shares and results should be interpreted by taking into account the given assumption.

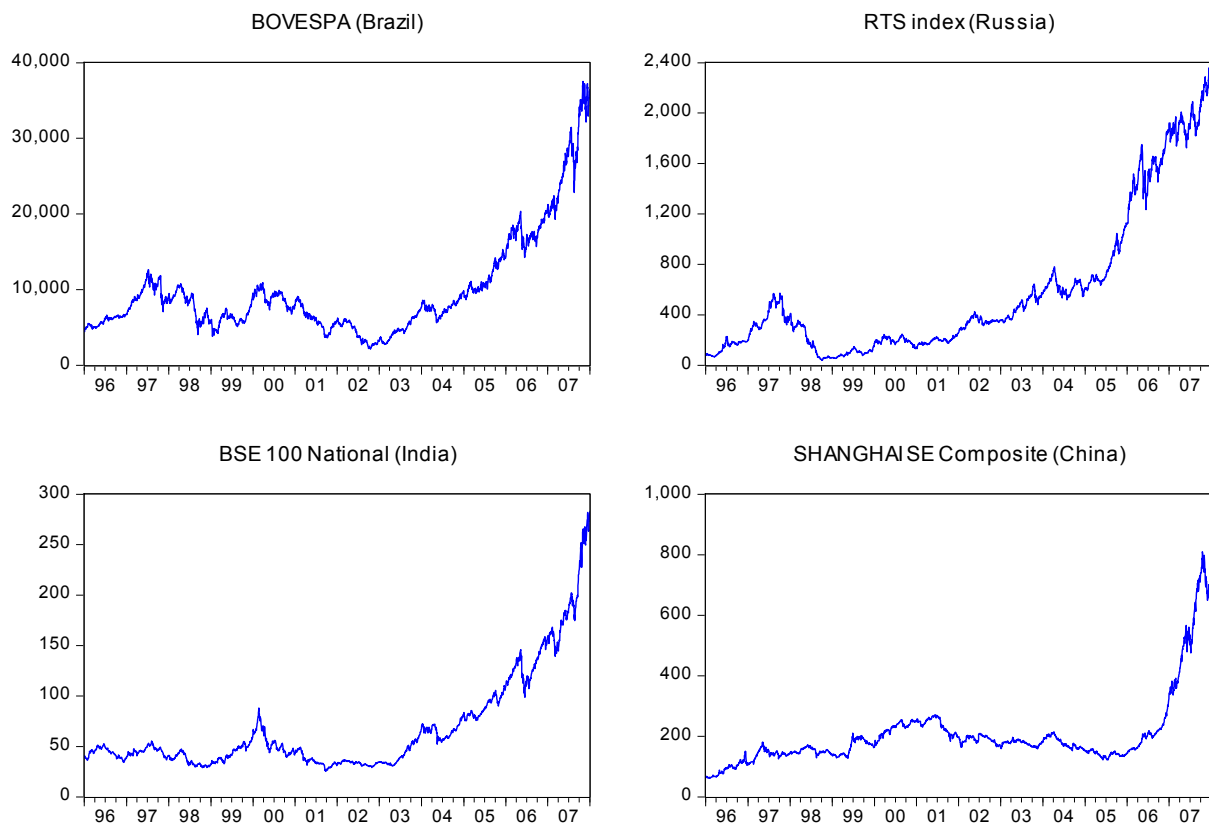
not possible to find such precise data and transformation was performed using Reuters currency spot exchange value for the same day (also downloaded from DataStream).

In this study the logarithm of daily returns ($\Delta Y_t = \ln(P_t) - \ln(P_{t-1})$) and the logarithm of daily levels ($Y_t = \ln(P_t)$) is analysed, where P_t is the closing price of an index⁸³ on day t . Having established the dataset it is now possible to proceed to the preliminary examination of the series in graphs, descriptive statistics and unconditional correlation.

6.2. Descriptive statistics

It is worth noting that a preliminary examination of the dynamics of the BRIC indices reveals a similar pattern in the overall trend (Figure 6.2-1), which may be explained by the approximately similar market liberalisation period (1991-1993) as discussed in Bhar and Nikolova (2009a, p. 204) and in Bekaert, *et al.* (2003) for other emerging markets.

Figure 6.2-1
BRIC countries



⁸³ Note that oil price in the study stands for the logged return of the oil price, if other interpretations are not mentioned.

Figure 6.2-2
Dynamics of mature markets and oil price.

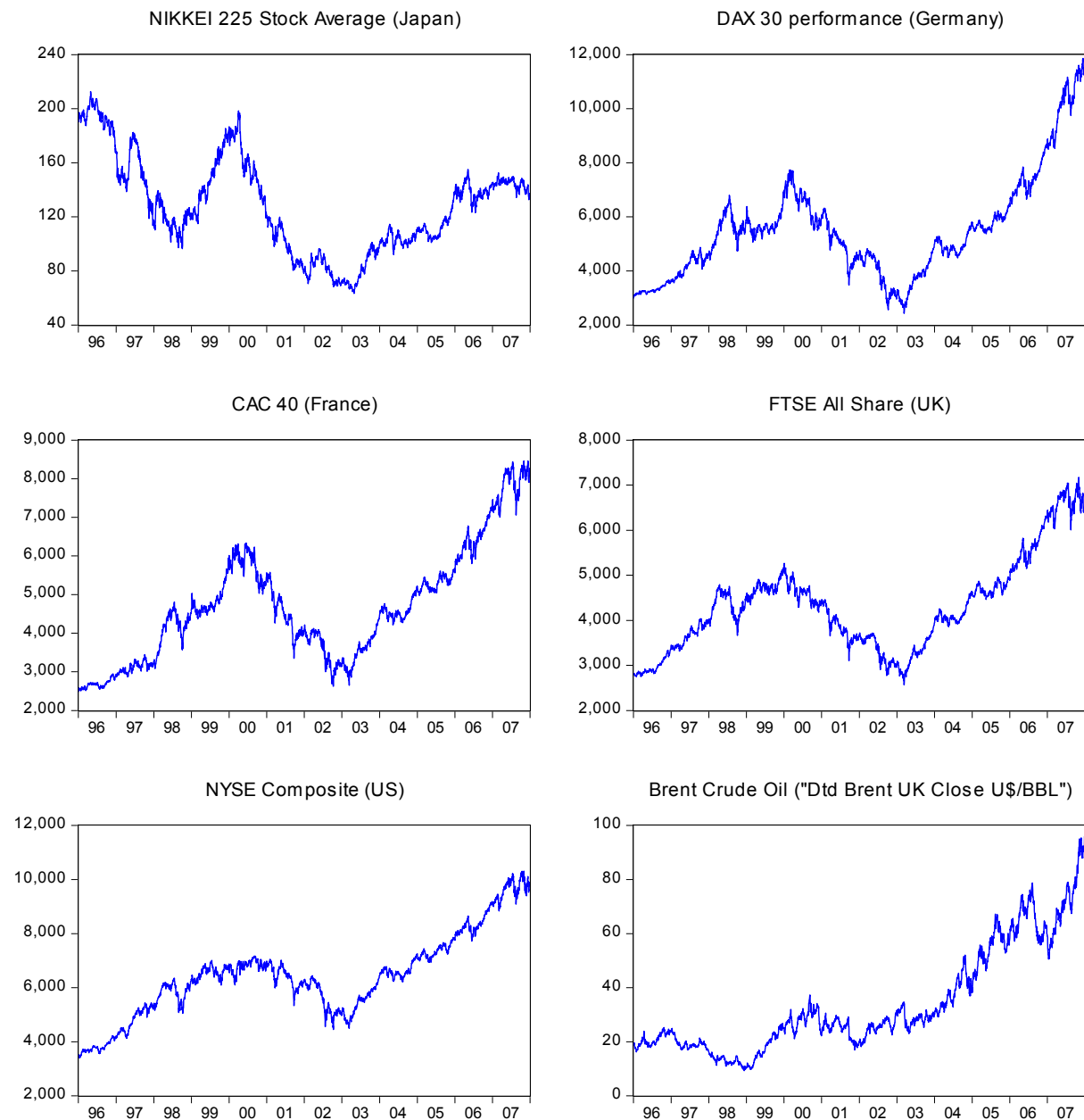


Table 6.2 1 represents summary statistics for the participating indices. The mean of the given series varies from -0.010878 for Japan to 0.106027 for Russia. The standard deviation of returns lies between 0.976190 and 2.715991.

Figure 6.2-2 demonstrates that, dynamics of the absolute values of the indices of mature markets shows some similarities in the trend, with possible exception for the Japanese stock market index, where the pattern is less pronounced and the oil price. This similarity is associated with the development of the Dot Com Bubble, which started approximately in 1996 with the peak and further collapse in the year 2000. The downward dynamic after the Dot Com Bubble is continued until the

start of the Iraq War in March, 2003, which induced a raising dynamic of the stock market indices of the developed countries, this continued to the end of the sample under investigation.

The values of skewness show that negative shocks are more common than positive ones for all indices, except Japan where it is found to be positive (0.207850). BRIC countries are found to have a greater value of kurtosis with a 10.20, 9.02, 8.35 and 6.65 for Russia, China, Brazil and India respectively. The Jarque-Bera (Bera and Jarque, 1981) test rejects the hypothesis of normality for all participating series. This may refer to the use of a flexible probability density function as an alternative to standard normal distribution and, as suggested by Michelfelder and Pandya (2005, p. 71), the estimation of EGARCH together with G.E.D. may be a better alternative to the standard normal probability density function (see page 91).

The Ljung and Box (1978) Portmanteau test is performed for the returns $Q(k)$ and squared returns $Q^2(k)$, where k are lag 5 and 10 respectively. The null hypothesis that the series are uncorrelated is not rejected at 5% level of significance for Crude oil. The null hypothesis of uncorrelated squared returns is rejected at 1% level of significance for all participating series. These may refer to the existence of non-linear dependencies and heteroscedasticity, which justifies the use of the ARMA as well as GARCH process.

Table 6.2-1
Descriptive statistics of logged return.

	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Q(5)	Q(10)	Q2(5)	Q2(10)
Japan	-0.010878	1.543897	0.207850	6.209365	1365.831 **	13.503 *	17.471	209.75 **	362.71 **
China	0.075994	1.649782	-0.240048	9.024234	4763.063 **	19.424 **	33.109 **	493.39 **	598.12 **
India	0.061911	1.652571	-0.381586	6.650440	1813.854 **	41.750 **	70.655 **	593.77 **	710.03 **
Russia	0.106027	2.715991	-0.491649	10.20162	6889.937 **	44.960 **	61.379 **	485.94 **	817.43 **
Germany	0.043731	1.451351	-0.201053	5.491015	830.3428 **	5.3558	18.537 *	893.15 **	1767.9 **
France	0.038080	1.300934	-0.158673	5.235578	664.9316 **	24.412 **	32.101 **	746.51 **	1437.9 **
UK	0.027121	1.009613	-0.249185	5.157051	639.2035 **	28.252 **	41.393 **	902.26 **	1503.1 **
Brazil	0.066892	2.476202	-0.241689	8.349094	3762.060 **	29.251 **	50.946 **	817.00 **	1088.6 **
US	0.032845	0.976190	-0.249169	6.551333	1677.198 **	4.7314	18.585 *	397.39 **	711.83 **
Crude Oil	0.051495	2.260390	-0.230701	6.248082	1403.665 **	5.4830	13.614	112.33 **	150.62 **

Notes: The data represented in the table are daily equity index returns and oil price returns for the period January 1996 to December 2007. Mean, Standard deviation, Skewness and Kurtosis are reports for each of the returns of participating series. Jarque-Bera test represents critical values on the null hypothesis of a normal distribution of the series, where the * and ** represents the rejection at 5% and 1% level of significance. The Portmanteau statistic with the null hypothesis of no series serial correlations measured with an up to lag 5 and 10 represented in a columns Q(5) and Q(10) respectively, while Q2(5) and Q2(10) refers to the same test with squared data series. The significance of both Q and Q2 statistics is denoted as * and **, representing 5% and 1% level of significance.

Table 6.2-2

Cross-correlation of returns at the same day and the previous day.

	Japan	China	India	Russia	Germany	France	UK	Brazil	US	Crude Oil
Japan	-	0.0545	0.1841	0.0894(p)	0.2326(p)	0.2410(p)	0.2208(p)	0.2014(p)	0.2862(p)	0.0305
China	0.0545	-	0.0555	0.0283(p)	0.0570(p)	0.0491(p)	0.0544(p)	0.0504(p)	0.0475(p)	-0.0152
India	0.1841	0.0555	-	0.1748	0.1369	0.1652	0.1800	0.1501(p)	0.1450(p)	0.0037
Russia	0.1549	0.0084	0.1748	-	0.2747	0.2795	0.2834	0.2190	0.2042(p)	0.0841
Germany	0.1928	0.0038	0.1369	0.2747	-	0.8024	0.6923	0.3447	0.5050	0.0076
France	0.2067	-0.0100	0.1652	0.2795	0.8024	-	0.7707	0.3516	0.4823	0.0226
UK	0.2109	0.0021	0.1800	0.2834	0.6923	0.7707	-	0.3467	0.4481	0.0426
Brazil	0.1141	0.0079	0.1276	0.2190	0.3447	0.3516	0.3467	-	0.4887	0.0229
US	0.0920	-0.0104	0.0794	0.1611	0.5050	0.4823	0.4481	0.4887	-	-0.0094
Crude Oil	0.0305	-0.0152	0.0037	0.0841	0.0076	0.0226	0.0426	0.0229	-0.0094	-

Notes: Cross-correlation function is used with respect to the different time zone of indices. Cross-correlation at time (t) is used for the indices with overlapped trading time (i.e.: Russia and Germany – 0.2747) and for the indices that close before the open of the other (i.e.: Japan and US – 0.092). Cross-Correlation at lag ($t-1$) is used to denote previous day effect (i.e.: US and Japan – 0.2862), which is marked by “(p)” abbreviation.

Table 6.2-2 represents bi-variate cross-correlation among stock market index returns. The smallest value is found between China and the Crude oil price index (-0.0152) and the highest value is found between Germany and France (0.8024). The pattern of cross correlation is consistent with the time zone structure and geographical proximity of the participating countries; these support the Gjerde and Sættem (1995), Bracker, *et al.* (1999) cross-correlation table and the cross correlation function table by Gebka and Serwa (2007). The European market, represented by lag 0 cross-correlation, demonstrates a high degree of dependency having all correlation coefficients high and positive. The cross-correlation of current day returns with the previous days' returns is marked by the “(p)” abbreviation and it provides a clear suggestion that the time period between the closing times of two markets is one of the crucial factors which determine the degree of co-movements.

As specified in Gebka and Serwa (2007, p. 209), contemporaneous correlation⁸⁴ occurs between the indices that have trading time overlaps, as well as for markets with different operating hours, where a later closing market absorbs and processes the behaviour of an earlier closing market. Thus, the two contemporaneous correlations should be separated: for Japan between Japan (t) and US (t); for the US between US($t-1$) and Japan(t). Thus, cross correlation between Japan (t) and US (t) is 0.092, while Japan (t) and US ($t-1$) is 0.2862. This may suggest that the time period between the closing times of indices may be a crucial factor which may affect the signal propagation from one index to another. Arguably, the two other important factors, which may produce a significant distortion of the signal from Japan to the US, is a cascade of signals issued by other markets (e.g. Asia, Middle

⁸⁴ Similar specification can be found in Bessler and Yang (2003, p. 270).

East and Europe) and a chain of events which appear before the closing time of the US market, assuming that the market players apply them in a decision-making process. Thus, the Japanese signal is processed by the US market together with signals from other markets and expectations of events' consequences. In contrast, the US signal is processed by Japan being relatively pure assuming that a small number of events will occur in the time period between closing times in the US and Japan, and the fact that most markets that open in the Asia-Pacific region have overlaps with Japan. This may explain the difference between the two contemporaneous correlations of Japan and the US.

7. Empirical results

7.1. Full sample and rolling unit root test

The analysis of the empirical results starts with an investigation of the stationarity characteristics of the data set.

It is widely accepted that most financial series, especially stock market data, are integrated at order 1 ($I(1)$). However, the routine procedure of series testing for the unit root is applied before application to the main models. Against this background the Augmented Dickey Fuller test (Dickey and Fuller, 1979; Said and Dickey, 1984) is one of the most popular unit root tests. The ADF test is a widely used method, which owes its popularity to its ability to tackle serial correlation in residuals. The test is performed using the following regression:

$$\Delta y_t = \alpha + \delta t + \beta y_{t-1} + \sum_{i=1}^k \psi_i \Delta y_{t-i} + u_t.$$

The null hypothesis of a stochastic trend (unit root) is tested using t -statistics of $\beta=0$, knowing the alternative hypothesis of deterministic trend (trend stationary). Thus, the ADF t -statistic is a regression t -statistic, where β should be equal to zero. Other parameters are: (t) is a deterministic trend, serial correlation in residuals is treated by the inclusion of Δy_{t-i} (first difference of y_t), u_t is an identically distributed error term with no serial correlation.

The next unit root test to be applied in this study is a Phillips and Perron unit root test (Phillips and Perron, 1988). The test is based on the Dickey and Fuller (1979) test, but without parametric correction. Instead the correction is performed using new statistics which take serial correlation into account by eliminating the nuisance parameter on the asymptotic distribution.

Full sample results of both tests are given in Table 7.1-1. Augmented Dickey Fuller and Phillips-Perron tests provide the evidence that series are $I(1)$ in given sample period.

Table 7.1-1
Augmented Dickey-Fuller and Phillips-Perron unit root test
for 9 indices and Brent Crude Oil price.

Series	Logged Level		Logged First difference	
	ADF T-stat	PP T-stat	ADF T-stat	PP T-stat
JAPAN	-1.631 (0)	-1.503	-58.092 (0) **	-58.274 **
CHINA	-0.543 (0)	-0.583	-56.238 (0) **	-56.241 **
INDIA	-0.462 (1)	-0.439	-50.377 (0) **	-50.419 **
RUSSIA	-1.476 (1)	-1.547	-49.740 (0) **	-49.872 **
GERMANY	-1.076 (0)	-1.042	-56.190 (0) **	-56.210 **
FRANCE	-1.654 (0)	-1.497	-54.399 (0) **	-54.660 **
UK	-1.444 (0)	-1.299	-55.168 (0) **	-55.469 **
BRAZIL	-0.929 (1)	-0.829	-51.273 (0) **	-51.147 **
US	-2.184 (0)	-2.070	-55.528 (0) **	-55.778 **
OIL	-2.466 (0)	-2.511	-53.886 (0) **	-53.878 **

Notes: Lag lengths of Augmented Dickey-Fuller and Phillips-Perron tests are selected by SIC. Lag length for ADF is displayed in brackets. All tests included a constant and trend term.

The critical values for the augmented Dickey-Fuller test statistic are -3.411243 and -3.960974 at the 5% and 1% levels, respectively. * and ** represents significance at the 5% and 1% level.

The critical values for the Phillips-Perron test statistic are -3.411242 and -3.960973 at the 5% and 1% levels, respectively. * and ** represents significance at the 5% and 1% level.

In this series high turbulence periods are conditioned by the existence of periods of crisis (e.g. Asian crisis 1997; Russian crisis 1998), which are likely to affect the test statistics of the unit root test. With this in mind, it was decided not to use any of the specific tests currently available in related literature, since the question of stationarity/non-stationarity in the presence of breaks is still open to discussion and it can be argued that more time is required to find the most suitable and robust test, which would encompass all the possible data properties. However, with respect to this study it is assumed that the use of the rolling window approach together with descending window sizes will be able to detect abnormal behaviour (anomalies) of series in terms of non-stationarity even with the standard ADF test, due to the fact that each of the large rolling sub-samples will also be decomposed in the same test but on smaller rolling sub-samples assuming the descending window structure shown in Table 5.3-1. The use of the notation of abnormal behaviour or anomalies refers to the test results, where the test outcome is in contradiction to the expected verdict about series stationarity. Thus, it is assumed that the logarithm of levels of daily financial series should be $I(1)$, while the anomaly in this regard will be the test outcome that logarithm of levels is $I(0)$. Therefore, to prove the stability of non-stationarity test, the ADF test is applied to the rolling window approach, to the set of window sizes given in Section 5.3 and the rejection rate for the non-stationarity hypothesis is calculated using expression (23) for each window size given in the same way as it is given for *non-causality HRF* in Section 5.3.1.

Thus, the rolling window approach is used to identify the rolling sub-samples with non-stationarity anomalies of series, which should be reported, but in studies by other authors is usually limited by full sample estimation only anticipating the use of thorough co-integration tests. This appears inconsistent, since the application of recursive (e.g. Lucey and Voronkova, 2008) and rolling co-integration (e.g. Awokuse, *et al.*, 2009), is applied on series that are confirmed to have a unit root in their logged levels in full sample estimation only. Therefore, there is a possibility that some rolling or recursive sub-samples may express $I(0)$ nature, despite the expected $I(1)$ not being excluded. In this regard if a group of sub-samples is confirmed to be $I(0)$, then they cannot participate in co-integration test since it violates a preliminary condition of co-integration test that series should be $I(1)$ in their levels (Engle and Granger, 1987, p. 253; Johansen, 1991, p. 1559; Gregory and Hansen, 1996, p. 100).

Table 7.1-2
Percent of subsamples proved to be stationary in ADF test conducted on logged levels⁸⁵

Series	Rolling window size (number of rolling sub-samples)						
	W=3131 (N=1)	W=2730 (N=401)	W=1930 (N=1201)	W=1130 (N=2001)	W=330 (N=2801)	W=250 (N=2882)	W=150 (N=2982)
Constant, no trend							
JAPAN	0%	0%	0%	0%	5%	4%	4%
CHINA	0%	27%	9%	0%	2%	2%	2%
INDIA	0%	0%	0%	0%	1%	2%	2%
RUSSIA	0%	0%	0%	0%	3%	1%	3%
GERMANY	0%	0%	0%	0%	2%	4%	4%
FRANCE	0%	0%	0%	0%	1%	2%	7%
UK	0%	0%	0%	0%	0%	2%	5%
BRAZIL	0%	0%	0%	0%	1%	1%	1%
US	0%	0%	3%	5%	8%	5%	4%
OIL	0%	0%	0%	11%	0%	0%	2%
Constant and trend							
JAPAN	0%	0%	0%	4%	10%	12%	15%
CHINA	0%	0%	0%	0%	1%	2%	4%
INDIA	0%	0%	1%	1%	1%	1%	3%
RUSSIA	0%	0%	21%	4%	2%	2%	3%
GERMANY	0%	0%	0%	5%	3%	5%	8%
FRANCE	0%	0%	0%	18%	4%	3%	6%
UK	0%	0%	0%	15%	4%	3%	6%
BRAZIL	0%	0%	0%	11%	2%	4%	3%
US	0%	0%	0%	14%	6%	7%	7%
OIL	0%	0%	0%	9%	2%	2%	2%

Notes: The ADF test is conducted for each rolling sub-sample for each of the window sizes (W) and (N) is a total number of sub-samples for each of the given window sizes. The percent in each cell represents the proportion of sub-samples where the non-stationarity hypothesis is rejected at 5% level of significance confirming that the logged levels are $I(0)$.

Table 7.1-2 consist of the values of consolidated statistics (expression (23)) given in Section 5.3.1, where M is the total number of rolling sub-samples where the hypothesis of non-stationarity is

⁸⁵ Application of ADF test on the first and the second differences of the series in a given rolling approach shows rejection of the hypothesis of non-stationarity. The ADF test performed on first difference revealed 100% rejection frequency of non-stationarity hypothesis on all observed series within all window sizes; for this reason the results are not tabulated.

rejected at 5% level of significance, and N is a total number of sub-samples for each of the given window sizes. Thus, in Table 7.1-2 the consolidated statistics are given in percentage terms for each country and corresponding window size W with the total number of rolling subsamples N .

Having applied the rolling window technique together with the ADF test, it is possible to identify the anomalies. The application of the rolling window approach for China and Russia demonstrate a large proportion of rejections of the non-stationarity hypothesis for the window sizes 2730 and 1930 respectively. It shows that 27% of rolling sub-samples for China and 21% rolling sub-samples for Russia for the window sizes 2730 and 1930 are $I(0)$, despite the expected $I(1)$. Other indices (including oil price) also express anomalies but on smaller window sizes, mainly starting from the 1130 observation window size. This result might be a case of spurious rejection when breaks exist inside the sample, as discussed in the studies by Leybourne *et al.* (1998), Leybourne and Newbold (2000), Kim, *et al.* (2003). It is worth noting that India is the most stable in both constant only and constant no trend testing, since the rejection rate of the non-stationarity hypothesis is close to the level of insignificant noise.

Overall, the results show that integration characteristics are not stable and they should be taken into account before the application of a co-integration test, since co-integration applied on $I(0)$ series violates preliminary conditions of co-integration (Engle and Granger, 1987, p. 253; Johansen, 1991, p. 1559; Gregory and Hansen, 1996, p. 100).

On the basis of this result it has been decided not to provide any kind of sorting to the rolling sub-sample with respect to their integration properties, and further analysis is to be done on logged returns, assuming that series are $I(1)$ in their logged levels.

7.2. Classic and contemporaneous causality based on full sample estimation.

Since most of the models in this thesis utilise non-synchronism correction, it is useful to investigate the consequences of ignoring the non-synchronism problem on the regression model, which is usually applied for the purpose of simplicity (see for example Furstenberg, *et al.*, 1989; Malliaris and Urrutia, 1992a). Therefore, this section provides comparison between the Granger Causality test in its classic form and in a form where same day effect causality is allowed (contemporaneous form for early opened markets). Due to the existence of anomalies (Section 7.1 and Table 7.1-2) it was decided to avoid the use of the co-integration adjusted structure of the equations. Instead, equations conducted on the logged return are used, where equations 4 and 5 assume classic Granger Causality with previous day effect only, and equations 8 and 9 assume a contemporaneous

structure of causal effects that allow the existence of causality within one day. The lag detection is performed by minimizing Schwarz information criterion for the $k=1...10$, where the maximum detected value is $k=3$, as given in the full model output found in Appendices A.2, Table A.2-1 for the classic Granger Causality and Table A.2-2 for the non-synchronism corrected form.

A classic form of the Granger Causality is represented in Table 7.2-1, assuming that the previous day value of one index is causing the current day value of another index. The indices are ordered in a sequence starting from the early opening ones (Japan) and ending with later closing ones (US). In order to focus on the sequence of stock market indices the oil price is put at the end of the ordered sequence.

An initial inspection of the table reveals the existence of the delimitation, represented by a diagonal line. This shows that the upper half of the table is more likely to show the existence of causal linkages. For example, Japan is caused by all indices except China. China, in its turn, is found to be caused by all other indices except Japan, India and Russia. On the other hand, Brazil and the US cause all other indices including the oil price, while no indices cause them. Thus, the US together with Brazil appears to be the most dominating markets in the estimated period, using the classic Granger Causality framework.

The thinking behind this finding is that the US and Brazil close later, compared to other indices. This can partly be explained by the traditionally established Standard Time structure, which puts the US and Brazil at the end of the day. The perception is that the allocation of the trading time of the market inside the working day is a crucial factor that affects the measurement of the linkages between stock markets. The markets, which have the latest closing time during the day, are likely to affect the others in the classical Granger Causality test. Another point is that any day closing index will experience higher causal effect on the other indices, since its day closing value is already adjusted to all current day innovations and their reflections from other indices.

Therefore, the next day all indices will be affected by its (later closing index) closing value as an innovation for the new day. The sequence of indices' day closing time is a product of traditional time structure (GMT line ruler) and any change in the traditional time structure will affect the Granger Causality pattern, and the indices that close earlier will probably always be treated as dependent ones.

Table 7.2-1
Classic causality test, without any corrections for non-synchronism of data.

	JP	CH	IN	RU	GE	FR	UK	BR	US	OIL
JP		CH -x-> JP	IN ->> JP**	RU ->> JP**	GE ->> JP**	FR ->> JP**	UK ->> JP**	BR ->> JP**	US ->> JP**	CR -x-> JP
CH	JP -x-> CH		IN -x-> CH	RU -x-> CH	GE ->> CH**	FR ->> CH**	UK ->> CH**	BR ->> CH**	US ->> CH*	CR -x-> CH
IN	JP -x-> IN	CH -x-> IN		RU ->> IN**	GE ->> IN**	FR ->> IN**	UK ->> IN**	BR ->> IN**	US ->> IN**	CR -x-> IN
RU	JP ->> RU*	CH -x-> RU	IN -x-> RU		GE -x-> RU	FR -x-> RU	UK ->> RU*	BR ->> RU**	US ->> RU**	CR -x-> RU
GE	JP -x-> GE	CH -x-> GE	IN -x-> GE	RU -x-> GE		FR ->> GE**	UK -x-> GE	BR ->> GE**	US ->> GE**	CR -x-> GE
FR	JP -x-> FR	CH -x-> FR	IN -x-> FR	RU -x-> FR	GE ->> FR**		UK -x-> FR	BR ->> FR**	US ->> FR**	CR -x-> FR
UK	JP -x-> UK	CH -x-> UK	IN -x-> UK	RU -x-> UK	GE ->> UK**	FR ->> UK*		BR ->> UK**	US ->> UK**	CR -x-> UK
BR	JP -x-> BR	CH -x-> BR	IN -x-> BR	RU -x-> BR	GE -x-> BR	FR -x-> BR	UK -x-> BR		US -x-> BR	CR -x-> BR
US	JP -x-> US	CH -x-> US	IN -x-> US	RU -x-> US	GE -x-> US	FR -x-> US	UK -x-> US	BR -x-> US		CR -x-> US
OIL	JP -x-> CR	CH -x-> CR	IN -x-> CR	RU -x-> CR	GE -x-> CR	FR -x-> CR	UK -x-> CR	BR ->> CR*	US ->> CR*	

Notes: The given table is a summary of the non-causality hypothesis testing in the form suggested by Ganger⁸⁶ (1969) based on the Newey and West (1987) Heteroscedasticity consistent regression. Lag detection is performed up to 10 lags by minimising SIC. The non-causality hypothesis is tested using Wald test on equations (4) and (5) for all $\beta_{y,z}$ and $\beta_{x,i}$ respectively. For equation (4) the joint test is performed by testing $H_{y,0}: \beta_{y,z}=0$, knowing that $z=1\dots k$. And vice versa, where for the equation (5) the joint test is performed by testing $H_{x,0}: \beta_{x,i}=0$, knowing that $i=1\dots k$. The rejection of the $H_{y,0}$ and $H_{x,0}$ hypothesis is performed using the Wald test in asymptotic χ^2 distribution at 1% and 5% levels of significance, denoted in the table by “***” and “*”. The rejection of $H_{y,0}$ and $H_{x,0}$ hypothesis is located in cells where the country in the column attempts to cause the country in the row. Since the equations represent both directions of causality, then their location is symmetrically opposite, knowing that $H_{y,0}$ is located above the diagonal line (e.g. US ->> CH*, represents causality at the 5% level of significance) and $H_{x,0}$ is located below the diagonal line (e.g. CH -x-> US, representing a failure to cause at least at the 5% confidence level). The series consists of 3130 observations in returns dated from 02/01/1996 to 31/12/2007. The full outcome of the equations used in construction of the table is given in Table A.2-1.

Table 7.2-2
Granger causality test with allowance for the same day effect.

	JP	CH	IN	RU	GE	FR	UK	BR	US	OIL
JP		CH ->> JP**	IN ->> JP**	RU ->> JP**	GE ->> JP**	FR ->> JP**	UK ->> JP**	BR ->> JP**	US ->> JP**	CR -x-> JP
CH	JP ->> CH**		IN ->> CH**	RU -x-> CH	GE ->> CH**	FR ->> CH**	UK ->> CH**	BR ->> CH**	US ->> CH*	CR -x-> CH
IN	JP ->> IN**	CH ->> IN**		RU ->> IN**	GE ->> IN**	FR ->> IN**	UK ->> IN**	BR ->> IN**	US ->> IN**	CR -x-> IN
RU	JP ->> RU**	CH -x-> RU	IN ->> RU**		GE ->> RU**	FR ->> RU**	UK ->> RU**	BR ->> RU**	US ->> RU**	CR ->> RU**
GE	JP ->> GE**	CH -x-> GE	IN ->> GE**	RU ->> GE**		FR ->> GE**	UK ->> GE**	BR ->> GE**	US ->> GE**	CR -x-> GE
FR	JP ->> FR**	CH -x-> FR	IN ->> FR**	RU ->> FR**	GE ->> FR**		UK ->> FR**	BR ->> FR**	US ->> FR**	CR -x-> FR
UK	JP ->> UK**	CH -x-> UK	IN ->> UK**	RU ->> UK**	GE ->> UK**	FR ->> UK**		BR ->> UK**	US ->> UK**	CR -x-> UK
BR	JP ->> BR**	CH -x-> BR	IN ->> BR**	RU ->> BR**	GE ->> BR**	FR ->> BR**	UK ->> BR**		US ->> BR**	CR -x-> BR
US	JP ->> US**	CH -x-> US	IN ->> US**	RU ->> US**	GE ->> US**	FR ->> US**	UK ->> US**	BR ->> US**		CR -x-> US
OIL	JP -x-> CR	CH -x-> CR	IN -x-> CR	RU ->> CR**	GE -x-> CR	FR -x-> CR	UK -x-> CR	BR -x-> CR	US -x-> CR	

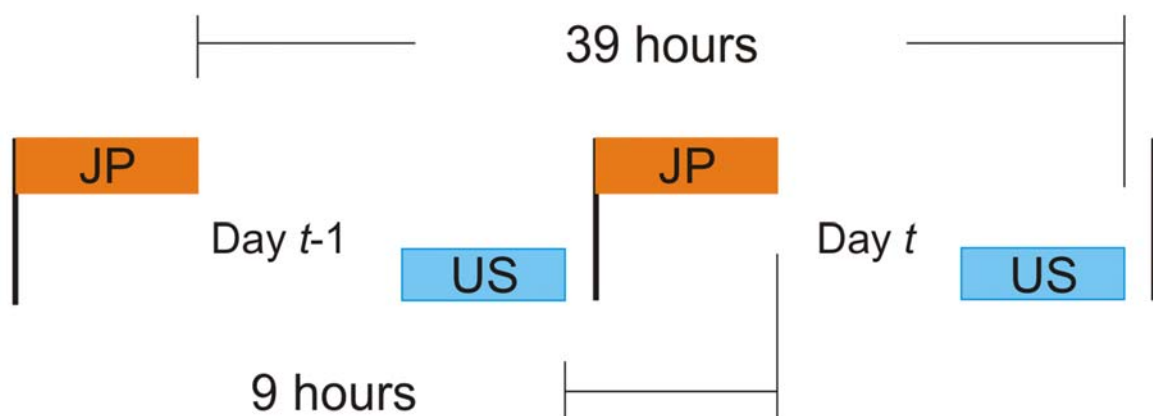
Notes: The given table is a summary of the non-causality hypothesis testing in non-synchronism corrected form in the Granger (1969) sense based on the Newey and West (1987) Heteroscedasticity consistent regression. Lag detection is performed up to 10 lags by minimising SIC. The non-causality hypothesis is tested using the Wald test on equations (8) and (9) for all $\beta_{y,z}$ and $\beta_{x,i}$ respectively. For equation (8) the joint test is performed by testing $H_{y,0}: \beta_{y,z}=0$ and $H_{y,0}: \beta_{x,i}=0$, knowing that $z=l_{x,y}, \dots, k-1+l_{x,y}$ and $i=l_{y,x}, \dots, k-1+l_{y,x}$ respectively and, $l_{x,y}$ and $l_{y,x}$ values are collected from Table 5.1-2 regarding the non-synchronism correction scheme given in Section 5.2.1.2.. The rejection of the $H_{y,0}$ and $H_{x,0}$ hypothesis is performed using the Wald test in asymptotic χ^2 distribution at 1% and 5% levels of significance, denoted in the table by “***” and “*”. The rejection of the $H_{y,0}$ and $H_{x,0}$ hypothesis is located in cells where the country in the column attempts to cause the country in the row. Since the equation represents both directions of causality, then their location is symmetrically opposite, knowing that $H_{y,0}$ is located above the diagonal line (e.g. US ->> CH*, represents causality at the 5% level of significance) and $H_{x,0}$ is located below diagonal line (e.g. CH -x-> US, representing failure to cause at least at the 5% confidence level). The series consist of 3130 observations in returns dated from 02/01/1996 to 31/12/2007. The full outcome of the equation used in construction of the table is given in Table A.2-2.

⁸⁶ The so called classic form of causality is given in Equation (5.1) on page 431 of the study by Granger (1969).

Table 7.2-2 provides the Granger Causality based on non-synchronism corrected equations, assuming allowances for the same day effect. The results are similar to findings in studies by Gjerde and Sættem (1995), with a similar correction technique. In the corrected form all indices appear to be dependent to a high level of significance based on a full sample analysis. However, one fact should be pointed out. The isolated position of China with only a region-wide influence on Japan and India is affected by indices, which tend to cause China in contemporaneous term. The oil price demonstrates bi-directional causality with Russia only, which may be explained by a net oil-exporter the position of Russian economy.

The contrast between the classic and non-synchronism corrected form of Granger Causality shows that the application of the classic form for daily data might greatly underestimate the significance of causality (spillover) of early closing markets, by hiding their same day causal effect in direction to other indices. However, the fact that the early closing stock markets indices still have a positive amount of time to cause later closing markets within the same day effect, cannot be ignored. Therefore, the application of the non-synchronism correction in order to derive a same day effect for the early closed market is vital. On the contrary, the significance of causality (spillover) of later closing markets might be substantially overestimated in classic causality form. This question requires further investigation from the different perspective of time gap examination as performed by Furstenberg, *et al.* (1989).

Figure 7.2-1
Duration of the time gaps between closing values
of Japanese and the US markets in standard GMT time.



In order to clarify the phenomena of early and later closing markets it is important to demonstrate the scheme of interactions between Japan and the US (see Figure 7.2-1). From this, it is possible to see that 39 hours would pass for the current days US markets' closing value to be affected by the closing value of the Japanese market in day ($t-1$). Whilst the US market affects the Japanese current

day market closing value after 9 hours. This poses the question: “Is this the right measurement for the fulfillment of an equivalence condition for the participating indices?” Another potential concern is the disproportion gap between durations. The time gap between Japan to the US is more than 4 times larger than time gap from the US to Japan.

For other indices, it is possible to examine the matrix of time gaps between the closing values of markets which are used in this study. First, looking at Table 7.2-3 it is possible to see the existence of large time gaps between the closing values of the Japanese market to the US market, the classic form of Granger Causality can also be found in all early closing markets, which confirms previous statements regarding early closing markets. For example, the transmission of the signal from China from day ($t-1$) in standard GMT time to the day (t) of the US will take 38 hours. On the other hand, all later closing indices are likely to have the advantage of smaller gaps for signal transmission from day ($t-1$) to day (t).

Referring to the results of the Granger Causality in the classical form without any non-synchronism correction it is possible to divide the matrix into two halves due to the strong disparity between the time gap durations. All lower half time gaps are in excess of 24 hours whilst all upper half time gaps are below 24 hours. The diagonal line represents a 24 hours gap between the current (t) and previous ($t-1$) for each markets own values of the index.

Table 7.2-3
Duration of the time gaps between closing values of indices
from day ($t-1$) to day (t) (classic Granger causality).

	JP	CH	IN	RU	GE	FR	UK	BR	US
JP	24	23	20	15	14	14	13.5	11	9
CH	25	24	21	16	15	15	14.5	12	10
IN	28	27	24	19	18	18	17.5	15	13
RU	33	32	29	24	23	23	22.5	20	18
GE	34	33	30	25	24	24	23.5	21	19
FR	34	33	30	25	24	24	23.5	21	19
UK	34.5	33.5	30.5	25.5	24.5	24.5	24	21.5	19.5
BR	37	36	33	28	27	27	26.5	24	22
US	39	38	35	30	29	29	28.5	26	24

Note: Table represents duration of the time gaps from the closing value of country in column to closing value of country in row.

The smaller the time gap between closing values, the more likely that the signal of the market, which attempts to cause, will be kept pure after the absorption process in the market that attempts to be caused, since the transmitted signal is mixed with the other indices information and day innovations that occur within the time gap. In other words, the smaller the time gap, the smaller the amount of

information that interferes with the signal of the causing market⁸⁷. The stock markets that are synchronized in trading time are likely to have a very small time gap, assuming instantaneous interaction and, thus the signal is transmitted without being mixed with other information (a good example is EU countries, e.g. Germany, France and the UK), therefore they are likely to demonstrate high correlation and magnitude of mean spillovers (Gjerde and Sættem, 1995; Bessler and Yang, 2003; Gebka and Serwa, 2007; Singh, *et al.*, 2010). Summarising the explanation given above, it should be concluded that the existence of time gaps between closing values inevitably affects the significance of causality (spillovers) and the disproportionate gap between durations puts smaller gap (later closing market) indices in a favorable position, while the position of the indices with the large gap (earlier closing market) are diminished.

There are a number of possible questions which may arise, while discussing this problem:

First, is a concern regarding the process of information transmission and information absorption by markets, one could say that information is transmitted and absorbed during the market trading session and the effect is less pronounced once the market is closed. In most studies the measurements are conducted using proxies for closing values (continuously compounded returns) of the stock markets and this discussion retains the same approach.

The second question regards measurement, where the time gap between the closing values doesn't have a direct reference to the returns usually observed in the literature. This thesis uses an example of closing values of the indices for the purpose of the reducing the complexity of the discussion, it is suggested that the relative comparison of gap durations is a fair indication of possible overestimation and underestimation of the effects of participating markets⁸⁸.

The third question suggests that stock market trading time structures, set up for decades, is a reality which is faced cyclically every day and it is impossible to move the trading time of stock market indices to ensure perfect synchronicity. To answer this question refer to the point made earlier that the closing market causality (spillover) significance is likely to be underestimated and the later

⁸⁷ As discussed in Furstenberg, *et al.* (1989, p. 132).

⁸⁸ Another point, is that the market closing time can be used directly when daily data expresses $I(0)$ behaviour on levels (see Kleimeier and Sander, 2002, pp. 13-15) for discussion on aspects of level and return application for Granger Causality testing). The study by Furstenberg, *et al.* (1989, p. 149) may be taken as an example where the closing time difference of stock markets is switched to the difference between returns. The authors pointed out that: "If time-zone trading occurs in efficient markets, Tokyo's rate of change, ΔJ , for instance, can be influenced only by the news first reflected in the preceding markets on the previous date. Tokyo itself influences all succeeding markets on the same date via j (changes in closing stock price average in percent of the Japanese market) news. Taken together this means that ΔG , ΔB , and ΔA (returns of Germany, the UK and the US) would be correlated with ΔJ_{+1} in one direction and with $\Delta J (= \Delta J_0)$ in the other, but be uncorrelated with ΔJ at any time and subscript other than 0 and +1. Analogous arguments follow for Germany and Great Britain."

closing market causality (spillover) significance is likely to be overestimated. This raises concern about the existence of earlier/later closing market bias, when causality (spillover) measurement is applied. Having demonstrated the existence of Causality disparity (Table 7.2-1 compared to Table 7.2-2) and gap duration disparity (Table 7.2-3) between earlier and later closing markets it is now possible to examine how a later closing market will react when it is placed in the condition of the earlier closing market. If the significance of the causal links is diminished, then it provides a direct proof of the existence of the earlier/later closing market bias.

This part of the section simulates the condition where a later closing market becomes an earlier closing one. This can be done by emulating a virtual time shift on the standard GMT line ruler. It is necessary to do this because, according to Chendroyaperumal (2008), the standard GMT time line is not axiomatic, but just a traditionally established line ruler.

At this stage, it would be desirable to know how sensitive the time gaps are between closing values with respect to the shift in GMT time. This is depicted in Table 7.2-4. The first line (row 1) of the table represents normal working day, where the US market is closed at the 21.00 standard GMT line (column III), which allows the US to be called the later closing market. At the same time, Japan closes at the 6.00 standard GMT line (column V), which allows Japan to be treated as an earlier closing market. Therefore, the summation of columns IV and V gives the time gap between the closing value of the US and Japan (column VII), while the summation of columns VI and III gives the time gap between the closing value of Japan and the US (column VIII).

By increasing the time shift value (column II) it is possible to observe how the gap durations change. The time gap pair reduces radically after the point where GMT shift is equal to -3 hours (row 4), in which case the US market becomes the earliest market to be closed during the day. This induces the US to have a time gap towards the Japanese market closing value by nearly 4 times greater than it was in the shift for -2 hours (row 3) and in the case without a shift (GMT time shift equals to 0, which is standard GMT time). In contrast the same (-3 hours) shift forces Japan to decrease its time gap with the US from 39 hours (Column VIII, row 1) to 15 hours (Column VIII, row 4). The time gaps restore to the preliminary condition when GMT time is shifted for -18 (row 19), then the Japanese market returns to the position of the earlier closing market. This finding allows one to state that there is a clear difference in duration of the time gap depending on the earlier/later close factor of the stock market. Regularity of the particular time gap relies on the closing value allocation in the 24 hours day time ruler of GMT line.

Table 7.2-4
US-Japan time gaps distribution
with respect to the shift in GMT line ruler.

Row №	GMT shift for hours (-1 means shift back for 1 hour)	US close hour in standard GMT after shift	Hours left to the end of the day after US is closed (24 hours - III)	Japan close hour in standard GMT after shift	Hours left to the end of the day after Japan is closed (24 hours - V)	US->JP (IV+V)	JP->US (VI+III)
I	II	III	IV	V	VI	VII	VIII
1	0 (Standard GMT)	21	3	6	18	9	39
2	-1	22	2	7	17	9	39
3	-2	23	1	8	16	9	39
4	-3	0	24	9	15	33	15
5	-4	1	23	10	14	33	15
6	-5	2	22	11	13	33	15
7	-6	3	21	12	12	33	15
8	-7	4	20	13	11	33	15
9	-8	5	19	14	10	33	15
10	-9	6	18	15	9	33	15
11	-10	7	17	16	8	33	15
12	-11	8	16	17	7	33	15
13	-12	9	15	18	6	33	15
14	-13	10	14	19	5	33	15
15	-14	11	13	20	4	33	15
16	-15	12	12	21	3	33	15
17	-16	13	11	22	2	33	15
18	-17	14	10	23	1	33	15
19	-18	15	9	0	24	9	39
20	-19	16	8	1	23	9	39
21	-20	17	7	2	22	9	39
22	-21	18	6	3	21	9	39
23	-22	19	5	4	20	9	39
24	-23	20	4	5	19	9	39

This means that earlier closing markets possibly always will be underestimated in the traditional schemes of classic econometric models (not corrected for the non-synchronism problem). Since most of the models are lag-based, it is likely that the later closing market will always experiencing shorter time gaps with respect to the earlier closing market, and logically, their shorter time gap provides them with an advantage in causality over earlier closing ones, since the signal is absorbed with less innovation and other distortions during the day. The opposite can be stated regarding the earlier closing markets.

Using the shift of GMT time it is possible to investigate how the US market will affect other markets, when it is placed in the condition of the earlier closing market. By shifting day borders back by 4 hours, as given in the form of the scheme in Figure 7.2-2, the figure shows that the gap structure has changed significantly because the US market closing time appears before the Japanese. But even

after the shift in the GMT line the US to Japan gap (33 hours, Figure 7.2-2) is still less than the gap between Japan to the US (39 hours, Figure 7.2-1) in the standard GMT line⁸⁹.

Figure 7.2-2

Duration of the time gaps between closing values

of Japan and the US markets in standard GMT time shifted back in time by 4 hours.

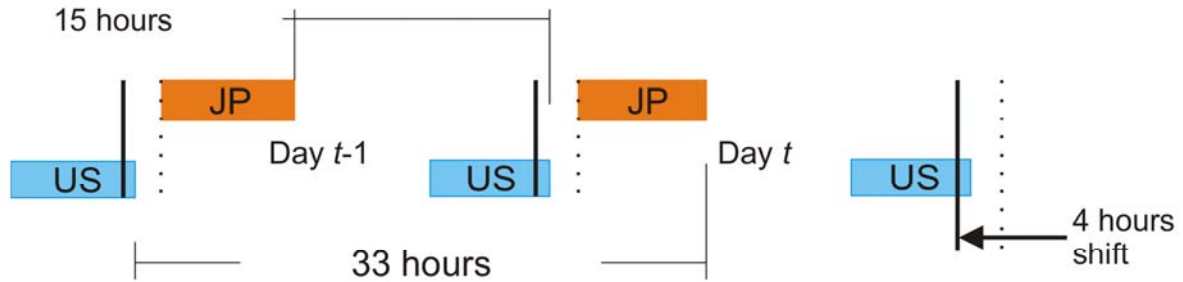
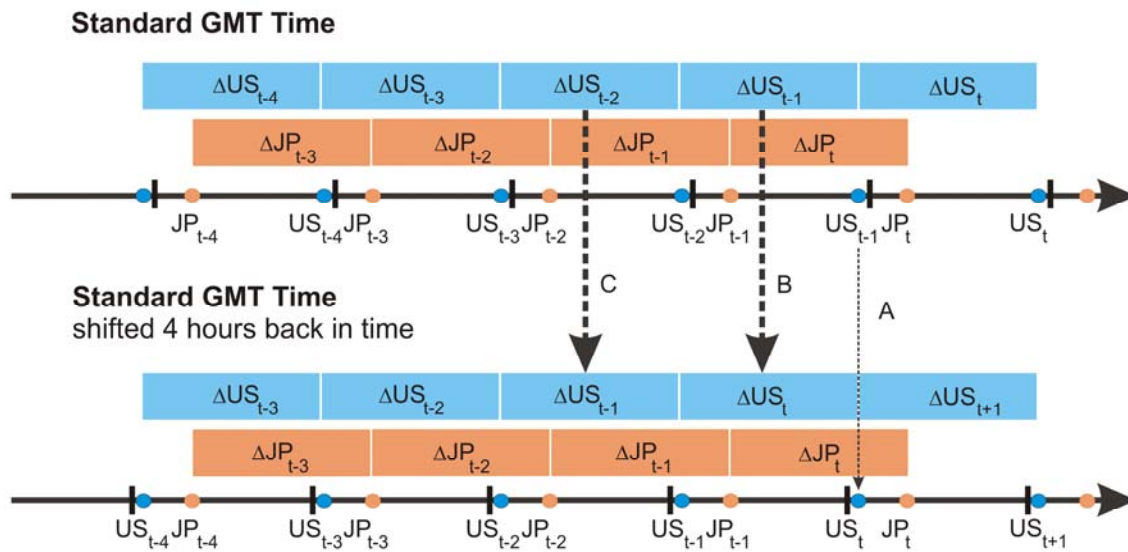


Figure 7.2-3

US and Japan indices returns structure based on Standard and four hours shifted back GMT lines.



⁸⁹ For example, consider a pure lag process assuming a standard GMT timeline where the US and Japan series are $I(0)$ at their levels:

- 1) $US_t = JP_{t-1} + \varepsilon_t$, time gap between JP_{t-1} and US_t is equal to 39 hours;
- 2) $JP_t = US_{t-2} + \varepsilon_t$, time gap between US_{t-2} and JP_t is equal to 33 hours.

The market with shorter time lag will be in beneficial position. Moreover, the application of the US_{t-2} in respect of the JP_t demonstrates that time gap is still below 39 hours, while the application of the contemporaneous term (Gebka and Serwa, 2007, p. 214) also shows disparity between the duration of the time gaps between the closing values of the market indices:

- 1) $US_t = JP_t + \varepsilon_t$, time gap between JP_t and US_t is equal to 15 hours;
- 2) $JP_t = US_{t-1} + \varepsilon_t$, time gap between US_{t-1} and JP_t is equal to 9 hours.

A similar difference can be found for the later closing case, the gap from the US to Japan (9 hours, Figure 7.2-1) in the standard GMT line is less than the gap from Japan to the US (15 hours, Figure 7.2-2) in the shifted GMT line. Such a time shift inevitably rebuilds a sequence of US variables (Figure 7.2-3). The time shift allows the US market closing value to close earlier than Japan, forcing its $(t-1)$ values on the standard GMT line to be observed under time script (t) in the shifted GMT line (Arrow A in Figure 7.2-3). The changes in the time scripts of the day closing time of the US index induce ΔUS_{t-1} returns in the standard GMT line to become ΔUS_t of the shifted GMT time line (Arrow B in Figure 7.2-3), and similar with ΔUS_{t-2} , which becomes ΔUS_{t-1} (Arrow C in Figure 7.2-3), etc. for the higher lags of returns. At the same time the variable structure of Japan remains the same, since the time shift is not inducing the Japanese index closing time to switch to a different day.

This operation puts the later closing US market into the condition of the earlier closing Japanese market. By applying this shift it is possible to investigate how such an assumption will affect the causality pattern of the US and, thus, it may also reveal to what extent the US dominant position, widely accepted by other authors (see Section 2.2), is dependent on the factor of the late closing market.

Having established a new time lag structure for the US, it is now possible to apply a regression reformulated with a new set of parameters. In this case the Japanese return (ΔJP_t) should be regressed with respect to its own past lags (ΔJP_{t-1}) and ΔUS_{t-1} of the shifted GMT line which corresponds to ΔUS_{t-2} of the standard GMT line (See Figure 7.2-3). In the regression form without any correction for non-synchronism we use the equations (4) and (5) reformulated for Japanese and US variables. The reformulated forms are given in equations (24) and (25)

$\Delta JP_t = \delta_{Y,0} + \sum_{q=1}^k \alpha_{Y,q} \Delta JP_{t-q} + \sum_{z=2}^{k+1} \beta_{Y,z} \Delta US_{t-z} + \varepsilon_{Y,t}$	(24)
$\Delta US_{t-1} = \delta_{X,0} + \sum_{j=2}^{k+1} \alpha_{X,j} \Delta US_{t-j} + \sum_{i=1}^k \beta_{X,i} \Delta JP_{t-i} + \varepsilon_{X,t}$	(25)

Therefore, after adjustment of the time shift, the US in a classic Granger Causality is induced to cause Japan from the lag $(t-2)$ instead of $(t-1)$. The replacement of $(t-1)$ by $(t-2)$ transcripts is made by allowing the summation from $z=2$ to $k+1$, instead of $z=1$ to k in a classic form. By contrast, in equation (25), where Japan tends to cause the US, we assume that ΔUS_t of shifted GMT line should be regressed with respect to its own lags (ΔUS_{t-1} of shifted GMT line) and Japanese returns starting from ΔJP_{t-1} . In which case ΔUS_t of shifted GMT line should be replaced by the ΔUS_{t-1} of the standard GMT line; its own past lags (ΔUS_{t-1} of shifted GMT line) should be replaced by ΔUS_{t-2} of the standard

GMT line, while ΔP_{t-1} remains the same, since Japanese returns are not affected by the shift in the GMT line. Therefore, the final form of equation (25) should be represented as follows:

$\Delta US_t = \delta_{X,0} + \sum_{j=1}^k \alpha_{X,j} \Delta US_{t-j} + \sum_{i=0}^{k-1} \beta_{X,i} \Delta P_{t-i} + \varepsilon_{X,t}$	(26)
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Equation (26) after reformulation of equation (25) returns to the contemporaneous term, again due to the time shift in the GMT line. Therefore, the shifts in the GMT line induce the market to switch from a later closing position to an earlier closing position, and this in fact triggers the structure of equations when attempting to resolve the non-synchronism problem. The equation where the market attempts to cause becomes less favourable, since the lag specification is replaced from ordinary $(t-1)$ to $(t-2)$ (see equation (24)).

Simultaneously, the equation, where the market is tested to be caused by the other market, switches to the contemporaneous (t) structure from the ordinary $(t-1)$ structure. Most findings on contemporaneous interactions confirm that the lag 0 (contemporaneous lag) tends to be significant more frequently (Gjerde and Sættem, 1995; Bessler and Yang, 2003; Singh, *et al.*, 2010), while the high lag values are less likely to have significant estimates.

This structure of equation 24 to some extent corresponds to the Gebka and Serwa (2007) contemporaneous structure equation specification. As they noted (2007, p. 214): “... *one should keep in mind that spillovers from Europe and America to Asia at lag 1 indicate ‘contemporaneous’ causality and are equivalent to those from Asia and from Europe to America at lag 0*”. This research agrees with this argument. This indicates that the later closing markets of Europe and America at lag 1 indicate “contemporaneous” causality, which means that they remain in a beneficial position compared to lag 1 of the earlier closing markets (for instance, see Singh, *et al.*, 2010). Therefore, in causality at time $(t-1)$, in the standard GMT line, the US expresses behaviour similar to earlier closing markets at time (t) . Moreover, in developing the Gebka and Serwa’s (2007) notation for higher lags it is possible to state that causality from time $(t-1)$ for earlier closing markets will be appropriately comparable to the US causality from time $(t-2)$. As far as can be ascertained, the only study which utilizes the lag structure from $(t-2)$ and higher, simultaneously ignoring the (t) and $(t-1)$ variables for the US or any other later closing markets in standard the GMT time, is a study by Malliaris and Urrutia⁹⁰ (1992a). Other studies usually utilise the more traditional $(t-1)$ for stock markets including

⁹⁰ The study by Malliaris and Urrutia (1992a, p. 357) is referenced in this regard since the authors attempted to regress Japanese returns $(t+1)$ with respect to the US returns $(t-1)$, which may be reformulated to Japanese (t) with respect to the US $(t-2)$. Overall, the study demonstrated that Granger Causality conducted using joint test at lag 2 and higher for later closing markets and at lag 1 and higher for early closing markets is found to be insignificant during the 1987 pre-crash and post crash periods, while it is found to be significant during the

the US⁹¹. However, it is suggested that testing for the causality from Japan and other markets at lag 0 (t) to the US and causality from the US at lag 2 ($t-2$) will place the US in the position of earlier closing market, as discussed above (see equation (24)).

It is also possible to add that the standard (Gjerde and Sættem, 1995; Bessler and Yang, 2003; Gebka and Serwa, 2007) correction procedures allow the correction of the unfavorable earlier closing market effect for Japan by suggesting lag 0 (t) instead of lag 1 ($t-1$). However, no correction is made in order to investigate the position of the US causality when the later closing market factor bias will be replaced by the earlier closing market factor bias, meaning replacement of the lag 1 ($t-1$) by ($t-2$).

The correction of the lag structure is performed only for the US, while lags of the other indices remain the same since the shift in the GMT timeline is not inducing their closing value to switch to another day. The lags represented in Table 7.2-5 repeat the structure of Table 5.1-1 but add the US at the beginning of the indices' sequence with the lags discussed above. By setting up a new lag structure for the causality testing in the regression form it is possible to use equations (8) and (9), while the $l_{x,y}$ lag transcript are collected from the corresponding cells of Table 7.2-5.

The result of the estimation which imposes the early closing market bias on the US inevitably shows that its behaviour is similar to other indices and no causality is found from the US to the other markets except Japan. It is also worth noting that the causality from the US is confirmed to India and Brazil at 10% level of significance⁹², while no causality is confirmed from the US to EU countries. It is interesting to note that the result of the US does not break the structure of Table 7.2-1, confirming that the earlier/later closing market effect exists.

This finding conforms to the evidence found in the study by Furstenberg, *et al.* (1989, p. 149) that stock market returns are uncorrelated at a time other than lag 0 and lag 1. A similar result was also obtained in a study by Malliaris and Urrutia (1992a), where the author found no evidence of Granger Causality for the earlier closing market from lag 1 and from lag 2 for the later closing markets. Overall, the results show the necessity of careful examination of the lag structure and confirm that

crash time, including the US-Japan case. Peiró, *et al.* (1993, 1995) also examined the effect of the US ($t-2$) on Japan (t) in correlation and regression form. They found the evidence that lag 1 of the US corresponds to the lag 0 of Japan.

⁹¹ Use of lag 1 for the US has a long tradition. See for example: Agmon (1972, p. 850) by applying US lag -3 to lag +3 in explaining other indices confirmed that US has an effect within one period (lag 1); Schollhammer and Sand (1987) demonstrated that lead-lag relationships are found at lag 1 or lower (Furstenberg, *et al.*, 1989); Eun and Shim (1989, p. 243) applied the VAR model, allowing the lag structure to start from lag 1, simultaneously mentioning about the non-synchronism problem, but avoiding correcting of the VAR by leaving the non-synchronism issues for the interpretation phase. Cheung and Mak (1992) used a regression model with lag starting from lag 1 and higher for all participating indices.

⁹² The result is not displayed in the table, but concluded directly from the outcome of the equations.

causality, detected from one market to another, may be explained by the sequence of location of the markets on the GMT timeline and it shows that the US, when placed into the condition of an earlier closing market, does not demonstrate any abnormal dominant behavior associated with multiple causality pattern from US.

Table 7.2-5
New lag structure of the US assuming the condition of early closing market.

	US	JP	CH	IN	RU	GE	FR	UK	BR	OIL
US	NA	0	0	0	0	0	0	0	0	0
JP	2	NA	1	1	1	1	1	1	1	1
CH	2	1	NA	1	1	1	1	1	1	1
IN	2	1	1	NA	1	1	1	1	1	1
RU	2	1	1	1	NA	1	1	1	1	1
GE	2	1	1	1	1	NA	1	1	1	1
FR	2	1	1	1	1	1	NA	1	1	1
UK	2	1	1	1	1	1	1	NA	1	1
BR	2	1	1	1	1	1	1	1	NA	1
OIL	2	1	1	1	1	1	1	1	1	NA

Table 7.2-6
Classic Granger causality test applying new lag structure after the shift in GMT line.

	US	JP	CH	IN	RU	GE	FR	UK	BR	OIL
US		JP → US**	CH -x-> US	IN → US**	RU → US**	GE → US**	FR → US**	UK → US**	BR → US**	CR -x-> US
JP	US → JP**		CH -x-> JP	IN → JP**	RU → JP**	GE → JP**	FR → JP**	UK → JP**	BR → JP**	CR -x-> JP
CH	US -x-> CH	JP -x-> CH		IN -x-> CH	RU -x-> CH	GE → CH**	FR → CH**	UK → CH**	BR → CH**	CR -x-> CH
IN	US -x-> IN	JP -x-> IN	CH -x-> IN		RU → IN**	GE → IN**	FR → IN**	UK → IN**	BR → IN**	CR -x-> IN
RU	US -x-> RU	JP → RU*	CH -x-> RU	IN -x-> RU		GE -x-> RU	FR -x-> RU	UK → RU*	BR → RU**	CR -x-> RU
GE	US -x-> GE	JP -x-> GE	CH -x-> GE	IN -x-> GE	RU -x-> GE		FR → GE**	UK -x-> GE	BR → GE**	CR -x-> GE
FR	US -x-> FR	JP -x-> FR	CH -x-> FR	IN -x-> FR	RU -x-> FR	GE → FR**		UK -x-> FR	BR → FR**	CR -x-> FR
UK	US -x-> UK	JP -x-> UK	CH -x-> UK	IN -x-> UK	RU -x-> UK	GE → UK**	FR → UK*		BR → UK**	CR -x-> UK
BR	US -x-> BR	JP -x-> BR	CH -x-> BR	IN -x-> BR	RU -x-> BR	GE -x-> BR	FR -x-> BR	UK -x-> BR		CR -x-> BR
OIL	US -x-> CR	JP -x-> CR	CH -x-> CR	IN -x-> CR	RU -x-> CR	GE -x-> CR	FR -x-> CR	UK -x-> CR	BR → CR*	

Notes: The given table is a summary of the non-causality hypothesis testing in non-synchronism corrected form in the Granger (1969) sense based on Newey and West (1987) Heteroscedasticity consistent regression. Lag detection is performed up to 10 lags by minimising SIC. The non-causality hypothesis is tested using the Wald test on equations (8) and (9) for all $\beta_{y,z}$ and $\beta_{x,i}$ respectively. Where for the equation (8) the joint test is performed by testing $H_{y,0}: \beta_{y,z}=0$ and $H_{x,0}: \beta_{x,i}=0$, knowing that $z=l_{x,y}, \dots, k-1+l_{x,y}$ and $i=l_{y,x}, \dots, k-1+l_{y,x}$ respectively and, $l_{x,y}$ and $l_{y,x}$ values are collected from Table 7.2-5 with respect to the equations (24) and (26) regarding the discussion on early/late closing market bias given in Section 7.2. The rejection of the $H_{y,0}$ and $H_{x,0}$ hypothesis is performed using the Wald test in asymptotic χ^2 distribution at 1% and 5% level of significance, denoted in the table by "***" and "**". The rejection of $H_{y,0}$ and $H_{x,0}$ hypothesis is located in cells where the country in the column attempts to cause the country in the row. Since the equation represents both directions of causalities, then their location is symmetrically opposite, knowing that $H_{y,0}$ is located above the diagonal line (e.g. US → CH*, represents causality at 5% level of significance) and $H_{x,0}$ is located below diagonal line (e.g. CH -x-> US, representing failure to cause at least at the 5% confidence level). The series consists of 3130 observations in returns dated from 02/01/1996 to 31/12/2007. The full outcome of the equation used in construction of the table is given in Table A.2-3.

7.3. Application of the Cheung and Ng (1996) CCF-GARCH causality test.

7.3.1. Extraction of the standardized residuals for the application in CCF test.

Daily continuously compound daily returns⁹³ are applied to the EGARCH models (14) and (20). During the full sample estimation phase, the standardized residuals are derived from the variable lag optimised ARMA(m,n)-EGARCH(p,q) model, representing the first stage of the Cheung and Ng (1996) CCF causality test. In order to detect the correct model specification, the Ljung and Box (1978) portmanteau test is used to confirm that levels and squares of standardized residuals are exempted from serial correlation, the following steps are taken:

Step 1. : Conduct Ljung-Box Q-stat, Q^2 -stat and LM-test econometric tests on standardized residuals extracted from model (14) (20) observed in all the combinations of the m,n,p,q lag parameters. The models with non-rejection of mentioned tests are stored in the list of models with an eligible lag structure.

Step 2. : The model which has the minimum value of Schwarz information criterion is chosen from the list of models with an eligible lag structure. If step 1. finds no eligible specification, then the optimal variable lag structure is found by choosing the minimum SIC value from the models (14 and 20) observed in all the combinations of the m, n, p, q lag parameters.

In this regard, the model optimal lag structure detection is performed on the following intervals of the main parameters: $m=0...3$; $n=0...3$; $p=1...2$; $q=1...2$, which have intervals approximately consistent with the other studies (e.g. Fujii, 2005, p. 326).

Model (14) outputs, as well as results of the tests mentioned above for each of the 9 countries' stock indices, are reported in Table 7.3-1. No serial correlation is found in the standardised residuals for all participating major countries (US, Japan, Germany, France) together with Brazil. However, it was not possible to improve the optimal lag structure that suits the simultaneous non-rejection of LM-test(10), Q-statistics(10) and Q^2 -statistics(10) of the standardized residuals and squared standardized residuals for China, India and Russia. These three countries rejected the hypothesis of no autocorrelation in the standardized residuals in the Ljung-Box Q-statistics(10) at a 1% level for Russia, and at a 5% level of significance for India. Since none of the m,n,p,q combinations met the simultaneous non-rejection of Q-statistics(10), Q^2 -statistics(10) and LM-test(10) for India and Russia, it was necessary to move on to step 2, where the optimal lag structure is found by minimizing the Schwarz information criterion. It is worth noting that it was expected that Brazil would have a highly

⁹³ Continuously compound daily returns are also applied to the EGARCH in studies by Kanas (1998), Kanas (2000), Lobo (2000), Gokcan (2000).

persistent ARCH effect in Q^2 -statistics(10), which was also found in the study by Fujii (2005) for AR(m)-GARCH(1,1) framework on data from 01/01/1990 to 14/11/2001, but in this research no support was found for those findings on ARMA(m,n)-EGARCH(p,q) in the sample period used in the current investigation.

Table 7.3-1

Application of the logged return to the EGARCH model (14).

Country	JP	CH	IN	RU	GE	FR	UK	BR	US	OIL
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
AR(m)	0	0	1	0	0	0	0	2	0	0
MA(n)	0	3	2	1	0	0	1	0	0	1
ARCH(p)	2	1	1	1	1	1	1	2	2	1
GARCH(q)	1	1	1	1	1	1	1	1	1	1

Constant	-0.016102 (-0.7283)	1.34E-05 (0.001249)	0.105396 ** (3.331921)	0.158750 ** (5.749326)	0.063731 ** (3.365265)	0.056569 ** (3.043821)	0.040525 ** (2.724773)	0.111883 ** (3.140788)	0.034911 ** (2.693678)	0.087863 * (2.418424)
AR(1)			0.904940 ** (20.52768)					0.098873 ** (5.870329)		
AR(2)								-0.030123 (-1.659643)		
AR(3)										
MA(1)		-0.006439 (-0.550921)	-0.787085 ** (-16.63289)	0.072539 ** (4.591153)			0.025069 (1.400308)			0.031448 (1.767627)
MA(2)		0.002344 (0.199722)	-0.074848 ** (-3.679592)							
MA(3)		0.011639 (0.995308)								

Constant	-0.110132 ** (-7.172355)	-0.138186 ** (-11.45472)	-0.140097 ** (-7.590348)	-0.144391 ** (-10.79341)	-0.115353 ** (-8.059119)	-0.090937 ** (-7.518022)	-0.109102 ** (-7.289048)	-0.069927 ** (-3.492911)	-0.089725 ** (-7.022632)	-0.040272 * (-2.079113)
ARCH(1)	-0.011692 (-0.260716)	0.257555 ** (10.71436)	0.256246 ** (9.409929)	0.259714 ** (11.47192)	0.156149 ** (8.26449)	0.121873 ** (7.662104)	0.131671 ** (6.989792)	0.076409 (1.503145)	-0.047261 (-1.26037)	0.135119 ** (6.836944)
ARCH(2)	0.176488 ** (3.7334)							0.156178 ** (3.123535)	0.154571 ** (3.869207)	
Asymmetric effect	-0.063146 ** (-5.613803)	-0.034528 (-1.950638)	-0.101134 ** (-6.266202)	-0.016682 (-1.206332)	-0.069150 ** (-6.399005)	-0.058316 ** (-5.580597)	-0.083738 ** (-7.182296)	-0.141938 ** (-8.836615)	-0.123504 ** (-11.01803)	-0.031700 ** (-2.614043)
GARCH(1)	0.977257 ** (183.866)	0.956685 ** (93.93706)	0.932748 ** (77.87575)	0.973253 ** (180.0173)	0.982579 ** (281.401)	0.984435 ** (277.4617)	0.973219 ** (204.6187)	0.928740 ** (96.54438)	0.973176 ** (222.476)	0.959112 ** (83.75388)
GARCH(2)										

LB Q-stat(10)	6.4432	16.260	19.596 *	38.375 **	12.709	18.253	18.058	9.6445	15.159	6.9632
LB Q2-stat(10)	6.6060	3.6589	5.9314	8.7703	7.4416	14.540	9.5795	12.000	6.1946	9.4119
LM-test(10)	Not rej.	Not rej.	Not rej.	Not rej.	Not rej.	Not rej.	Not rej.	Not rej.	Not rej.	Not rej.
LogLikelihood	-5511.709	-5356.060	-5571.199	-6788.642	-5125.355	-4892.252	-4114.402	-6790.083	-3943.187	-6850.442

Notes: Each column represents an output of model (14) for the country's stock market index represented in logged returns. Estimation is performed assuming the Generalised Error Distribution (G.E.D.). Estimated coefficients and z-statistics in brackets are allocated with respect to the variables (AR, MA, ARCH, GARCH) decomposed in SIC chosen lags. The 1% and 5% level of significance of z-statistics is denoted by "***" and "**" respectively. LB Q-stat and LB Q^2 -stat is a Ljung and Box (1978) statistics conducted on levels and squares of standardized residuals derived from the given equations at lag 10. LM-test (10) represents Lagrange Multiplier test (Breusch and Pagan, 1980) conducted at lag 10. The series consist of 3130 observations in returns dated from 02/01/1996 to 31/12/2007.

The EGARCH asymmetric effect estimate is found to be negative and highly significant for all the participating countries' stock markets (excluding Russia and China), which shows that different signs of shocks affect the variance differently. The GARCH parameter estimates report that volatility is persistent for all the countries and with a high level of significance, starting from 0.92874 for Brazil and ending with 0.9844 for France.

Table 7.3-2

Application of the logged return into the EGARCH model (20).

Country	JP	CH	IN	RU	GE	FR	UK	BR	US
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS
AR(m)	0	2	1	0	0	1	1	0	0
MA(n)	0	0	2	1	0	0	0	1	0
ARCH(p)	2	1	1	2	1	1	1	2	1
GARCH(q)	1	1	1	1	1	1	1	1	1

Constant	-0.017839 (-0.810294)	-1.27E-05 (-0.001233)	0.101860 ** (3.184803)	0.179213 ** (6.682078)	0.062534 ** (3.306174)	0.056156 ** (3.046703)	0.044256 ** (2.965889)	0.109247 ** (3.030865)	0.037860 ** (2.896416)
Oil price return	0.015626 (1.543807)	1.45E-05 (0.002983)	-0.006940 (-0.741018)	0.069979 ** (5.714895)	0.008045 (0.928002)	0.013434 (1.662001)	0.021394 ** (3.294409)	0.020732 (1.535862)	0.001397 (0.252265)
AR(1)		-0.006040 (-0.497033)	0.904567 ** (20.97207)			0.007879 (0.437134)	0.024174 (1.335006)		
AR(2)		0.000641 (0.054099)							
AR(3)									
MA(1)			-0.786407 ** (-16.93212)	0.070332 ** (4.282578)				0.103161 ** (6.21454)	
MA(2)			-0.073624 ** (-3.629398)						
MA(3)									

Constant	-0.110102 ** (-7.163402)	-0.148563 ** (-13.27125)	-0.139468 ** (-7.546725)	-0.142119 ** (-10.3801)	-0.115153 ** (-8.040101)	-0.094074 ** (-7.477498)	-0.123800 ** (-7.063837)	-0.084185 ** (-4.103817)	-0.080236 ** (-6.291117)
ARCH(1)	-0.012662 (-0.282248)	0.247516 ** (11.8705)	0.255836 ** (9.384855)	0.311753 ** (6.403478)	0.155915 ** (8.240944)	0.124422 ** (7.382931)	0.149023 ** (6.773644)	0.060120 (1.1774)	0.094640 ** (5.741999)
ARCH(2)	0.177425 ** (3.751695)			-0.070299 (-1.415025)				0.184332 ** (3.712651)	
Asymmetric effect	-0.063096 ** (-5.576975)	-0.022753 (-1.461536)	-0.102164 ** (-6.317177)	-0.009225 (-0.715741)	-0.069321 ** (-6.432952)	-0.061819 ** (-5.984969)	-0.089084 ** (-7.106132)	-0.143809 ** (-8.828181)	-0.122896 ** (-11.35429)
GARCH(1)	0.977263 ** (183.7545)	0.974247 ** (131.8203)	0.932622 ** (77.81333)	0.979053 ** (204.8943)	0.982573 ** (281.2724)	0.984202 ** (281.9167)	0.969337 ** (207.5439)	0.931450 ** (100.5392)	0.976702 ** (253.363)
GARCH(2)									

LB Q-stat(10)	6.5808	17.926	19.791 *	34.741 **	12.942	17.671	18.244	8.3611	16.038
LB Q2-stat(10)	6.0134	4.2123	5.9813	8.1417	7.6873	14.405	6.6516	11.166	3.6481
LM-test(10)	Not rej.	Not rej.	Not rej.	Not rej.	Not rej.	Not rej.	Not rej.	Not rej.	Not rej.
LogLikelihood	-5510.572	-5355.009	-5570.934	-6772.027	-5124.973	-4887.440	-4109.958	-6797.946	-3948.649

Notes: Each column represents an output of model (20) for each country's stock market index represented in logged returns. Estimation is performed assuming the Generalised Error Distribution (G.E.D.). Estimated coefficients and z-statistics in brackets are allocated with respect to the variables (AR, MA, ARCH, GARCH) decomposed in SIC chosen lags. The 1% and 5% level of significance of z-statistics is denoted by "***" and "**" respectively. LB Q-stat and LB Q2-stat is a Ljung and Box (1978) statistics conducted on levels and squares of standardized residuals derived from the given equations at lag 10. LM-test (10) represents Lagrange Multiplier test (Breusch and Pagan, 1980) conducted at lag 10. The series consist of 3130 observations in returns dated from 02/01/1996 to 31/12/2007.

Similar results are also shown in Table 7.3-2, where model (20) is used. The Q-statistics results remain the same for all participating equity indices, confirming that serial correlation in returns still exists for India and Russia. Therefore, the optimal lag structure for these countries is detected using SIC and ignoring the non-rejection restrictions for Q-statistics(10), Q²-statistics(10) and LM-test(10). The asymmetric effect result for Russia is decreased in magnitude, but still remains insignificant. The Log-likelihood comparison does not provide any evidence of significant changes, due to the application of oil price in a conditional mean equation.

The given models are used to derive the (squared) standardized residuals for further test in CCF Cheung and Ng (1996) approach.

7.3.2. Market grouping and markers assignment

The literature survey conducted in Sections 3.2.2, 3.2.3, 3.2.4 and 3.2.5 demonstrates the existence of a division of countries with respect to two criteria: oil status and economic profile. This thesis attempts to use such a division in order to verify whether sub-groups organised by criteria express

different behaviour in relation to the oil price and the linkages between markets of such sub-groups respond differently with respect to the oil price.

First, it is assumed that the countries' "oil status" based on oil consumption/production indicators⁹⁴, can affect the cross-market lead-lag relationship when cases with and without oil adjustment are compared. Following the discussion on countries' oil status by Bhar and Nikolova's (2009b, pp. 1039,1040) it is assumed that there are three categories of status: oil exporter (or net oil exporter) is a country, in which oil production surpasses oil consumption; oil self-sufficiency status is given to a country if in the observed period it reaches self-sufficiency; oil importer (or net oil importer) is a country, in which oil consumption surpasses oil production. The reason for such a division is explained by the extensive literature on the different responses of the oil exporters and importers to oil price shocks (Driesprong, *et al.*, 2008). Oil self-sufficiency is also included as a separate status, but the literature on countries with such a status is sparse.

Second, is the emerging/developed profile of the country⁹⁵. It is also important to note that a countries economic profile affects its behaviour in respect to the oil price as suggested by Ramos and Veiga (2009; 2010). As discussed in Section 2.2 developed and emerging economies express different asset class behaviour (Bekaert and Harvey, 1995; Bekaert, *et al.*, 2003; Bhar and Nikolova, 2007; Gebka and Serwa, 2007). Therefore, it is important to trace how the countries profile affects the behaviour linkages of the market with the oil price, and how oil price affects linkages between two markets.

Figure 7.3-1
Allocation of the countries into the groups
with respect to the oil status and countries profile.

Marker	Exporter	Self-Sufficient	Importer
Developed	(DE) n.a.	(DS) UK	(DI) Japan, Germany, France, US
Emerging	(EE) Russia	(ES) Brazil	(EI) China, India

Having established the criteria for a countries' allocation, it is possible to put each country into a specific grouping this is depicted in Figure 7.3-1 .

⁹⁴ The oil production/consumption diagrams regarding all participating countries are given in Appendix A.1, Figure A.1-1 for countries with mature markets, and Figure A.1-2 for market of the BRIC countries.

⁹⁵ Assignment of the emerging/developed profile is taken from S&P Global Stock Market Factbook ("Standard&Poors. Global Stock Market Factbook 2008").

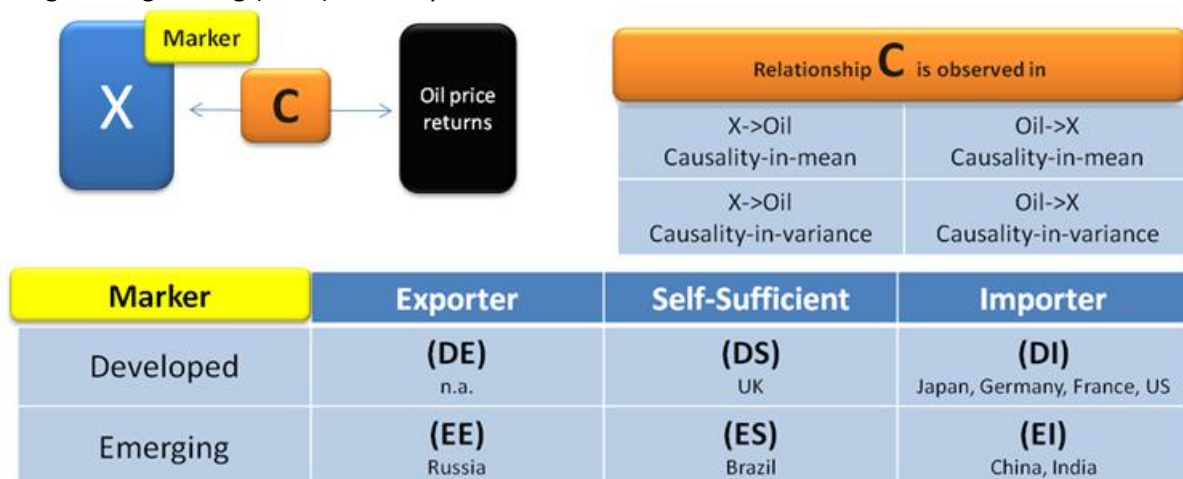
Knowing the countries' status and profile may allow interpretation of the linkages between the oil price of one market and oil price effect on linkages between 2 stock markets, which is discussed further on in this thesis.

7.3.3. Application of CCF test for causality testing between stock market indices and oil price.

Switching to the application of the Cheung and Ng (1996) CCF EGARCH causality test. The Cheung and Ng (1996) causality test is first applied to the traditional established scheme⁹⁶ of the estimation, where the oil price effect is observed in relation with the stock market index, which conforms to research objective 4⁹⁷. In order to perform this investigation the CCF causality test is applied (both, in mean and in variance) on standardised and squared standardised residuals extracted from the ARMA (m,n)-EGARCH(p,q) model⁹⁸ implemented on the oil price and participating stock market index returns.

Figure 7.3-2

Examination of the relationship between the oil price and the stock market index using Cheung and Ng (1996) causality test



For ease of comprehension Figure 7.3-2 explains the task of research objective 4 (Section 1, page 5 with a discussion on page 69). Relationship C is observed in causality-in-mean and causality-in-variance in both directions. In this thesis an attempt is made to explain the result with respect to the oil status and economic profile of each of the participating countries indices.

⁹⁶ This scheme of estimation assumes investigation of the oil price impact on stock market indicators' behaviour, as discussed in Section 3.2.

⁹⁷ As discussed in Section 3.3, page 89.

⁹⁸ Standardized residuals were extracted from the equations (14) with a discussion given in Section 5.2.2 .

Table 7.3-3 presents the results of the CCF test as suggested in the methodology chapter. The cross-correlation coefficients are observed in 0(1)-5 lags horizons in both directions (country to oil price, oil price to country).

It is also worth noting that the investigation of the causal linkages through the CCF test is performed using the vertical lag representation, compared to the classical form by Cheung and Ng (1996), Fujii (2005) or the matrix form by Alba and Park (2007) and Gebka and Serwa (2007). The calculation generates a large number of figures and, to aid simplicity of comprehension and interpretation, the decision was made to display only the significant cross-correlation linkages found by *s*-statistics. In order to determine the *s*-statistics, expression (17) is used for standardized residuals at their levels and squares.

The significance of the cross correlation can be tested using a χ^2 distribution, where the critical values are obtained using expressions (18) and (19). The significance of each lag is detected using $(k-j+1)$ degrees of freedom as suggested by Cheung and Ng (1996), where k is maximum lag and j is the starting lag. This means that, in order to test a standalone lag, the degree of freedom should be equal to 1, assuming that $j=k$. Each pair of indices is also corrected for the day closing time non-synchronism problem as discussed in Section 5.2.2.1 and using the lag correction technique given in Cheung and Ng (1996) and Fujii (2005). Thus, “NA” denotes the impossibility of causation from one index to another due to the absence of overlaps in trading time.

BRIC countries are heterogeneous in relation to oil price. However, it is possible to highlight the following.

Brazil (ES). Brazil's relationship with the oil price is positive and the previous day relation has a slightly higher effect but overall, the relationship is too low. The findings by Bhar and Nikolova (2009b) demonstrated a lesser effect of the oil price on Brazil. As for the causality-in-variance, no relationship is found between Brazil and oil price returns, which conforms to Bhar and Nikolova (2009b) findings on oil price effect on stock market volatility.

Russia (EE). Russia, as a net oil exporter, has significant positive contemporaneous bidirectional causality with oil price and oil price affecting Russia at higher lags (up to lag 2) but with a lower magnitude, which is in line with findings by Bhar and Nikolova (2009b, 2010). Surprisingly, Russia has no variance causality with the oil price, and, arguably, the adjustment for the presence of mean causality from oil price affected the existence of variance causality. These findings contradict the Bhar and Nikolova (2009b, 2010) evidence obtained from oil price standardized innovations in the variance equation.

India (EI). India has a positive mean causality to oil but only at lags 3 and 4 (0.0353 and 0.0395), which may be a result of the insignificant distortion.

China (EI). No relationship is found between China and oil price returns in mean. The findings are consistent at lag 1 to a study by Bhar and Nikolova (2009b), where the oil price effect in the mean is also found to be insignificant. The findings contradict those of Jiao, *et al.* (2007) where the authors found evidence of a rapid and high magnitude effect of the oil price on the Chinese market. Besides this, Bhar and Nikolova (2009b) found no confirmation of the oil price effect on volatility of China and India, which is also in line with findings of Table 7.3-3 .

Mature markets are also heterogeneous in relation to the oil price. Mature market countries are likely to have both: mean (except Germany) and variance (except Japan) causality with the oil price. The UK's (DS) contemporaneous relationship with oil price is found to be highest among mature markets and second highest after the Russian market, which may be as a result of the UK's oil-exporting status rather than oil-self-sufficient, despite the discrepancy in the results e.g. Jones and Kaul (1996) found detrimental effect of the oil price on UK with the magnitude lesser than the US; O'Neill, *et al.* (2008) found where the UK responded negatively to the oil price effect, which is mostly observed for oil-importing countries (also conforms to Apergis and Miller, 2009). The US (DI) effect at lag 1 on oil price is likely to be contemporaneous; this means that the US has 2 hours from the beginning of the trading session to affect the oil price on the same day, knowing that the oil price is represented by the snapshot of the oil futures price recorded at 16.30 each working day. The value 0.598 shows that the US has a significant effect in causing the oil price, and it is comparable to the UK and Russian case and far higher than the effect of the self-sufficient Brazil. This feature of the US market may be a crucial factor when examining the effect of the oil price on linkages among market. It may also demonstrate that the US being a net oil importer may express behaviour similar to an oil self-sufficient country, or even to a net oil exporter. This will be taken into account while examining the effect of the oil price on causal linkages among countries.

Table 7.3-3
CCF causality between oil price and BRIC and mature market countries.

Pair X - Y	Lead						Lag					
	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
Panel A. Causality-in-mean												
OIL - BR						0.0376	0.0376	0.0479				
OIL - RU				0.0374	0.0361	0.094	0.094					
OIL - IN										0.0353	0.0395	
OIL - CH												
OIL - JP						0.0368	0.0368					
OIL - GE												
OIL - FR						0.0354	0.0354					
OIL - UK						0.0604	0.0604				0.0357	
OIL - US	-0.0373							0.0598				

Notes: The Cheung and Ng (1996) CCF causality test performed for each lag using χ^2 distribution at 1 degree of freedom for 5% level of significance critical value (3.8414). The negative lag represents causality from X to Y, positive lags represent causality from Y to X. Panel A is estimated using standardized residuals obtained from model (14) for examining causality in mean among countries with mature stock markets.

Pair X - Y	Lead						Lag					
	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
Panel C. Causality-in-variance												
OIL - BR												
OIL - RU												
OIL - IN												
OIL - CH												
OIL - JP												
OIL - GE						0.0381	0.0381					
OIL - FR						0.0601	0.0601					
OIL - UK						0.0392	0.0392		0.0498			
OIL - US	0.0352											0.0388

Notes: The values displayed in Panel C are a cross correlation function estimated using squared standardized residuals and found to be significant at 5% in s-statistics, suggested by Cheung and Ng (1996). The test is performed for each lag using χ^2 distribution at 1 degree of freedom for 5% level of significance critical value (3.8414). The negative lags in a title represent causality from X to Y, positive lags represent causality from Y to X. Panel C is estimated using squared standardized residuals obtained from model (14) for examining causality in variance among indices of BRIC countries. Squared standardized residuals obtained from model (14) are adjusted for the causality in mean (if it exists) from the minimum allowed lag to the maximum detected lag using Cheung and Ng (1996) and Gebka and Serwa (2007) adjustments. For example, Oil causes France at lag 0 (0.0354) in mean. Knowing that the minimum possible lag in this causality structure is 0 (Oil price can affect France on the same day) and the maximum detected lag is 0, it is possible to construct an augmented model from model (14) to obtain squared standardized residuals adjusted for the causality in mean from Oil at lag 0. Knowing the optimal m , n , p and q parameters, it is possible to estimated model (14) with a conditional mean equation replaced by the following formula:

$$FR_t = \alpha_0 + \sum_{g=0}^0 \lambda_g OIL_{t-g} + \sum_{z=1}^m \alpha_z FR_{t-z} + \sum_{s=1}^n \varphi_s \zeta_{t-s} + \zeta_t.$$

After the estimation of the given mean-adjusting EGARCH model, the residuals are saved and used to detect causality in variance. Thus, if causality in mean is detected for both cases (1. Oil to France; 2. France to Oil), then, in order to find variance causality for both cases, it is necessary to obtain the mean adjusted squared standardized residuals from each of them and then perform the CCF Cheung and Ng (1996) test.

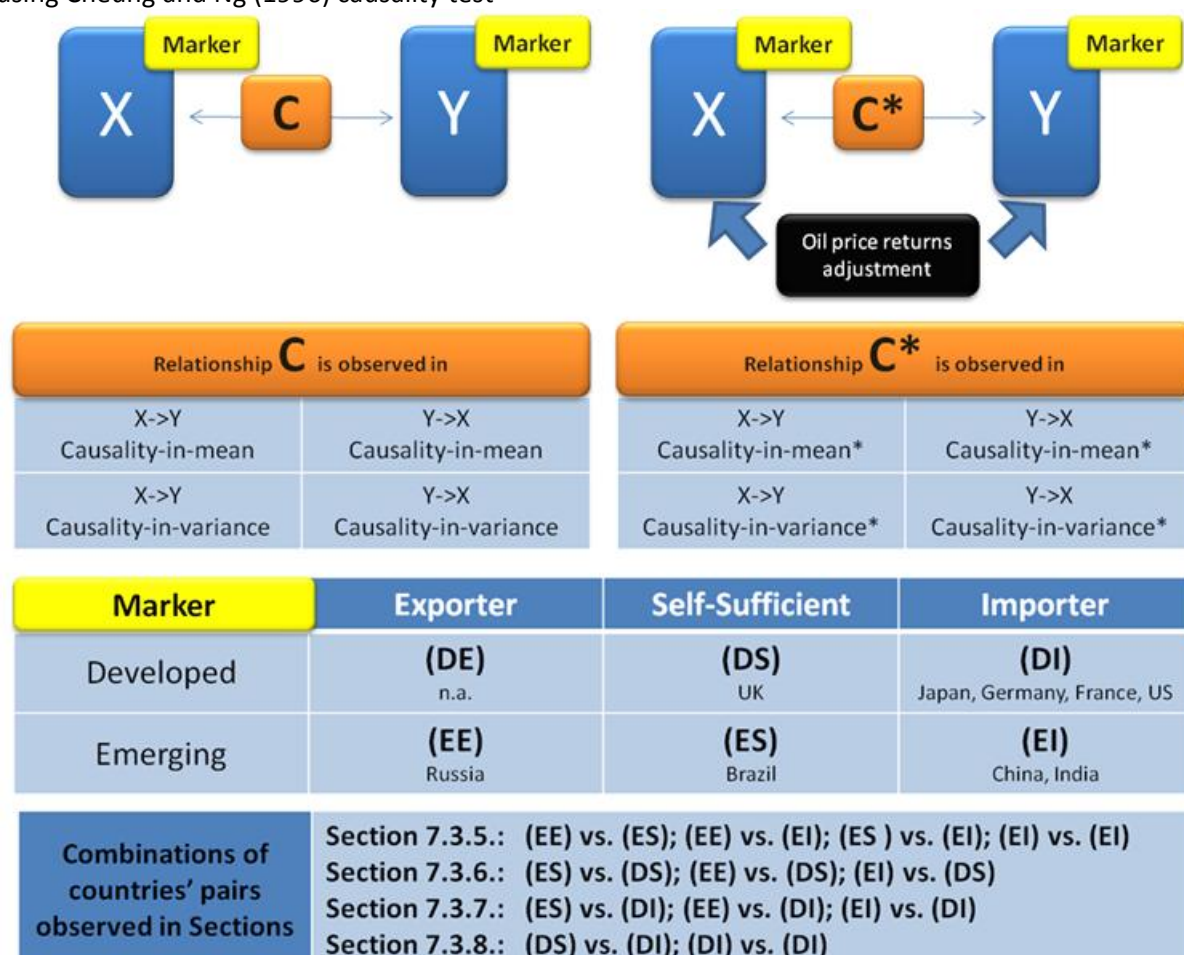
7.3.4. Application of CCF test for causality testing with and without oil price adjustment.

The second estimation scheme is performed in order to investigate the oil price effect on the causality (both in mean and in variance) linkages between stock market indices as suggested in the second (Section 1, page 4 with a discussion on page 68) and the third (Section 1, page 5 with a discussion on page 69) research objectives. In order to perform this investigation, the CCF causality

test (both, in mean and in variance) is applied on standardised and squared standardised residuals extracted both with and without oil price adjustments from the $ARMA(m,n)$ -EGARCH(p,q) model⁹⁹.

Figure 7.3-3

Examination of the oil price effect on relationship between stock market indices using Cheung and Ng (1996) causality test



For ease of comprehension, Figure 7.3-3 explains the task associated with research objectives 2 and 3. Relationship C is observed in causality-in-mean and causality-in-variance in both directions, with and without the oil price adjustment. The oil status and economic profile of each country organises the unique combinations of pairs, when mutual interactions between countries are observed.

The results are explained not only for the oil status and economic profile of each of the participating country, but also refer countries in pairs. Therefore, observing pairs of stock market indices each with its own oil status and economy profile.

It is also assumed that both mean and variance causality can be detected on a 5 day lag horizon, as suggested by Cheung and Ng (1996), which was also used in the study by Fujii (2005), Gebka and

⁹⁹ Standardized residuals were extracted from equation (14) without oil price adjustment and equation (20) with oil price adjustment as discussed in Section 5.2.2 .

Serwa (2007). It is also worth noting that the investigation of the causal linkages through the CCF test is performed using vertical lag representation, compared to the classical form by Cheung and Ng (1996), Fujii (2005) or the matrix form by Alba and Park (2007) and Gebka and Serwa (2007). The calculation generates a large number of figures¹⁰⁰ and, to aid simplicity of comprehension and interpretation, the decision was made to display only the significant cross-correlation linkages found by *s*-statistics. In order to determine the *s*-statistics, expression (17) is used for standardized residuals at their levels and squares.

The significance of the cross correlation could be tested using a χ^2 distribution, where the critical values are obtained using expressions (18) and (19). The significance of each lag is detected using $(k-j+1)$ degrees of freedom as suggested by Cheung and Ng (1996), where k is the maximum lag and j is the starting lag. This means that, in order to test a standalone lag, the degree of freedom should be equal to 1, assuming that $j=k$. Each pair of indices is also corrected for the day closing time non-synchronism problem as discussed in Sections 5.2.2.1 and using the lag correction technique given in Cheung and Ng (1996), Fujii (2005). Thus, “NA” denotes the impossibility of causation from one index to another due to the absence of overlaps in trading time.

The results of the CCF test are organised in the following tables: BRIC countries linkages and the oil price effect (Table 7.3-4); the relationship between BRIC countries, the UK and the oil price effect (Table 7.3-7); the relationship between BRIC countries, mature markets and the oil price effect (Table 7.3-10-Table 7.3-13); linkages among mature markets and the influence of the oil price (Table 7.3-16).

Since the tables have a similar structure, it is important to highlight the general specificity. To perform the linkage examination, the decision was made to organise four panels inside each table (Panel A, B, C, D). Panels A and C represent causality in mean and variance, estimated using standardized residuals at their levels and squares obtained from equation (14), while Panels B and D represent standardized residuals at their levels and squares obtained from equation (20)¹⁰¹. Since, equation (20) contains oil price return in the mean equation, it is assumed that it will be a common factor that could explain part of the dependant variable dynamics, but also (presumably) will affect the other estimators. This research is particularly interested in capturing such effects through the Cheung and Ng (1996) framework. Note that the oil price in a conditional mean equation of model

¹⁰⁰ The traditional representation form of all pairs of indices can be found in Appendices A.3 Table A.3-1 and Table A.3-2 for mean and variance causality without adjustment for oil price, and tables Table A.3-3 and Table A.3-4 with adjustment for the oil price.

¹⁰¹ Since Table 7.3-3 represents lead-lag relationship between oil price and participating countries the adjustment for the oil price is not applied. Therefore, Panel B and D are omitted.

(20) is exogenous to the index, which is assumed to be a dependant variable despite the proposition of the endogeneity of the oil price (e.g. Barsky and Kilian, 2001, 2004; Kilian, 2008b).

As discussed in Section 5.2.2, the variance causality is estimated on squared standardized residuals adjusted for the causality in mean, if the latter exists at any lag in the same direction. Thus, the detected mean causality in Panel A (B) of a certain section ("Lead" or "Lag"), necessitates re-estimation of the equations (14) and (20) with the inclusion of a foreign market lag into the conditional mean equation from minimum¹⁰² to maximum lag detected in the CCF test. Squared standardized residuals obtained from the newly organised model are used in the CCF test in order to detect variance causality, which is recorded in Panel C (D). Panel B (D) is given in percentage terms in order to perform the overall effect of oil price as an adjustment for mean (variance) causality.

Some similarities in analysis can be found in studies by Hayo and Kutan (2005), Anatolyev (2005) and Jalilov and Miyakoshi (2005), but they were limited to implementing one pair of markets with a set of other exogenous variables (government bonds, exchange rate, industrial indices). In this research the focus is on the sign and magnitude of correlation, while in comparison with the CCF derived from equation 14 to the oil adjusted CCF derived from equation 20 the interest is in the percentage change sign which distinguishes between contemporaneous and higher lags causalities. Therefore, if the effect exists, changes in s-statistics significant correlation coefficients can be expected.

In order to check the robustness of the observed relationship, a rolling CCF causality test for the set of the descending window sizes was applied¹⁰³ to derive results of the frequency of appearance of the negative and positive signs of the percentage change value in the cross-correlation at a certain lag of the oil unadjusted and adjusted cases. The detailed output of frequency of appearance and verdict regarding prevalence of one sign over the other (Sign Prevalence - SP) in the observed relationship is given in Table A.4-1 and Table A.4-2, for causality-in-mean and causality-in-variance respectively. The SP from those tables are transmitted to the correspondent tables, pair of countries and a certain causality lag (Table 7.3-4; Table 7.3-7; Table 7.3-10 - Table 7.3-13 and Table 7.3-16) of the discussed country groups. If the negative sign prevails over the positive sign with respect to each window size (except full sample) then that case is marked by ^{-SP}. If the positive sign prevails over the negative one with respect to each window size (except full sample) then that case is marked by ^{+SP}. The comparison of the sign in full sample estimation and the sign obtained in SP gives a more detailed analysis and greater evidence of the effect of the oil price on stock market linkages at a certain lag, since total number of observed samples is increased.

¹⁰² Minimum lag is obtained from the contemporaneous structure Table 5.1-2

¹⁰³ The rolling window for descending window sizes is discussed in Section 5.3 and in Table 5.3-1.

Having established the main structure and notations, it is possible to focus on each table and draw conclusions regarding the dependencies found and the oil price effect. Section 7.3.5 is devoted to the examination of empirical results of dependencies among BRIC countries and the oil price influence. Section 7.3.6 is devoted to the dependencies of BRIC countries with the UK as a special case of a mature market with self-sufficiency status (net oil exporter). Section 7.3.7 represents dependencies between BRIC countries and mature markets and the influence of the oil price. Section 7.3.8 represents dependencies among mature markets and the influence of the oil price.

7.3.5. Linkages among the BRIC markets with and without oil price adjustment.

Summarising the given results with respect to the country's oil status and economic profile (Section 7.3.2) it is possible to group pairs of countries into the following table with possible explanation of the relationship.

We observe the following combination of pairs of countries:

- Emerging Exporter (EE) vs. Emerging Self-Sufficient (ES);
- Emerging Exporter (EE) vs. Emerging Importer (EI);
- Emerging Self-Sufficient (ES) vs. Emerging Importer (EI);
- Emerging Importer (EI) vs. Emerging Importer (EI).

From Table 7.3-4 and the oil price effect on linkages summary (Table 7.3-5 and

Table 7.3-6) it is possible to deduce a possible explanation of the oil price effect on markets linkages. The overall picture emerges from the comparison of relationships in mean and variance causality of certain lags, both with and without adjustment for the oil price.

From examining of each combination of countries it is possible to deduce the following:

Emerging Exporter (EE) – Emerging Self-sufficient (ES).

Causal linkages between Brazil and Russia. In Table 7.3-4 the existence of multiple causalities from Brazil to Russia together with bidirectional causality in contemporaneous term (0.2186) can be seen. This is the highest cross-correlation coefficient among the observed pairs. This also conforms to the study by Gebka and Serwa (2007), where causality-in-mean between Russian and Brazil had the highest magnitude among international lineages, while regional linkages are usually confirmed to be stronger. The adjustment for the oil price gives a slight decrease in contemporaneous bidirectional causality, which is also confirmed when solved in the rolling window approach. Unidirectional mean causality from Brazil is decreased at lag 1 to 3 with -SP confirmed at lags 1 and 4 and +SP at lag 3.

The variance causality from Brazil corresponds to the mean causality in lags (except not confirmed causality at lag 4). Adjustment for the oil price gave a decrease for variance causality in contemporaneous term and a significant decrease of causality from Brazil at higher lags.

Summarizing the Exporter–Self sufficient case in Table 7.3-5 and

Table 7.3-6 it is possible to conclude the following: the oil price adjustment causes a decrease in magnitude of mean spillover and a decrease in magnitude of the variance spillover between two oil producers (arguably, self-sufficiency partly expresses exporter's¹⁰⁴ behaviour). However, the percentage change is less than 1% in absolute terms.

Emerging Exporter (EE) - Emerging Importer (EI).

Causal linkages between Russia and China. In the BRIC group there are two pairs of indices that suit Exporter – Importer relations: Russia and China; Russia and India. By examining for the Russia-China pair it is possible to conclude the following. China has causality from the previous day represented by negative correlation (-0.0449), while Russia has a positive sign at lag 2 (0.0417). The magnitude of detected correlations after the adjustment for the oil price are 3.6% and -0.22% for Russia and China respectively, but the percentage change sign detected in the full sample estimation is not confirmed in SP for China. However, no causality in variance is detected between Russia and China in both unadjusted and adjusted cases.

Causal linkages between Russia and India. The Russia-India case in the same table gives the following result. Russia and India have a significant bidirectional contemporaneous correlation (0.1769), while Russia causes India at lag 1 (0.0567), but with lower magnitude. After adjustment for the oil price, the relationship increased between 1-2 % for each detected s-statistics significant CCF coefficients. India causes Russia in variance at lag 3 (0.06) and it is increased by (6.683%) after the adjustment for oil. No SP confirmation of the full sample estimation outcome is found in variance causality for both countries.

By summarising the results in Table 7.3-5 and

Table 7.3-6 it is possible to deduce the following: First, the magnitude of the relationship will rise due to the adjustment for the oil price at least at higher lags of the mean Causality. The inference behind the increase in mean causality is that the real relationship is probably clouded by the oil price distortion from the oil-exporter side, since the oil-exporter's dynamics are to some extent explained

¹⁰⁴ Self-sufficiency of Brazil partly explained by simultaneous development of the oil and bio-ethanol production ("International Energy Agency. World Energy Outlook 2006," p. 447).

by oil price dynamics, which give unnecessary distortion and reduction of the magnitude of the linkage between the two markets of the given type. Therefore, the relationship between an oil-exporter and oil-importer should be corrected for the oil price - regarding Russia's case, at least in the mean equation.

Second, the variance causality case requires further investigation, since Russia does not demonstrate a relationship in variance with China.

Emerging Self-Sufficient (ES) - Emerging Importer (EI).

Causal linkages between Brazil and China. Emerging Self sufficiency and Importer relationship is represented by the pairs: Brazil-China and Brazil-India. It is found that Brazil causes China from the previous day (0.0353) and at lag 5 (0.0428), both correlations are small. Adjustment for the oil price gives a small increase only in the case of previous day mean causality from Brazil. Unidirectional causality in variance is detected from China (0.0462) and (-6.93%) after adjustment for the oil price. Brazil has (0.0876 and 0.0434) cross-correlation values in variance causality at lag 2,4, and adjustment for oil gave 6.05% and 7.6% increase respectively.

Causal linkages between Brazil and India. The pair Brazil and India demonstrated bidirectional contemporaneous causality above 0.1309 and 0.1246 respectively. Brazil also has a mean causality at lag 3 (0.0821). After adjustment for the oil price, a slight decrease in magnitude is detected in contemporaneous mean causality from Brazil to India and from India to Brazil, while at lag 2 from Brazil a 2.07% decrease is found, also confirmed in SP. Causality-in-variance is detected from Brazil to India at various lags including the contemporaneous term, while India demonstrated a higher magnitude at lag 1 (0.0716). Adjustment for the oil price has changed causality from Brazil for lags 2 and 4 with lag 1 found with a positive SP, while India demonstrated a decrease in magnitude (3.77%) at lag 1. Variance causality at lags 2 and 4 similar to the Brazil-China pair, may be ascribed to the possible existence of the variance causality pattern from Brazil to Asian countries (also found in Fujii, 2005; Beirne, *et al.*, 2010).

Summarizing the causality linkages, given in relation to self-sufficiency and importer status, it is possible to conclude the following:

First, there is no prominent trend detected in changes of causality-in-mean, due to the lack of the causality from the Chinese market and controversial results from the Brazilian market to both countries.

Second, regarding changes in causality-in-variance, after adjustment for the oil price, it is possible to conclude the increase from the self-sufficient side at a higher lag.

Emerging Importer (EI) - Emerging Importer (EI).

Causal linkages between China and India. Causality in mean between China and India is represented by bidirectional contemporaneous correlation only (0.0626). A fall in magnitude is detected after the adjustment for oil price. No variance causality is detected (except at lag 5 from China). No variance of the causality relationship is detected with oil price adjustment.

Regarding the interaction (EI-EI) it is possible to conclude the following:

The response of the cross-market linkages to the oil price adjustment is still questionable for the oil importers. The oil price component might have a distortion effect on cross market linkage, which treatment may induce a rise in the magnitude of causality, or complementary effect (similar to oil producers) which after oil price adjustment will lead to a decrease in magnitude of the cross-market linkage.

The outcome of the CCF coefficients demonstrates a decrease in magnitude of causality-in-mean, which may suggest that a complementary effect of the oil price is also plausible in the case of oil importers linkages. However, the Chinese detached position, in terms of correlation with other markets, may bias findings on the oil price effect. Thus, further investigation of the relation between emerging importers, with and without oil price adjustment, is required.

Second, the detached position of China also does not allow a conclusion to be made regarding variance causality response to oil price adjustment.

It is also possible to highlight the limitations of the influence of oil price that were found. The relationships among BRIC countries are expressed by a relatively low degree of correlation¹⁰⁵, especially at higher lags. The changes due to the oil price adjustment in most cases are also small, with the exception of the Brazil - Russia case at higher lags. This could raise the issue that an oil price effect on the linkages among BRIC countries is comparable to level of insignificant noise. However, at certain lags, the oil price effect on causality may be large (change in mean causality of Brazil to Russia at lag 4: +10.16%). Existence of these cases demonstrates that the oil price may have an impact on the cross-market relationships and may raise the question of the necessity of the oil price adjustment, in order to remove the oil price component from the participating series and relations to provide a treatment at least for the higher lag causality.

¹⁰⁵ This is also stated in a study by Bracker, *et al.* (1999).

Table 7.3-4

CCF Cheung and Ng (1996) mean and variance causality among BRIC markets and oil price.

Pair	Lead						Lag					
X - Y	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
Panel A. Causality-in-mean, (no adjustment for oil)												
IN - CH						0.0626	0.0626					
RU - CH				0.0417		NA		-0.0449				
RU - IN					0.0567	0.1769	0.1769					
BR - CH	0.0428				0.0353	NA						
BR - IN			0.0821		0.1309	NA	0.1246					
BR - RU		0.0492	0.0376	0.0421	0.1843	0.2186	0.2186					
Panel B. Causality-in-mean, (adjustment for oil price)												
IN - CH						-1.76%	-1.76%					
RU - CH				3.6% ^{+SP}		NA		>-1% ^{+SP}				
RU - IN				{-SP}	1.59%	<1%	<1%			{-SP}		
BR - CH	1.17%				1.13%	NA						
BR - IN			-2.07% ^{-SP}		>-1%	NA	>-1%					
BR - RU		10.16% ^{-SP}	-1.6% ^{+SP}	>-1%	-2.5% ^{-SP}	>-1% ^{-SP}	>-1% ^{-SP}					

Notes: The Cheung and Ng (1996) CCF causality test performed on s-statistics for each lag using χ^2 distribution at 1 degree of freedom for 5% level of significance critical value (3.8414). The negative lag represents causality from X to Y, positive lags represent causality from Y to X. Panel A is estimated using standardized residuals obtained from model (14) for examining causality in mean among BRIC countries' indices. Panel B is estimated using standardized residuals obtained from model (20), and represented as the percentage change in a magnitude of the significant parameters found in panel A after adjustment for the oil price.

Pair	Lead						Lag					
X - Y	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
Panel C. Causality-in-variance, (no adjustment for oil)												
IN - CH												0.0353
RU - CH						NA						
RU - IN										0.06		
BR - CH		0.0434		0.0876		NA	0.0462					
BR - IN		0.0467		0.0356	0.0392	NA		0.0716				
BR - RU			0.0767	0.0537	0.0902	0.0888	0.0888					
Panel D. Causality-in-variance, (adjustment for oil price)												
IN - CH						NA						-
RU - CH												
RU - IN										6.83%		
BR - CH		7.6%		6.05%		NA	-6.93%					
BR - IN		6.42%		1.12%	>-1% ^{+SP}	NA		-3.77%				
BR - RU			-10.56%	-12.48%	-22.06%	>-1%	>-1%		{-SP}			

Notes: The values displayed in Panels C and D are cross correlations function estimated using squared standardized residuals and found to be significant at 5% in s-statistics, as suggested by Cheung and Ng (1996). The test is performed for each lag using χ^2 distribution at 1 degree of freedom for 5% level of significance critical value (3.8414). The negative lags in a title represent causality from X to Y, positive lags represent causality from Y to X. Panel C is estimated using squared standardized residuals obtained from model (14) for examining causality in variance among indices of the BRIC countries. Panel D is estimated using squared standardized residuals obtained from model (20) for examining the percentage changes in magnitude of variance causality after adjustment for the oil price. Squared standardized residuals are obtained from models (14) and (20) and adjusted for the causality in mean (if it exists) from the minimum allowed lag to the maximum detected lag using Cheung and Ng (1996) and Gebka and Serwa (2007) adjustments. For example, Russia causes Brazil at lag 0 (0.2186) in mean. Knowing that the minimum possible lag in this causality structure is 0 (Russia can affect Brazil on the same day) and the maximum detected lag is 0, it is possible to construct an augmented model from model (14) to obtain squared standardized residuals adjusted for the causality in mean from Russia at lag 0. Knowing the optimal m , n , p and q parameters, it is possible to estimated model (14) with a conditional mean equation replaced by the following formula:

$$BR_t = \alpha_0 + \sum_{g=0}^0 \lambda_g RU_{t-g} + \sum_{z=1}^m \alpha_z BR_{t-z} + \sum_{s=1}^n \varphi_s \zeta_{t-s} + \zeta_t.$$

After the estimation of the given mean-adjusting EGARCH model, the residuals are saved and used to detect causality in variance. Thus, if causality in mean is detected for both cases (1. Brazil to Russia; 2. Russia to Brazil), then, in order to find variance causality for the both cases, it is necessary to obtain mean adjusted squared standardized residuals from each of them and then perform the CCF Cheung and Ng (1996) test. Similar adjustment is performed for panel D, if in the corresponding row in panel B the mean causality is detected.

The changes in magnitude of the cross-correlation coefficient in a range from -1 to 0 is marked by ">-1", while the range 0 to 1 is marked by "<1%". Mark ^{+SP} and ^{-SP} represents a prevalence of positive and negative sign in percentage change after adjustment for the oil price. SP is collected from the same pairs of countries located in Table A.4-1 for the changes in magnitude of the causality-in-mean (for the Panel B of the current table) and in Table A.4-2 for the changes in magnitude of the causality-in-variance (for the Panel D of the current table).

Table 7.3-5

Changes in mean causality among BRIC countries due to the adjustment for oil price.

Causality in mean				Explanation
Exporter			Self-sufficient ¹⁰⁶	
RU	$\downarrow^{sp} \rightarrow$	$\leftarrow \downarrow^{sp} \downarrow^{sp}$	BR	Linkage is between two producers due to the oil price changes, at least in the contemporaneous term. Thus after adjustment the magnitude of linkage is dropped.
Exporter			Importer	
RU	$\uparrow^{sp} \rightarrow$	$\leftarrow \uparrow^{sp}$	CH	Raise at a higher lag causality from Emerging Exporter's side
RU	$\uparrow \uparrow \rightarrow$	$\leftarrow \uparrow \downarrow^{sp}$	IN	
Self-sufficient			Importer	
BR	$\uparrow \uparrow \rightarrow$		CH	<i>Inconclusive</i>
BR	$\downarrow^{sp} \downarrow \rightarrow$	$\leftarrow \downarrow$	IN	
Importer			Importer	
IN	$\downarrow \rightarrow$	$\leftarrow \downarrow$	CH	Decrease in magnitude after adjustment.

Note: The sign of the percentage change of the CCF coefficients are represented by arrows. Upward (Downward) arrows represent increase (decrease) in the CCF coefficient when the oil price adjustment is applied. Lined and dashed arrows represent the location of the CCF coefficients, contemporaneous and higher lag respectively. (SP) mark located near the arrow demonstrates that sign of the percentage change of CCF coefficient is confirmed to be stable in rolling window method.

Table 7.3-6

Changes in variance causality among BRIC countries due to the adjustment for oil price.

Causality in variance				Explanation
Exporter			Self-sufficient	
RU	$\downarrow^{sp} \downarrow \rightarrow$	$\leftarrow \downarrow \downarrow$	BR	Linkage is due to the oil price changes. Thus, after adjustment the magnitude of the linkage is dropped.
Exporter			Importer	
RU	No relation		CH	<i>Inconclusive</i>
RU	$\leftarrow \uparrow$		IN	
Self-sufficient			Importer	
BR	$\uparrow \rightarrow$	$\leftarrow \downarrow$	CH	Increase in variance from self-sufficient side at higher lag
BR	$\uparrow \uparrow^{sp} \rightarrow$	$\leftarrow \downarrow$	IN	
Importer			Importer	
IN	No relation		CH	<i>Inconclusive</i>

Note: The sign of the percentage change of the CCF coefficients are represented by arrows. Upward (Downward) arrows represent increase (decrease) in CCF coefficient when oil price adjustment is applied. Lined and dashed arrows represent location of the CCF coefficients, contemporaneous and higher lag respectively. (SP) mark located near the arrow demonstrates that sign of the percentage change of CCF coefficient is confirmed to be stable in rolling window method.

¹⁰⁶ Dependence on the oil price of a self-sufficient country may be confirmed before the actual self-sufficiency statistical data is available. Arguably, an increase of proved reserves of oil and the promulgation of a plan for future extraction/production of oil may be an additional factor for dependence, which may partially indicate likely future revenues. Thus, it may synchronise asset prices with oil price dynamics, since asset prices are the present discounted value for future net earnings Jones, Leiby and Paik (2004, p. 24) before the actual oil price self-sufficiency data.

7.3.6. BRIC and the UK. Case of an oil self-sufficient mature market.

The UK differs from the other mature markets. Since, according to the BP energy report (“BP. Energy report 2008”), it has now lost its net oil exporting status and the tendency is towards a decrease in oil production¹⁰⁷. Therefore, the UK is treated as a developed self-sufficient country in this study (DS).

By investigating the UK’s cross-market relationships it is expected that a pattern will be distinguished, which is inherent to the oil self-sufficiency position of the UK. As discussed in Section 7.3.2, the discussion focuses on country pairs regarding their oil status and the following generic pairings emerge:

- Emerging Self-Sufficient (ES) vs. Developed Self-Sufficient (DS);
- Emerging Exporter (EE) vs. Developed Self-Sufficient (DS);
- Emerging Importer (EI) vs. Developed Self-Sufficient (DS).

Emerging Self-sufficient (ES) vs. Developed Self-sufficient (DS).

Causal linkages between Brazil and the UK. Bidirectional causality is found between Brazil and the UK at lag 0 (0.3449), at lag 1 (0.1518) and at lag 5 (-0.0351) from Brazil. The adjustment for the oil price provides a small decrease in magnitude of the relationship at lag 0, and (-2.17%) at lag 1 from Brazil. The sign of the relationship remains the same when solved in the rolling approach with additional SP detected from the UK side at lag 3. Besides contemporaneous interactions found in variance (0.1817), there is a variance causality from Brazil to the UK at lag 1 (0.0517). The adjustment for the oil price gave a decrease in contemporaneous variance causality (-1.87%) and a decrease in causality at lag 1 from Brazil (-4.64%). The relationship is also confirmed to be stable in sign at lag 0.

Emerging Exporter (EE) – Developed Self-sufficient (DS).

Causal linkages between Russia and the UK. Russia and the UK express bidirectional contemporaneous causality at lag 0 (0.798). Besides this, the UK causes Russia at higher lags (1, 3 and 4), while no mean causality is detected from Russia’s side to the UK at higher lags. The adjustment for the oil price demonstrated a decrease in magnitude for all found dependencies, while lag 3 from the UK to Russia lost its significance. The rolling estimation percentage change sign coincides with the full sample estimation sign, but with additional –SP at lag 5 from the side of Russia and lag 3 from the side of the UK.

¹⁰⁷ This is found by comparison of the oil production/consumption of the UK (see Figure A.1-1).

Table 7.3-7

CCF Cheung and Ng (1996) mean and variance causality for UK with BRIC markets and oil price.

Pair X - Y	Lead						Lag					
	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
Panel A. Causality-in-mean, (no adjustment for oil)												
BR - UK	-0.0351				0.1518	0.3449	0.3449					
RU - UK						0.2798	0.2798	0.0761		0.0351	0.0472	
IN - UK						0.1717	0.1717	0.113		0.0577		
CH - UK							NA	0.0554			0.0576	
Panel B. Causality-in-mean, (adjustment for oil price)												
BR - UK	3.7%				-2.17%	>-1% ^{-SP}	>-1% ^{-SP}			{-SP}		
RU - UK	{-SP}					-1.07% ^{-SP}	-1.07% ^{-SP}	-3.94% ^{-SP}		{-SP}	-4.45%	
IN - UK						<1%	<1%	<1% ^{-SP}		>-1%		
CH - UK							NA	>-1% ^{-SP}			2.43%	

Notes: The Cheung and Ng (1996) CCF causality test performed on s-statistics for each lag using χ^2 distribution at 1 degree of freedom for the 5% level of significance critical value (3.8414). The negative lag represents causality from X to Y, the positive lags represent causality from Y to X. Panel A is estimated using standardized residuals obtained from model (14) for examining causality in mean between UK and BRIC countries indices'. Panel B is estimated using standardized residuals obtained from model (20), and represented as the percentage change in magnitude of the significant parameters found in panel A after adjustment for the oil price.

Pair X - Y	Lead						Lag					
	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
Panel C. Causality-in-variance, (no adjustment for oil)												
BR - UK					0.0517	0.1817	0.1817					
RU - UK						0.0537	0.0537		0.0575	0.0672	0.0371	0.1208
IN - UK					0.0855	0.0419	0.0419					
CH - UK							NA					
Panel D. Causality-in-variance, (adjustment for oil price)												
BR - UK					-4.64%	-1.87% ^{-SP}	-1.87% ^{-SP}					
RU - UK						2.23%	2.23%		10.09%	-3.57% ^{+SP}		-2.4%
IN - UK					-4.56%	>-1% ^{-SP}	>-1% ^{-SP}					
CH - UK							NA					

Notes: The values displayed in Panels C and D are the cross correlation function estimated using squared standardized residuals and found to be significant at 5% in s-statistics, as suggested by Cheung and Ng (1996). The test is performed for each lag using χ^2 distribution at 1 degree of freedom for 5% level of significance critical value (3.8414). The negative lags in a title represent causality from X to Y, positive lags represent causality from Y to X. Panel C is estimated using squared standardized residuals obtained from model (14) for examining causality in variance between the UK and BRIC countries. Panel D is estimated using squared standardized residuals obtained from model (20) for examining the percentage changes in magnitude of variance causality after adjustment for the oil price. Squared standardized residuals are obtained from models (14) and (20) and adjusted for the causality in mean (if it exists) from the minimum allowed lag to the maximum detected lag using Cheung and Ng (1996) and Gebka and Serwa (2007) adjustments. For example, Russia causes the UK at lag 0 (0.2798) in mean. Knowing that the minimum possible lag in this causality structure is 0 (Russia can affect the UK on the same day) and the maximum detected lag is 0, it is possible to construct an augmented model from model (14) to obtain squared standardized residuals adjusted for the causality in mean from Russia at lag 0. Knowing the optimal m , n , p and q parameters, it is possible to estimated model (14) with a conditional mean equation replaced by the following formula:

$$UK_t = \alpha_0 + \sum_{g=0}^0 \lambda_g RU_{t-g} + \sum_{z=1}^m \alpha_z UK_{t-z} + \sum_{s=1}^n \varphi_s \zeta_{t-s} + \zeta_t.$$

After the estimation of the given mean-adjusting EGARCH model, the residuals are saved and used to detect causality in variance. Thus, if causality in mean is detected for both cases (1. Russia to the UK; 2. The UK to Russia), then, in order to find variance causality for both cases, it is necessary to obtain mean adjusted squared standardized residuals from each of them and then perform the CCF Cheung and Ng (1996) test. Similar adjustment is performed for panel D, if in the corresponding row in panel B mean causality is detected. The changes in magnitude of the cross-correlation coefficient in a range from -1 to 0 is marked by ">-1", while the range 0 to 1 is marked by "<1%". Mark ^{+SP} and ^{-SP} represents a prevalence of the positive and negative sign in the percentage change after adjustment for the oil price. SP is collected from the same pairs of countries located in Table A.4-1 for the changes in magnitude of the causality-in-mean (for the Panel B of the current table) and in Table A.4-2 for the changes in magnitude of the causality-in-variance (for the Panel D of the current table).

The variance causality is found to be at a contemporaneous term (0.0537), and at higher lags from the UK side (lags 2 - 5). Adjusting for the oil price raises both contemporaneous and lag 2 causalities, with the exception of lag 5. It appears that the oil adjustment improves the magnitude of linkages between Russia and the UK. The contemporaneous causality-in-variance is increased by (+2.23%) and causality from the UK to Russia is increased by (10.09%) at lag 2. At the same time the

magnitude remains low (0.0537 and 0.0575 before adjustment for both lags 0 and 2). SP exists on lag 3 from UK to Russia and it is found to be positive.

After a discussion on the relationship and the oil price effect on it, it is possible to organise the results in a simplified form for mean (Table 7.3-8) and variance causality (Table 7.3-9) for the pairs where both countries are oil producers (EE-DS; ES-DS):

First, oil related countries express a decrease in mean causality after adjustment for the oil price, which is confirmed in the Brazil-UK and Russia-UK cases. Therefore, it can be stated that the relationship of an oil self-sufficient mature market with an emerging oil exporter conforms to the relationships of an emerging oil self-sufficient market and emerging oil exporter, at least in the case of the mean relationship between Russia and Brazil. However, the percentage change in the case of Brazil and the UK is less than 1% in absolute terms.

Second, despite causality-in-mean, the response of the causality-in-variance to the oil price adjustment is mixed. One would expect that the changes, after adjustment for the oil price in variance causality between UK-Brazil and UK-Russia, will rise after removal of the similar component from the stock market dynamics. However, in the case of Russia and the UK, the magnitude of the variance causality is raised, while in case of Brazil and the UK, the magnitude is decreased and it is confirmed by the sign prevalence at the contemporaneous term. Higher, lag causality-in-variance is found from Brazil to the UK side, while the UK is found to be causing Russia at a higher lag.

Emerging Importer (EI) – Developed Self-sufficient (DS).

Causal linkages between India and the UK. India and the UK have contemporaneous bidirectional causality (0.1717) and the UK causes India at higher lags (1 and 3). Adjustment for the oil price gave a small increase to the relationship between the two countries in contemporaneous mean causality. The negative SP is detected at lag 1 from the UK side. India and the UK have causality in variance in the contemporaneous term (0.0419) and at lag 1 (0.0855) from India to the UK. After adjustment for the oil price the variance causality is decreased in all observed lags, while SP is confirmed on contemporaneous causality only.

Causal linkages between China and the UK. The linkages between China and the UK have only causality from the UK side - contemporaneous (0.0554) and lag 4 mean causalities. Adjustment for the oil price brought a SP confirmed decrease in contemporaneous term (-0.9%) and an increase in causality at lag 4 from the UK. No causality is detected in variance between China and the UK, and no changes are found after equation adjustment for the oil price.

Table 7.3-8

Changes in mean causality between UK and BRIC countries due to the adjustment for oil price.

Causality in mean				Explanation
Self-sufficient			Self-sufficient	
BR	$\downarrow \downarrow^{SP} \rightarrow$	$\leftarrow \downarrow \downarrow^{SP}$	UK	Linkage due to the existence of oil price, therefore decrease after adjustment for the oil price.
Exporter			Self-sufficient	
RU	$\downarrow \downarrow^{SP} \rightarrow$	$\leftarrow \downarrow \downarrow^{SP}$	UK	Linkage due to the existence of oil price, therefore decrease after adjustment for the oil price.
Self-sufficient			Importer	
IN	$\uparrow \rightarrow$	$\leftarrow \uparrow \downarrow^{SP}$	UK	<i>Inconclusive</i>
CH		$\leftarrow \downarrow \uparrow^{SP}$	UK	

Note: The sign of the percentage change of the CCF coefficients are represented by arrows. Upward (Downward) arrows represent increase (decrease) in CCF coefficient when oil price adjustment is applied. Lined and dashed arrows represent the location of the CCF coefficients, contemporaneous and higher lag respectively. (SP) mark located near the arrow demonstrates that sign of the percentage change of CCF coefficient is confirmed to be stable in the rolling window method.

Table 7.3-9

Changes in variance causality between UK and BRIC countries due to the adjustment for oil price.

Causality in variance				Explanation
Self-sufficient			Self-sufficient	
BR	$\downarrow \downarrow^{SP} \rightarrow$	$\leftarrow \downarrow^{SP}$	UK	Linkage due to the existence of oil price, at least in contemporaneous term.
Exporter			Self-sufficient	
RU	$\uparrow \rightarrow$	$\leftarrow \uparrow \uparrow$	UK	Correction for the oil price induced raise in magnitude at least in contemporaneous causality.
Self-sufficient			Importer	
IN	$\downarrow \downarrow^{SP} \rightarrow$	$\leftarrow \downarrow^{SP}$	UK	<i>Inconclusive</i>
CH	No relation		UK	

Note: The sign of the percentage change of the CCF coefficients are represented by arrows. Upward (Downward) arrows represent increase (decrease) in CCF coefficient when oil price adjustment is applied. Lined and dashed arrows represent the location of the CCF coefficients, contemporaneous and higher lag respectively. (SP) mark located near the arrow demonstrates that sign of the percentage change of CCF coefficient is confirmed to be stable in the rolling window method.

Overall, it is difficult to generalise for the UK vs. participating emerging importers (India and China), since there are few observable cases (e.g. China has no relationship with the UK in this respect). The only plausible relation is found for the UK-India case, where the oil price adjustment has only a small (less than 1% in absolute terms) effect in mean causality, but it is not enough to make an overall conclusion. Therefore, the overall result is inconclusive.

7.3.7. BRIC and mature markets. Cases of mature markets (oil importers).

In this section, each of BRIC country is observed in their relationships with the developed oil importers. Therefore, in accordance with the generic type groupings provided in Section 7.3.2 the following pairs will be examined, in order to identify the oil price effect.

- Emerging Self-Sufficient (ES) vs. Developed Importer (DI);
- Emerging Exporter (EE) vs. Developed Importer (DI);
- Emerging Importer (EI) vs. Developed Importer (DI).

Emerging Self-Sufficient (ES) vs. Developed Importer (DI).

Causal linkages between Brazil and developed oil importers. Brazil has significant linkages with all indices. However, the linkages are stronger for the countries with market trading time overlaps. Thus, bidirectional causality of Brazil with Japan has a significantly lower coefficient of correlation, compared to the other markets. Brazil also causes Japan from the previous day with a higher magnitude (0.2032), compared to the Japanese (0.1159) causality on the same day. Brazil has the strongest correlation in contemporaneous time with the US (0.4966) and the US also causes Brazil at a higher lag but with a much lower coefficient of correlation (0.0517 at lag 1, 0.0363 at lag 3). The dependencies with the EU countries are also interesting, since they have a lower contemporaneous correlation (0.3493-0.3581) compared to the US one, but correlations at lag 1 are (0.1315-0.1374) which may be explained as follows: when the EU markets are already closed, Brazil absorbs US innovations which will be transmitted to EU countries the next day.

The causality in mean, adjusted for the oil price, does not affect market linkages significantly. The percentage change of the magnitude of correlation suggests that the oil price adjustment does not make any significant changes to linkages between Brazil and other markets. Changes in magnitude of contemporaneous correlation are small for the participating EU countries (positive for Germany and negative for France with negative SP). Some negative changes are confirmed on higher lags of BR-GE and BR-FR, but not confirmed in SP. BR-JP demonstrate negative change in contemporaneous correlation and it is confirmed on rolling estimation (-SP) from Brazil. For higher lags the changes are found to be positive in full sample estimation. The BR-US contemporaneous relationship is decreased after adjustment for the oil price. However, the (-SP) is confirmed only at lag 1 from the US side.

Brazil has a lesser magnitude of contemporaneous correlation of squared standardized residuals compared to the correlation in their levels. However, the causality pattern is multiple and located mainly on Brazil's side.

Table 7.3-10
CCF Cheung and Ng (1996) mean and variance causality
for Brazil with mature markets and oil price.

Pair X - Y	Lead						Lag					
	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
Panel A. Causality-in-mean, (no adjustment for oil)												
BR - JP				0.0367	0.2032	NA	0.1159				0.0362	
BR - GE					0.1315	0.3581	0.3581				0.0466	
BR - FR					0.1374	0.3493	0.3493					
BR - US						0.4966	0.4966	0.0517		0.0363		
Panel B. Causality-in-mean, (adjustment for oil price)												
BR - JP				<1%	>-1% ^{-SP}	NA	-1.98%				<1%	
BR - GE					-1.83%	<1%	<1%				-2.15%	
BR - FR					-4.29%	>-1% ^{-SP}	>-1% ^{-SP}					
BR - US						>-1%	>-1%	-4.64% ^{-SP}		-3.31%		

Notes: The Cheung and Ng (1996) CCF causality test performed on s-statistics for each lag using χ^2 distribution at 1 degree of freedom for the 5% level of significance critical value (3.8414). The negative lag represents causality from X to Y, the positive lags represent causality from Y to X. Panel A is estimated using standardized residuals obtained from model 14 for examining causality in mean between Brazil and countries with mature stock markets. Panel B is estimated using standardized residuals obtained from model 20, and represented as the percentage change in magnitude of the significant parameters found in panel A after adjustment for the oil price.

Pair X - Y	Lead						Lag					
	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
Panel C. Causality-in-variance, (no adjustment for oil)												
BR - JP		0.0467		0.0418	0.08	NA						
BR - GE			0.0388	0.049	0.0859	0.1129	0.1129				0.0385	
BR - FR		0.0421		0.0569	0.0526	0.152	0.152					
BR - US		0.0743		0.1		0.2447	0.2447		0.0388			
Panel D. Causality-in-variance, (adjustment for oil price)												
BR - JP		-1.71%		0%	-1.25%	NA						
BR - GE			-5.67%	-6.94%	-4.89% ^{+SP}	2.83%	2.83%				-1.04%	
BR - FR		3.09%		2.81%	-1.9%	<1%	<1%					
BR - US		13.46% ^{+SP}		2.8%		1.68%	1.68%		4.38%			

Notes: The values displayed in Panels C and D are the cross correlation function estimated using squared standardized residuals and found to be significant at 5% in s-statistics, as suggested by Cheung and Ng (1996). The test is performed for each lag using χ^2 distribution at 1 degree of freedom for 5% level of significance critical value (3.8414). The negative lags in a title represent causality from X to Y, positive lags represent causality from Y to X. Panel C is estimated using squared standardized residuals obtained from model (14) for examining causality in variance between Brazil and mature markets. Panel D is estimated using squared standardized residuals obtained from model (20) for examining the percentage changes in magnitude of variance causality after adjustment for the oil price. Squared standardized residuals are obtained from models (14) and (20) and adjusted for the causality in mean (if it exists) from the minimum allowed lag to the maximum detected lag using Cheung and Ng (1996) and Gebka and Serwa (2007) adjustments. For example, Russia causes the UK at lag 0 (0.2798) in mean. For example, Brazil causes Japan at lag 1 (0.2032), lag 2(0.0367). Knowing that the minimum possible lag in this causality structure is 1 (Brazil can't affect Japan on the same day) and the maximum detected lag is 2, it is possible to construct an augmented model from model (14) to obtain squared standardized residuals adjusted for the causality in mean from Brazil at lag 1-2. Knowing the optimal m , n , p and q parameters, it is possible to estimated model (14) with a conditional mean equation replaced by the following formula:

$$JP_t = \alpha_0 + \sum_{g=1}^2 \lambda_g BR_{t-g} + \sum_{z=1}^m \alpha_z JP_{t-z} + \sum_{s=1}^n \varphi_s \zeta_{t-s} + \zeta_t.$$

After the estimation of the given mean-adjusting EGARCH model, the residuals are saved and used to detect causality in variance. Thus, if causality in mean is detected for both cases (1. Brazil to Japan; 2. Japan to Brazil), then, in order to find variance causality for both cases, it is necessary to obtain mean adjusted squared standardized residuals from each of them and then perform the CCF Cheung and Ng (1996) test. Similar adjustment is performed for panel D, if in the corresponding row in panel B the mean causality is detected. The changes in magnitude of the cross-correlation coefficient in a range from -1 to 0 is marked by ">-1", while the range 0 to 1 is marked by "<1%". Mark ^{+SP} and ^{-SP} represents a prevalence of the positive and negative sign in the percentage change after adjustment for the oil price. SP is collected from the same pairs of countries located in Table A.4-1 for the changes in magnitude of the causality-in-mean (for the Panel B of the current table) and in Table A.4-2 for the changes in magnitude of the causality-in-variance (for the Panel D of the current table).

Brazil has the highest variance causality among other BRIC countries, which may be explained by the unique location of Brazil's trading time (between EU and US).

The adjustment for the oil price does not give any significant changes. However, there is evidence of an increase in contemporaneous causality at lag 0, with a simultaneous decrease in the causal linkages at lag 1 for EU countries. The Brazil to US relationship demonstrated positive change in magnitude of the bidirectional causality at lag 2 and unidirectional at lag 4 from Brazil side, which is also confirmed in SP.

To summarise the overall findings on it is possible to state that adjustment for the oil price induced a fall in magnitude of contemporaneous mean causality with the exception of the Brazil-Germany case. Regarding the variance causality, there was a rise in the contemporaneous term, with the exception of the Brazil-Japan case, where a decrease in the contemporaneous term is detected.

Emerging Exporter (EE) vs. Developed Importer (DI).

Causal linkages between Russia and developed oil importers. Russia has significant contemporaneous linkages with the developed countries in mean, which have a positive sign. The minimum correlation is detected in the contemporaneous relationship to Japan, which causes Russia at lag 0 (0.1498) and is caused by Russia at lag 1 (0.1191). A similar disproportion is found in relation to the US, which causes Russia at lag 1 (0.2263) and is caused by Russia at lag 0 (0.1656). No causality is detected in mean from Russia at higher lags, while mature markets have causality to Russia at lag 1 and even higher. However, the magnitude of this causality is much smaller compared to a contemporaneous one (similar to Wang and Firth, 2004; Singh, *et al.*, 2010).

Changes between Russia and mature markets due to the adjustment for oil price returns demonstrate no pronounced results. A small rise in contemporaneous causality from Russia to the US (+1.63%) and a decrease in causality from mature markets to Russia are mainly at higher lags. (– SP) is confirmed on percentage change at a contemporaneous term between RU-JP and from US, while changes at higher lags causality-in-mean are confirmed by negative SP at lag 3 from France.

Russia has a much smaller contemporaneous bi-directional causality-in-variance with mature markets compared to Brazil. The maximum level detected is in the lag 1 relationship with the US (0.1131). This could be explained by the regional proximity and the time zone factors, as pointed out by Gjerde and Sættem (1995), since Brazil has a trading time that overlaps trading times of both the US and the EU markets, while Russia overlaps only the EU markets.

Table 7.3-11
CCF Cheung and Ng (1996) mean and variance causality
for Russia with mature markets and oil price.

Pair X - Y	Lead						Lag					
	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
Panel A. Causality-in-mean, (no adjustment for oil)												
RU - JP					0.1191	NA	0.1498					
RU - GE						0.2716	0.2716	0.0642				
RU - FR						0.2791	0.2791	0.0672				
RU - US						0.1656	NA	0.2263		0.0411		
Panel B. Causality-in-mean, (adjustment for oil price)												
RU - JP					<1% ^{-SP}	NA	-2.4% ^{-SP}					
RU - GE						<1%	<1%	-3.89%				
RU - FR						>-1%	>-1%	-4.76%		{-SP}		
RU - US						1.63%	NA	-1.5% ^{-SP}		1.95%		

Notes: The Cheung and Ng (1996) CCF causality test performed on s-statistics for each lag using χ^2 distribution at 1 degree of freedom for 5% level of significance critical value (3.8414). The negative lag represents causality from X to Y, the positive lags represent causality from Y to X. Panel A is estimated using standardized residuals obtained from model (14) for examining causality in mean between Russia and countries with mature stock markets. Panel B is estimated using standardized residuals obtained from model (20), and represented as the percentage change in magnitude of the significant parameters found in panel A after adjustment for the oil price.

Pair X - Y	Lead						Lag					
	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
Panel C. Causality-in-variance, (no adjustment for oil)												
RU - JP					0.0536	NA						
RU - GE						0.0727	0.0727		0.0506	0.0425		0.0533
RU - FR						0.0473	0.0473		0.0501			0.0421
RU - US						0.0606	NA	0.1131				
Panel D. Causality-in-variance, (adjustment for oil price)												
RU - JP					1.12%	NA	{-SP}					
RU - GE						-3.3%	-3.3%		-5.93%	{+SP}		-2.81%
RU - FR						2.96%	2.96%		<1%	{+SP}		-4.28% ^{-SP}
RU - US						{-SP}	-6.6%	NA	-3.45%			

Notes: The values displayed in Panels C and D are the cross correlation function estimated using squared standardized residuals and found to be significant at 5% in s-statistics, as suggested by Cheung and Ng (1996). The test is performed for each lag using χ^2 distribution at 1 degree of freedom for the 5% level of significance critical value (3.8414). The negative lags in a title represent causality from X to Y, positive lags represent causality from Y to X. Panel C is estimated using squared standardized residuals obtained from model (14) for examining causality in variance between Russia and mature markets. Panel D is estimated using squared standardized residuals obtained from model (20) for examining the percentage changes in magnitude of variance causality after adjustment for the oil price. Squared standardized residuals are obtained from models (14) and (20) and adjusted for the causality in mean (if it exists) from the minimum allowed lag to the maximum detected lag using the Cheung and Ng (1996) and Gebka and Serwa (2007) adjustments. For example, Japan causes Russia at lag 0 (0.1498). Knowing that the minimum possible lag in this causality structure is 0 (Japan can affect Russia on the same day) and the maximum detected lag is 0, it is possible to construct an augmented model from model (14) to obtain squared standardized residuals adjusted for the causality in mean from Japan at lag 0. Knowing the optimal m , n , p and q parameters, it is possible to estimated the model (14) with a conditional mean equation replaced by the following formula:

$$RU_t = \alpha_0 + \sum_{g=0}^0 \lambda_g JP_{t-g} + \sum_{z=1}^m \alpha_z RU_{t-z} + \sum_{s=1}^n \phi_s \zeta_{t-s} + \zeta_t.$$

After the estimation of the given mean-adjusting EGARCH model, the residuals are saved and used to detect causality in variance. Thus, if causality in mean is detected for both cases (1. Russia to Japan; 2. Japan to Russia), then, in order to find variance causality for both cases, it is necessary to obtain mean adjusted squared standardized residuals from each of them and then perform the CCF Cheung and Ng (1996) test. Similar adjustment is performed for panel D, if in the corresponding row in panel B the mean causality is detected. The changes in magnitude of the cross-correlation coefficient in a range from -1 to 0 is marked by ">-1", while the range 0 to 1 is marked by "<1%". Mark ^{+SP} and ^{-SP} represent a prevalence of the positive and negative sign in the percentage change after adjustment for the oil price. SP is collected from the same pairs of countries located in Table A.4-1 for the changes in magnitude of the causality-in-mean (for the Panel B of the current table) and in Table A.4-2 for the changes in magnitude of the causality-in-variance (for the Panel D of the current table).

Changes in variance causality due to the oil price adjustment demonstrate a mixed causality pattern, basically at higher lags from mature markets and with the contemporaneous term found to be negative from DI side (except RU-FR case). The only case where SP coincides with the sign of the full sample estimation is found in RU to FR at lag 5. Other cases are not confirmed with the full sample estimation, but the sign prevalence does exist there. For example: (-SP) is found in a percentage change of the causality-in-variance for JP at lag 0 and from RU to US at lag 3 with negative sign, and (+SP) is found from GE and FR at lag 3.

As a conclusion on the discussed countries, it is, arguably, possible to state that adjustment for the oil price induces a decrease in contemporaneous causality-in-mean from the DI side, except in the case of Germany. Similar to the oil price effect on causality-in-mean, in causality-in-variance the oil price adjustment led to decrease in the contemporaneous term from importers side, except in the case of France.

Emerging Importer (EI) vs. Developed Importer (DI).

Causal linkages between India and developed oil importers. India has stronger contemporaneous relations with mature markets compared to Russia. Interestingly, causality at lag 1 from mature markets to India is still high for the EU countries spreading from (0.1) for France to (0.1216) for Germany. The contemporaneous relationship with the US is much smaller in the corresponding lag 0 (0.0816) from India to the US and in lag 1 and 2 (0.157 and 0.0533) from the US to India, confirming that the US has a stronger effect on India from the previous day compared to the Indian current day effect.

The change in relationship with Japan is found to be positive in the contemporaneous term and at lag 1 from India. Moreover, (+SP) is confirmed at contemporaneous term which demonstrates greater evidence of positive change in magnitude after adjustment for the oil price. Adjustment for the oil price led to small changes in the relationship between India and Germany, which are negative at lag 0 and 3 and positive at lag 1. The decrease in magnitude for all detected lags is found for the relationship with France. In contrast, the adjustment for oil price negatively affects the relationship with the US and the decrease is stronger for higher lags and positive for lag 2 in causality-in-mean from India to the US (3.73%). Existence of the SP only in case of India-Japan relationship may demonstrate that India is more likely to have strong regional linkages.

The causality in variance between India and mature markets is mostly smaller compared to Brazil and Russia, confirming the above mentioned supposition that the regional proximity and time zone are significant factors in causality, especially in variance.

Table 7.3-12
CCF Cheung and Ng (1996) mean and variance causality
for India with mature markets and oil price.

Pair	Lead						Lag						
X - Y	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5	
	Panel A. Causality-in-mean, (no adjustment for oil)												
IN - JP				0.0696	0.1719	0.1719							
IN - GE					0.1505	0.1505	0.1216			0.0637			
IN - FR					0.1709	0.1709	0.1	0.0428	0.0619				
IN - US				0.0482		0.0816	NA	0.157	0.0533	0.0685	0.0402		
	Panel B. Causality-in-mean, (adjustment for oil price)												
IN - JP				<1%	<1% ^{+SP}	<1% ^{+SP}							
IN - GE					>-1%	>-1%	<1%			>-1%			
IN - FR					>-1%	>-1%	>-1%	>-1%	>-1%	>-1%			
IN - US				3.73%		>-1%	NA	>-1%	-3.56%	<1%	-4.98%		

Notes: The Cheung and Ng (1996) CCF causality test performed on s-statistics for each lag using χ^2 distribution at 1 degree of freedom for the 5% level of significance critical value (3.8414). The negative lag represents causality from X to Y, positive lags represent causality from Y to X. Panel A is estimated using standardized residuals obtained from model (14) for examining causality in mean between India and countries with mature stock markets. Panel B is estimated using standardized residuals obtained from model (20), and represented as the percentage change in magnitude of the significant parameters found in panel A after adjustment for the oil price.

Pair	Lead						Lag						
X - Y	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5	
	Panel C. Causality-in-variance, (no adjustment for oil)												
IN - JP	0.1239												
IN - GE	0.043						0.0641	0.0409					
IN - FR	0.0803							0.0654					
IN - US	0.0561						NA	0.0474	0.0361				
	Panel D. Causality-in-variance, (adjustment for oil price)												
IN - JP	1.21% ^{-SP}												
IN - GE	-1.16%						-1.09%	>-1%	{-SP}				
IN - FR	>-1%							1.38%					
IN - US	-29.06%						NA	2.11%	3.6%				

Notes: The values displayed in Panels C and D are the cross correlation function estimated using squared standardized residuals and found to be significant at 5% in s-statistics, as suggested by Cheung and Ng (1996). The test is performed for each lag using χ^2 distribution at 1 degree of freedom for the 5% level of significance critical value (3.8414). The negative lags in a title represent causality from X to Y, positive lags represent causality from Y to X. Panel C is estimated using squared standardized residuals obtained from model (14) for examining causality in variance between India and mature markets. Panel D is estimated using squared standardized residuals obtained from model (20) for examining the percentage changes in magnitude of variance causality after an adjustment for the oil price. Squared standardized residuals are obtained from models (14) and (20) and adjusted for the causality in mean (if it exists) from the minimum allowed lag to the maximum detected lag using the Cheung and Ng (1996) and Gebka and Serwa (2007) adjustments. For example, India causes Japan at lag 0 (0.1719), lag 1(0.0696). Knowing that the minimum possible lag in this causality structure is 0 (India can affect Japan on the same day) and the maximum detected lag is 1, it is possible to construct an augmented model from model (14) to obtain squared standardized residuals adjusted for the causality in mean from India at lag 0-1. Knowing the optimal m , n , p and q parameters, it is possible to estimated model (14) with a conditional mean equation replaced by the following formula:

$$JP_t = \alpha_0 + \sum_{g=0}^1 \lambda_g IN_{t-g} + \sum_{z=1}^m \alpha_z JP_{t-z} + \sum_{s=1}^n \phi_s \zeta_{t-s} + \zeta_t.$$

After the estimation of the given mean-adjusting EGARCH model, the residuals are saved and used to detect causality in variance. Thus, if causality in mean is detected for both cases (1. India to Japan; 2. Japan to India), then, in order to find variance causality for both cases, it is necessary to obtain mean adjusted squared standardized residuals from each of them and then perform the CCF Cheung and Ng (1996) test. Similar adjustment is performed for panel D, if in the corresponding row in panel B the mean causality is detected. The changes in magnitude of the cross-correlation coefficient in a range from -1 to 0 is marked by ">-1", while the range 0 to 1 is marked by "<1%". Mark ^{+SP} and ^{-SP} represents a prevalence of the positive and negative sign in percentage change after adjustment for the oil price. SP is collected from the same pairs of countries located in Table A.4-1 for the changes in magnitude of the causality-in-mean (for the Panel B of the current table) and in Table A.4-2 for the changes in magnitude of the causality-in-variance (for the Panel D of the current table).

Table 7.3-13
CCF Cheung and Ng (1996) mean and variance causality
for China with mature markets and oil price.

Pair X - Y	Lead						Lag					
	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
Panel A. Causality-in-mean, (no adjustment for oil)												
CH - JP						0.0591	0.0591	0.0372	-0.036			
CH - GE							NA	0.0621			0.0416	
CH - FR							NA	0.0521			0.0456	
CH - US		-0.0388					NA	0.0451			0.0378	
Panel B. Causality-in-mean, (adjustment for oil price)												
CH - JP						0% ^{-SP}	0% ^{-SP}	2.42% ^{-SP}				
CH - GE							NA	>-1%			<1%	
CH - FR							NA	>-1% ^{-SP}			1.31%	
CH - US		-3.6%					NA	2.66%			-1.58%	

Notes: The Cheung and Ng (1996) CCF causality test performed on s-statistics for each lag using χ^2 distribution at 1 degree of freedom for the 5% level of significance critical value (3.8414). The negative lag represents causality from X to Y, positive lags represent causality from Y to X. Panel A is estimated using standardized residuals obtained from model (14) for examining causality in mean between China and countries with mature stock markets. Panel B is estimated using standardized residuals obtained from model (20), and represented as the percentage change in magnitude of the significant parameters found in panel A after adjustment for the oil price.

Pair X - Y	Lead						Lag					
	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
Panel C. Causality-in-variance, (no adjustment for oil)												
CH - JP												
CH - GE	0.0482						NA					
CH - FR		0.046					NA					
CH - US		0.0852				0.0963	NA					
Panel D. Causality-in-variance, (adjustment for oil price)												
CH - JP												
CH - GE	-1.87% ^{-SP}						NA				{+SP}	
CH - FR		>-1% ^{-SP}					NA					
CH - US		8.57%				-10.18%	NA					

Notes: The values displayed in Panels C and D are the cross correlation function estimated using squared standardized residuals and found to be significant at 5% in s-statistics, as suggested by Cheung and Ng (1996). The test is performed for each lag using χ^2 distribution at 1 degree of freedom for the 5% level of significance critical value (3.8414). The negative lags in a title represent causality from X to Y, the positive lags represent causality from Y to X. Panel C is estimated using squared standardized residuals obtained from model (14) for examining causality in variance between China and mature markets. Panel D is estimated using squared standardized residuals obtained from model (20) for examining the percentage changes in magnitude of variance causality after adjustment for the oil price. Squared standardized residuals are obtained from models (14) and (20) and adjusted for the causality in mean (if it exists) from the minimum allowed lag to the maximum detected lag using the Cheung and Ng (1996) and Gebka and Serwa (2007) adjustments. For example, Japan causes China at lag 0 (0.0591), lag 1 (0.0372), lag 2 (-0.036). Knowing that the minimum possible lag in this causality structure is 0 (Japan can affect China on the same day) and the maximum detected lag is 2, it is possible to construct an augmented model from model (14) to obtain squared standardized residuals adjusted for the causality in mean from Japan at lag 0-2. Knowing the optimal m , n , p and q parameters, it is possible to estimated model (14) with a conditional mean equation replaced by the following formula:

$$CH_t = \alpha_0 + \sum_{g=0}^2 \lambda_g JP_{t-g} + \sum_{z=1}^m \alpha_z CH_{t-z} + \sum_{s=1}^n \varphi_s \zeta_{t-s} + \zeta_t.$$

After the estimation of the given mean-adjusting EGARCH model, the residuals are saved and used to detect causality in variance. Thus, if causality in mean is detected for both cases (1. China to Japan; 2. Japan to China), then, in order to find variance causality for both cases, it is necessary to obtain the mean adjusted squared standardized residuals from each of them and then perform the CCF Cheung and Ng (1996) test. Similar adjustment is performed for panel D, if in the corresponding row in panel B mean causality is detected. The changes in magnitude of the cross-correlation coefficient in a range from -1 to 0 is marked by ">-1", while the range 0 to 1 is marked by "<1%". Mark ^{+SP} and ^{-SP} represents a prevalence of the positive and negative sign in percentage change after adjustment for the oil price. SP is collected from the same pairs of countries located in Table A.4-1 for the changes in magnitude of the causality-in-mean (for the Panel B of the current table) and in Table A.4-2 for the changes in magnitude of the causality-in-variance (for the Panel D of the current table).

It is also interesting that, except in the two cases (lag 2 from India to Japan and lag 5 from US to India), the variance causality is totally bidirectional mostly at lag 1.

After the adjustment for the oil price, the magnitude of causality in variance from India to the German, French and US markets is reduced at lags 0 and 1. A perceptible fall is detected in causality from India to the US (-29.06%) and from India to France (-0.75%). A slight increase in causality from India to Japan and from the US and France to India at lag above 0 is also found. The results of full sample estimation are arguable when compared with SP, since none of the percentage changes are found to be stable in sign. Despite this SP is found at lag 3 from Germany and lag 1 from India to Japan. SP at lag 1 from Japan also demonstrates that India causes mature markets, usually at lag 1 and CCF coefficients falls in response to the oil price.

Causal linkages between China and developed oil importers. In Table 7.3-13 it was shown that China does not affect other countries in terms of mean causality with exception of the China to the US (-0.0388) case and a single contemporaneous causality is detected in the relationship with Japan.

Germany, France and the US affected China from the previous day and simultaneously at lag 4 with an approximately similar magnitude of correlation. Small changes in mean causality are detected from Germany to China at lags 1 and 4. As for the US, the oscillation is found between lag 1 and lag 4 causality in relation to China. A rise of correlation in direction from France to China at lag 4 (+1.31%) is also found. Negative SP is found at lag 1 from Japan and France, which contradicts the positive sign of a percentage change in CCF in the full sample estimation. Therefore, at lag 1 only the US to China direction has a positive change in response to oil price adjustment.

No causality in variance is detected from mature markets to China (except positive SP found at lag 4 from Germany to China), while China causes Germany, France and the US at higher lags.

The comparison of the detected linkages with oil price adjusted ones demonstrates significant changes in variance causality. The maximum magnitude of change in absolute term is detected in contemporaneous causality from China (-10.18%) and at lag 4 from China to the US (+8.57%). Noticeable changes are also found in causality from China to Germany at lag 5 (-1.87%) and from China to France (-0.65%) with a corresponding SP confirmation.

To summarise the findings on oil price impact of the relations of India and China with the Developed oil Importers, it possible to state that oil price negatively affects contemporaneous mean causality (except IN-JP, CH-US cases), which for China is true for the DI side only. However, due to the lack of confirmed relationships observed in China's case it is hardly possible to come to a conclusion on the variance causality response. Therefore, further research is needed.

Table 7.3-14

Summary of mean causality changes for BRIC countries and mature markets oil importers¹⁰⁸.

Self			Importer	Exporter			Importer	Importer			Importer	Importer			Importer
Brazil	↑↓ ^{SP} →	←↓↑	Japan	Russia	↓ ^{SP} →	←↓ ^{SP}	Japan	India	↑↑ ^{SP} →	←↑ ^{SP}	Japan	China	→	←↓ ^{SP}	Japan
Brazil	↓↑→	←↑↓	Germany	Russia	↑→	←↑↓	Germany	India	↓→	←↓↑	Germany	China	→	←↓↑	Germany
Brazil	↓↓ ^{SP} →	←↓ ^{SP}	France	Russia	↓→	←↓↓	France	India	↓→	←↓↓	France	China	→	←↓ ^{SP} ↑	France
Brazil	↓→	←↓ ^{SP}	US	Russia	↑→	←↓ ^{SP} ↑	US	India	↑↓→	←↓↓	US	China	↓→	←↑↓	US

Note: The sign of the percentage change of the CCF coefficients are represented by arrows. Upward (Downward) arrows represent increase (decrease) in CCF coefficient when the oil price adjustment is applied. Lined and dashed arrows represent the location of the CCF coefficients, contemporaneous and higher lags respectively. (SP) mark located near the arrow demonstrates that sign of the percentage change of CCF coefficient is confirmed to be stable in rolling window method.

Table 7.3-15

Summary of variance causality changes for BRIC countries and mature markets oil importers.

Self			Importer	Exporter			Importer	Importer			Importer	Importer			Importer
Brazil	↓↓→		Japan	Russia	↑→	←↓ ^{SP}	Japan	India	↓ ^{SP} →		Japan	China			Japan
Brazil	↑ ^{SP} ↑→	←↑↓	Germany	Russia	↓→	←↓↓	Germany	India	↓↓→	←↓↓	Germany	China	↓ ^{SP} →	←↑ ^{SP}	Germany
Brazil	↓↑→	←↑	France	Russia	↑→	←↑↑	France	India	↓→	←↑	France	China	↓ ^{SP} →		France
Brazil	↑↑→	←↑↑	US	Russia	↓ ^{SP} ↓→	←↓	US	India	↓→	←↑↑	US	China	↑↓→		US

Note: The sign of the percentage change of the CCF coefficients are represented by arrows. Upward (Downward) arrows represent increase (decrease) in CCF coefficient when the oil price adjustment is applied. Lined and dashed arrows represent the location of the CCF coefficients, contemporaneous and higher lags respectively. (SP) mark located near the arrow demonstrates that sign of the percentage change of CCF coefficient is confirmed to be stable in rolling window method.

7.3.8. Linkages among the mature markets with and without oil price adjustment.

In this section the oil price effect on cross-market interaction of developed markets is observed. Developed markets are represented by two types of countries: Developed oil Self-sufficient (DS) and Developed Importer (DI). Therefore, as it is suggested in the paired groupings provided in Section 7.3.2, it is possible to observe the following types of countries' pairs:

- Developed Self-Sufficient (DS) vs. Developed Importer (DI);
- Developed Importer (DI) vs. Developed Importer (DI).

To start the discussion on each type of pair, first the results of developed markets are examined as a whole.

Panel A of Table 7.3-16 demonstrates a high magnitude of contemporaneous correlation among major countries, especially for indices with overlaps of the following pairs: FR-GE: 0.7851; UK-GE: 0.6677; UK-FR: 0.7266; US-GE: 0.4671; US-FR: 0.4592; US-UK: 0.4388; UK-JP: 0.212. It is a noticeable fact, that correlation at lag 1 is significantly lower, at the same time, the magnitude is higher for mean causality from US to other countries (US-GE: 0.2554; US-FR: 0.2549; US-UK: 0.2651), which

¹⁰⁸ Note that description from Table 7.3-14 and Table 7.3-15 is omitted to save space.

may indicate that US innovations are strong even on the next trading day. These findings are in line with a study by Singh, *et al.* (2010), where lag 0 relations were found to have higher magnitude and were more frequently found to be significant. The higher lag CCFs are difficult to interpret, since the multiple causalities are found with a low magnitude, different sign and without a prominent pattern. One point, however, should be noted, the European countries are likely to have higher lags (above 1) causalities among each other.

Table 7.3-16
CCF Cheung and Ng (1996) mean and variance causality
among mature markets and the oil price.

Pair	Lead						Lag						
X - Y	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5	
Panel A. Causality-in-mean, (no adjustment for oil)													
GE - JP	-0.0565			0.2233	NA	0.2324			-0.0399				
FR - JP			0.039	0.237	NA	0.2304	-0.0408	-0.0443					
FR - GE				0.0588	0.7851	0.7851	0.0363	-0.0399	-0.048				
UK - JP				0.212	NA	0.2304							
UK - GE				0.0403	0.6677	0.6677				-0.0369	0.0419		
UK - FR			-0.0363		0.7266	0.7266					0.0378		
US - JP			0.0592	0.315	NA	0.0974	-0.037						
US - GE				0.2554	0.4671	0.4671							
US - FR				0.2549	0.4592	0.4592	0.0475						
US - UK				0.2651	0.4388	0.4388						-0.0493	
Panel B. Causality-in-mean, (adjustment for the oil price)													
GE - JP	<1%			>-1% ^{-SP}	NA	>-1%			-1%				
FR - JP			-3.33%	>-1% ^{-SP}	NA	-1.17% ^{-SP}	6.37% ^{+SP}	>-1% ^{-SP}					
FR - GE				-2.55%	>-1%	>-1%	^{-SP}	-1.25%	<1%				
UK - JP				>-1% ^{-SP}	NA	>-1% ^{-SP}							
UK - GE				-2.98%	<1%	<1%	^{-SP}			2.44%	-2.39%		
UK - FR			-1.93%		>-1% ^{-SP}	>-1% ^{-SP}	^{-SP}				-1.59%		
US - JP			-1.86%	-1.11% ^{-SP}	NA	>-1%	<1%						
US - GE				<1%	<1%	<1%							
US - FR				-2.47% ^{-SP}	<1%	<1%	3.58%						
US - UK				-1.21% ^{-SP}	<1%	<1%						>-1%	

Notes: The Cheung and Ng (1996) CCF causality test performed on s-statistics for each lag using χ^2 distribution at 1 degree of freedom for the 5% level of significance critical value (3.8414). The negative lags represents causality from X to Y, positive lags represent causality from Y to X. Panel A is estimated using standardized residuals obtained from model (14) for examining causality in mean among countries with mature stock markets. Panel B is estimated using standardized residuals obtained from model (20), and represented as the percentage change in magnitude of the significant parameters found in panel A after adjustment for the oil price.

change in magnitude of the significant parameters found in panel A after adjustment for the oil price.													
Pair	Lead						Lag						
X - Y	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5	
Panel C. Causality-in-variance, (no adjustment for oil)													
GE - JP				0.0412	NA	0.0563							
FR - JP				0.062	NA	0.0601							
FR - GE				0.0683	0.8614	0.8614	0.0938	0.0406			0.0451		
UK - JP		0.0528		0.0725	NA								
UK - GE					0.4887	0.4887	0.0373			-0.049			
UK - FR				0.0571		0.6771	0.6771	0.0435	0.0748				
US - JP	0.0611					NA							
US - GE				0.0386	0.1119	0.2156	0.2156	0.0384				0.1288	
US - FR				0.0575	0.0413	0.2225	0.2225					0.0822	
US - UK						0.2101	0.2101		0.0516			0.0859	

Table 7.3-16 continues on the next page.

Table 7.3-16 continuation.

Panel D. Causality-in-variance, (adjustment for the oil price)							
GE - JP		>-1% ^{-SP}	NA	-1.78%			
FR - JP		-7.9% ^{-SP}	NA	-9.65% ^{-SP}			
FR - GE		-4.83% ^{-SP}	>-1%	-36.78%	-3.94% ^{-SP}		5.32% ^{-SP}
UK - JP	-1.89% ^{-SP} ^{-SP}	-7.59% ^{-SP}	NA				
UK - GE		<1% ^{+SP}	<1% ^{+SP}	1.61% ^{-SP}		-2.24% ^{-SP}	
UK - FR		-23.29%	1.62%	1.62%		-17.65%	
US - JP	-5.73%	^{+SP}	NA				
US - GE		3.11%	-5.45%	-3.2% ^{-SP}	-3.2% ^{-SP}		-1.79%
US - FR		<1%	-10.41%	<1% ^{-SP}	<1% ^{-SP}		<1%
US - UK			-1.95%	-1.95%		2.71% ^{-SP}	5.24%

Notes: The values displayed in Panels C and D are the cross correlation function estimated using squared standardized residuals and found to be significant at 5% in s-statistics, as suggested by Cheung and Ng (1996). The test is performed for each lag using χ^2 distribution at 1 degree of freedom for the 5% level of significance critical value (3.8414). The negative lags in a title represent causality from X to Y, positive lags represent causality from Y to X. Panel C is estimated using squared standardized residuals obtained from model (14) for examining causality in variance among mature markets. Panel D is estimated using squared standardized residuals obtained from model (20) for examining the percentage changes in magnitude of variance causality after adjustment for the oil price. Squared standardized residuals are obtained from models (14) and (20) and adjusted for the causality in mean (if it exists) from the minimum allowed lag to the maximum detected lag using Cheung and Ng (1996) and Gebka and Serwa (2007) adjustments. For example, Japan causes Germany at lag 0 (0.2324), lag 2 (-0.0399). Knowing that the minimum possible lag in this causality structure is 0 (Japan can affect Germany on the same day) and the maximum detected lag is 2, it is possible to construct an augmented model from model (14) to obtain squared standardized residuals adjusted for the causality in mean from Japan at lag 0-2. Knowing the optimal m , n , p and q parameters, it is possible to estimate model (14) with a conditional mean equation replaced by the following formula:

$$GE_t = \alpha_0 + \sum_{g=0}^2 \lambda_g J P_{t-g} + \sum_{z=1}^m \alpha_z GE_{t-z} + \sum_{s=1}^n \varphi_s \zeta_{t-s} + \zeta_t.$$

After the estimation of the given mean-adjusting EGARCH model, the residuals are saved and used to detect causality in variance. Thus, if causality in mean is detected for both cases (1. Germany to Japan; 2. Japan to Germany), then, in order to find variance causality for both cases, it is necessary to obtain mean adjusted squared standardized residuals from each of them and then perform the CCF Cheung and Ng (1996) test. Similar adjustment is performed for panel D, if in the corresponding row in panel B mean causality is detected. The changes in magnitude of the cross-correlation coefficient in a range from -1 to 0 is marked by ">-1", while the range 0 to 1 is marked by "<1%". Mark ^{+SP} and ^{-SP} represents a prevalence of the positive and negative sign in the percentage change after adjustment for the oil price. SP is collected from the same pairs of countries located in Table A.4-1 for the changes in magnitude of the causality-in-mean (for the Panel B of the current table) and in Table A.4-2 for the changes in magnitude of the causality-in-variance (for the Panel D of the current table).

Adjustment for the oil price (Panel B of Table 7.3-16) demonstrates small changes in magnitude in all cases at lag 0 and 1 (except: a fall at lag 1 from UK to Germany (-2.98%); an increase at lag 1 from France to US (3.58%), may also be treated as insignificant distortion. The SP sign when found conforms to the results of the full sample estimation. Additional SP is detected from Germany to France at lag 1 with a negative sign.

Similar to mean causality, the lead-lag relationship in variance has a high magnitude in contemporaneous terms and the existence of causalities at higher lags, which demonstrates an existence of multiple interactions between developed countries' stock markets.

However, the change in variance causality is more prominent, since the countries either don't have a relationship, or a decreasing relationship, which could be arguably be ascribed to a decrease in volatility. And the pairs, which are likely to have the absence of changes in causality relation, contain the Japanese stock market. The overall conclusion is a possibility to decrease the magnitude of the variance causality, when the oil price is included during the filtering procedure in the conditional mean equation of model (20).

There are also patterns found in the distribution of the SP pattern on the lag structure of causal interaction between indices in variance. Almost all confirmed the SP changes in variance causality are negative (except contemporaneous cases from US to JP and from UK to GE). The (-SP) in contemporaneous term is likely to appear in pairs of indices with US participation. However, interactions inside the EU are likely to have (-SP) at higher lags (see cases: FR-GE, UK-GE with exception to UK-FR).

By examining Table 7.3-16, Table 7.3-17 and Table 7.3-18 it is possible to highlight the following relationships regarding two types of country pairs:

Developed Self-Sufficient (DS) vs. Developed Importer (DI).

For the oil price effect on the UK mean causal relationships with other developed countries, it is possible to state that the magnitude of the CCF coefficient in both directions of higher lag causality-in-mean is decreased (except in the case of UK-JP).

In the case of causality-in-variance, the decrease in the CCF coefficients is detected at higher lag causality, from the DS side, with the exception of UK-GE.

Developed Importer (DI) vs. Developed Importer (DI).

The negative effect of the oil price on causality-in-mean of the Developed Importers is confirmed for all pairs except US-France and US-Germany, where the contemporaneous causality is raised in magnitude. However, the percentage change is mainly less than 1% in absolute terms. At lag 0, the conclusion is comparable to Emerging Importer- Emerging Importer case discussed in Section 7.3.5, where the decrease in contemporaneous mean causality was also detected.

The causality-in-variance demonstrates a decrease in magnitude of CCF coefficients or no response, except in the US-JP case where an increase was detected in SP.

The overall conclusion is that not all patterns of linkages of the mature market responses to the oil price are similar to those of the BRIC, but the response to the oil price is mainly traceable in pairs with identical economic profiles and the idea of the complementary effect on the magnitude of cross-market linkage seems to be viable. Therefore, controlling for the oil price induces the magnitude of cross-market linkage to decrease.

Table 7.3-17

Changes in mean causality among major countries
due to the adjustment for the oil price.

Causality in mean				Explanation
Self -sufficient			Importer	
UK	$\downarrow^{SP} \rightarrow$	$\leftarrow \downarrow^{SP}$	JP	Decrease at higher lag from both sides (except UK-JP)
UK	$\downarrow \uparrow \rightarrow$	$\leftarrow \uparrow \downarrow^{SP}$	GE	
UK	$\downarrow \downarrow^{SP} \rightarrow$	$\leftarrow \downarrow^{SP} \downarrow^{SP}$	FR	
UK	$\downarrow \uparrow \rightarrow$	$\leftarrow \uparrow \downarrow^{SP}$	US	
Importer			Importer	
GE	$\downarrow^{SP} \rightarrow$	$\leftarrow \downarrow \downarrow$	JP	Decrease in contemporaneous mean (except US-GE, US-FR), but percentage change is under 1% in absolute terms (except FR-JP, US-JP).
FR	$\downarrow \downarrow^{SP} \rightarrow$	$\leftarrow \downarrow^{SP} \uparrow^{SP}$	JP	
FR	$\downarrow \downarrow \rightarrow$	$\leftarrow \downarrow \downarrow^{SP}$	GE	
US	$\downarrow \downarrow^{SP} \rightarrow$	$\leftarrow \downarrow \uparrow$	JP	
US	$\uparrow \uparrow \rightarrow$	$\leftarrow \uparrow$	GE	
US	$\downarrow^{SP} \uparrow \rightarrow$	$\leftarrow \uparrow \uparrow$	FR	
Note: The sign of the percentage change of the CCF coefficients are represented by arrows. Upward (Downward) arrows represent increase (decrease) in CCF coefficient when the oil price adjustment is applied. Lined and dashed arrows represent the location of the CCF coefficients, contemporaneous and higher lags respectively. (SP) mark located near the arrow demonstrates that the sign of the percentage change of CCF coefficient is confirmed to be stable in the rolling window method.				

Table 7.3-18

Changes in variance causality among major countries
due to the adjustment for the oil price.

Causality in variance				Explanation
Self sufficient			Importer	
UK	$\downarrow^{SP} \downarrow^{SP} \rightarrow$	$\leftarrow$	JP	Decrease at higher lag from DS side (except GE)
UK	$\uparrow^{SP} \rightarrow$	$\leftarrow \uparrow^{SP} \downarrow^{SP}$	GE	
UK	$\downarrow \uparrow \rightarrow$	$\leftarrow \uparrow \downarrow$	FR	
UK	$\downarrow^{SP} \downarrow \rightarrow$	$\leftarrow \downarrow$	US	
Importer			Importer	
GE	$\downarrow^{SP} \rightarrow$	$\leftarrow \downarrow$	JP	Decrease or no change in variance (except US-JP in contemporaneous term and US-FR at a higher lag).
FR	$\downarrow^{SP} \rightarrow$	$\leftarrow \downarrow^{SP}$	JP	
FR	$\downarrow^{SP} \downarrow \rightarrow$	$\leftarrow \downarrow \downarrow$	GE	
US	$\downarrow \uparrow^{SP} \rightarrow$	$\leftarrow$	JP	
US	$\downarrow \downarrow^{SP} \rightarrow$	$\leftarrow \downarrow^{SP} \downarrow$	GE	
US	$\downarrow \downarrow^{SP} \rightarrow$	$\leftarrow \downarrow^{SP} \uparrow$	FR	
Note: The sign of the percentage change of the CCF coefficients are represented by arrows. Upward (Downward) arrows represent increase (decrease) in CCF coefficient when the oil price adjustment is applied. Lined and dashed arrows represent the location of the CCF coefficients, contemporaneous and higher lags respectively. (SP) mark located near the arrow demonstrates that the sign of the percentage change of CCF coefficient is confirmed to be stable in the rolling window method.				

However, there isn't a comparable example of variance causality in EI-EI from the BRIC group, which is only represented by the China-India relationship. Therefore, it is only possible to rely on findings of mature market dependencies in variance, which shows no changes or decreasing effect on volatility when the oil price is included in the model (except US-JP case in contemporaneous term).

7.4. Application of EGARCH for causality testing

7.4.1. Full sample and rolling estimation with and without oil price adjustment.

Cheung and Ng (1996, p. 37) suggested a CCF GARCH test as a simple test before the implementation of the more complex models. Therefore, this section presents the results of causality testing in ARMA (m,n) -EGARCH (p,q) form (equations (21) and (22)), in the sense of Granger Causality (Granger, 1969) as suggested in Section 5.2.2.1. Since this thesis is interested in the existence of the causal linkage between indices, the outcome of both mean and variance causality is reported.

By suggesting a comparison¹⁰⁹ between results of non-causality hypotheses testing in models (21) and (22) it is assumed that adjustment for the oil price, applied as a common factor, will affect the rejection of the non-causality hypothesis performed on joint bases. Therefore, in Table 7.4-1 we focus on the differences between panel A and B for the mean causality relationship, and panel C and D for variance causality relationships.

Before explaining the results of the joint causality test it is important to note the following:

First, parameters m, n, p, q are obtained from the CCF test at models (14) and (20) used for the extraction of standardized residuals. The lags of counter index explanatory variable in models (21) and (22) start from minimum lag g in the mean equation and w in the variance equation, which are equal to time subscript $l_{X,Y}$ obtained from the non-synchronism correction matrix (Table 5.1-2), and a maximum lag c in mean equation and f in variance equation, which is equal to the maximum lag found to be significant in s -statistics of CCF GARCH causality test of the correspondent pair of indices in causality-in-mean and causality-in-variance respectively. In those cases where CCF GARCH test is not found, which means that any cross-correlations are insignificant in s -statistics, the EGARCH models (21) and (22) are not applied, since a lag where the causality can be tested is not suggested by the CCF GARCH causality test. Those cases in Table 7.4-1 are marked by "A".

¹⁰⁹ The equations output without oil price adjustment (Model (21)) and with oil price adjustment (Model (22)) are represented in Table A.5-1 and Table A.5-2 respectively (Appendix Section A.5). Note also that Table 7.4-1 results of the non-causality hypothesis testing performed on full sample estimation both in mean and in variance on the results of hypothesis testing performed on a joint test basis.

Second, note that some models do not achieve a convergence¹¹⁰. For those cases where convergence is not achieved, the non-causality hypothesis results are not reported and in Table 7.4-1 they are marked “B”.

Table 7.4-1

Causal linkages between stock market indices observed in mean and variance with and without oil price adjustments using ARMA (m,n) - EGARCH (p,q) model.

Panel A. Mean causality between indices, (no adjustment for oil)

	JP ^(DI)	CH ^(EI)	IN ^(EI)	RU ^(EE)	GE ^(DI)	FR ^(DI)	UK ^(DS)	BR ^(ES)	US ^(DI)	OIL
JP ^(DI)		CH → JP** C1-C2	IN → JP** C1	RU → JP** C1-C2	GE → JP** C1	FR → JP** C1	UK → JP** C1	BR → JP** C1	US → JP** C1	OIL → JP C4-C3
CH ^(EI)	JP → CH C2		IN → CH C2	RU → CH C2	GE → CH C2	FR → CH C2	UK → CH C2	BR → CH C2	US → CH C2	A C2
IN ^(EI)	JP → IN** C1	CH → IN** C3		RU → IN** C1	GE → IN** C1	FR → IN** C1	UK → IN** C1	BR → IN** C1-C2	US → IN** C1-C2	A C2
RU ^(EE)	JP → RU** C1-C2	CH → RU C2	IN → RU** C1-C2		B C4	FR → RU** C1	UK → RU** C1	BR → RU** C1	US → RU** C1	OIL → RU** C1-C2
GE ^(DI)	JP → GE** C1	CH → GE C2	IN → GE** C1	RU → GE** C1		FR → GE** C1	UK → GE** C1	BR → GE** C1	US → GE** C1	OIL → GE C2
FR ^(DI)	JP → FR** C1	CH → FR C2	IN → FR** C1	RU → FR** C1	GE → FR** C1		B C4	BR → FR** C1	US → FR** C1	OIL → FR C2
UK ^(DS)	JP → UK** C1	A C2	IN → UK** C1	RU → UK** C1	GE → UK** C1	FR → UK** C1		BR → UK** C1	US → UK** C1	OIL → UK** C1-C2
BR ^(ES)	JP → BR** C1-C2	CH → BR C2	IN → BR** C1-C2	RU → BR** C1	GE → BR** C1	FR → BR** C1	UK → BR** C1		US → BR** C1	B C2
US ^(DI)	JP → US** C1-C2	CH → US* C3	IN → US** C1-C2	RU → US** C1-C2	GE → US** C1	FR → US** C1	UK → US** C1	BR → US** C1		OIL → US C2
OIL	JP → OIL C2	A C2	IN → OIL C2	RU → OIL** C1-C2	GE → OIL C2	FR → OIL** C3	UK → OIL** C1-C2	BR → OIL* C3	US → OIL* C3	

Panel B. Mean causality between indices adjusted for the oil price, (adjustment for oil price)

	JP ^(DI)	CH ^(EI)	IN ^(EI)	RU ^(EE)	GE ^(DI)	FR ^(DI)	UK ^(DS)	BR ^(ES)	US ^(DI)	OIL
JP ^(DI)		CH → JP** C1-C2	IN → JP** C1	RU → JP** C1-C2	GE → JP** C1	FR → JP** C1	UK → JP** C1	BR → JP** C1	US → JP** C1	-
CH ^(EI)	JP → CH C2		B C2	RU → CH C2	GE → CH C2	FR → CH C2	UK → CH C2	BR → CH C2	US → CH C2	-
IN ^(EI)	JP → IN** C1	CH → IN** C3		RU → IN** C1	GE → IN** C1	FR → IN** C1	UK → IN** C1	BR → IN** C1-C2	US → IN** C1-C2	-
RU ^(EE)	JP → RU** C1-C2	CH → RU C2	IN → RU** C1-C2		GE → RU** C1	B C4	UK → RU** C1	BR → RU** C1	US → RU** C1	-
GE ^(DI)	JP → GE** C1	CH → GE C2	IN → GE** C1-C2	RU → GE** C1		FR → GE** C1	UK → GE** C1	BR → GE** C1	US → GE** C1	-
FR ^(DI)	JP → FR** C1	CH → FR C2	IN → FR** C1	RU → FR** C1	GE → FR** C1		UK → FR** C1	BR → FR** C1	US → FR** C1	-
UK ^(DS)	JP → UK** C1	A C2	IN → UK** C1	RU → UK** C1	GE → UK** C1	FR → UK** C1		BR → UK** C1	US → UK** C1	-
BR ^(ES)	JP → BR** C1-C2	CH → BR C2	IN → BR** C1-C2	RU → BR** C1	GE → BR** C1	FR → BR** C1	UK → BR** C1		US → BR** C1	-
US ^(DI)	JP → US** C1-C2	CH → US C2	IN → US** C1-C2	RU → US** C1-C2	GE → US** C1	FR → US** C1	UK → US** C1	BR → US** C1		-
OIL	-	-	-	-	-	-	-	-	-	

Table 7.4-1 continue on the next page

¹¹⁰ The calculation utilises “speed method” of estimation as suggested in Eviews 7 software ("Eviews 7. User's Guide II," pp. 753-755). Models in the “accurate method” of estimations are more frequently found to be converged. At the same time only results of the estimation in a “speed method” are reported due to the application of the rolling estimation for significance stability testing, which is extremely time consuming. However, estimation of the models (21) and (22) on a full sample basis and rolling estimation demonstrate similar results with insignificant divergence.

Table 7.4-1 continue

Panel C. Variance causality between indices, (no adjustment for oil)

	JP ^(DI)	CH ^(EI)	IN ^(EI)	RU ^(EE)	GE ^(DI)	FR ^(DI)	UK ^(DS)	BR ^(ES)	US ^(DI)	OIL
JP ^(DI)		CH -x-> JP C2	IN ->> JP** C1-C2	RU ->> JP** C1-C2	GE ->> JP** C3	FR ->> JP** C1-C2	UK ->> JP** C1-C2	BR ->> JP** C1-C2	US ->> JP** C1-C2	OIL -x-> JP C2
CH ^(EI)	JP -x-> CH C2		IN -x-> CH C2	RU -x-> CH C2	GE -x-> CH C2	FR -x-> CH C2	UK -x-> CH C2	BR ->> CH* C3	US -x-> CH C2	A C2
IN ^(EI)	JP -x-> IN C2	CH -x-> IN C2		RU -x-> IN C2	GE -x-> IN C2	FR -x-> IN C2	UK ->> IN* C3	BR -x-> IN C2	US -x-> IN C2	A C2
RU ^(EE)	JP -x-> RU C2	CH -x-> RU C2	IN -x-> RU C2		B C4-C3	FR ->> RU** C1-C2	UK ->> RU** C1-C2	BR ->> RU** C1-C2	US -x-> RU C2	OIL -x-> RU C2
GE ^(DI)	JP -x-> GE C2	CH -x-> GE C2	IN ->> GE* C3	RU -x-> GE C2		FR ->> GE** C1-C2	UK ->> GE** C1-C2	BR ->> GE** C1-C2	US ->> GE** C1-C2	OIL -x-> GE C2
FR ^(DI)	JP -x-> FR C2	CH ->> FR* C3	IN -x-> FR C2	RU -x-> FR C2	GE ->> FR** C1-C2		B C4-C2	BR ->> FR** C1-C2	US ->> FR** C1-C2	OIL -x-> FR C2
UK ^(DS)	JP -x-> UK C2	A C2	IN -x-> UK C2	RU -x-> UK C2	GE ->> UK** C1-C2	FR ->> UK** C1-C2		BR ->> UK** C1-C2	US ->> UK** C1-C2	OIL -x-> UK C2
BR ^(ES)	JP -x-> BR C2	CH -x-> BR C2	IN -x-> BR C2	RU ->> BR** C1-C2	GE ->> BR** C1-C2	FR ->> BR** C1-C2	UK ->> BR** C1-C2		US ->> BR** C1-C2	B C2
US ^(DI)	JP -x-> US C2	CH ->> US** C1-C2	IN ->> US* C3	RU ->> US* C1-C2	GE ->> US** C1-C2	FR ->> US** C1-C2	UK ->> US** C1-C2	BR ->> US** C1-C2		OIL -x-> US C2
OIL	JP -x-> OIL C2	A C2	IN -x-> OIL C2	RU -x-> OIL C2	GE ->> OIL* C1-C2	FR ->> OIL* C1-C2	UK -x-> OIL C4-C2	BR -x-> OIL C2	US -x-> OIL C2	

Panel D. Variance causality between indices adjusted for the oil price, (adjustment for oil price).

	JP ^(DI)	CH ^(EI)	IN ^(EI)	RU ^(EE)	GE ^(DI)	FR ^(DI)	UK ^(DS)	BR ^(ES)	US ^(DI)	OIL
JP ^(DI)		CH -x-> JP C2	IN ->> JP** C1-C2	RU ->> JP* C1-C2	GE ->> JP** C3	FR ->> JP** C1-C2	UK ->> JP** C1-C2	BR ->> JP** C1-C2	US ->> JP** C1-C2	-
CH ^(EI)	JP -x-> CH C2		B C2	RU -x-> CH C2	GE -x-> CH C2	FR -x-> CH C2	UK -x-> CH C2	BR ->> CH** C3	US -x-> CH C2	-
IN ^(EI)	JP -x-> IN C2	CH -x-> IN C2		RU ->> IN* C3	GE -x-> IN C2	FR -x-> IN C2	UK ->> IN** C3	BR -x-> IN C2	US -x-> IN C2	-
RU ^(EE)	JP -x-> RU C2	CH -x-> RU C2	IN -x-> RU C2		GE ->> RU** C1-C2	B C4-C3	UK ->> RU** C1-C2	BR ->> RU** C1-C2	US -x-> RU C2	-
GE ^(DI)	JP -x-> GE C2	CH -x-> GE C2	IN -x-> GE C2	RU -x-> GE C2		FR ->> GE** C1-C2	UK ->> GE** C1-C2	BR ->> GE** C1-C2	US ->> GE** C1-C2	-
FR ^(DI)	JP -x-> FR C2	CH ->> FR* C3	IN -x-> FR C2	RU -x-> FR C2	GE ->> FR** C1-C2		UK ->> FR** C1-C2	BR ->> FR** C1-C2	US ->> FR** C1-C2	-
UK ^(DS)	JP -x-> UK C2	A C2	IN ->> UK* C3	RU -x-> UK C2	GE ->> UK** C1-C2	FR ->> UK** C1-C2		BR ->> UK** C1-C2	US ->> UK** C1-C2	-
BR ^(ES)	JP -x-> BR C2	CH -x-> BR C2	IN -x-> BR C2	RU ->> BR** C1-C2	GE ->> BR** C1-C2	FR ->> BR** C1-C2	UK ->> BR** C1-C2		US ->> BR** C1-C2	-
US ^(DI)	JP -x-> US C2	CH ->> US** C1-C2	IN -x-> US C2	RU -x-> US C4-C2	GE ->> US** C1-C2	FR ->> US** C1-C2	UK ->> US** C1-C2	BR ->> US** C1-C2		-
OIL	-	-	-	-	-	-	-	-	-	

Notes: The Granger causality is tested using model (21) for the mean causality (Panel A) and variance causality (Panel C). The Granger causality tested in model (22), which includes oil returns added to the mean equation, is tested for mean causality (Panel B) and variance causality (Panel D). The test is performed using Granger (1969) testing procedure applied to the Wald test with $H_0: \lambda_0 = \lambda_1 = \dots = \lambda_g = 0$, to test causality in mean and $H_0: \mu_0 = \mu_1 = \dots = \mu_w = 0$, to test causality in variance. The minimum lag for the exogenous variable is determined through the contemporaneous structure using non-synchronism correction matrix (Table 5.1-2) and the maximum lag is obtained from the maximum detected lag where the cross-correlation coefficient is found to be significant in s-statistics of the Cheung and Ng (1996) CCF causality test. Estimation is based on full sample data (3130 observations). The rejection of the causality hypothesis at 5% and 1% level of significance are represented by marks * and ** respectively. Mark "A" represent a case where the CCF causality test is not detected cross-correlation to be significant in s-statistics, thus, models (21) and (22) are not applied. Mark "B" represents a case where the convergence of estimated models is not achieved. Mark "-" displays not applicable cases in Panel B and Panel D, where oil price cannot be adjusted on itself.

Each cell of the table is also supplied by the non-causality HRF diagram cases markers (C1,C2,C3,C4) and transitional case markers (C1-C2, C4-C2, C4-C3) obtained from Table A.6-5. For example, case "C3" demonstrate strong evidence of instability of full sample estimation.

Third, it is assumed that this lag structure allows the causality in variance to be obtained in the presence of causality in mean, which is an issue in CCF GARCH causality testing (Cheung and Ng, 1996, pp. 36,37; Gebka and Serwa, 2007, p. 214) as discussed in Section 5.2.2 on page 93.

Fourth, the oil price in a conditional mean equation of model (22) is exogenous to the index, which is assumed to be a dependant variable. This assumption remains in line with the majority of the other studies represented in Section 3.2 (see, for instance, Bhar and Nikolova, 2009b, p. 1042), while the

possibility where oil price can be a dependent variable is left in model (21), where indices are allowed to affect oil price (e.g. Barsky and Kilian, 2001, 2004; Kilian, 2008b).

Following the discussion in Section 5.3 and 5.3.1, it is useful to examine the stability of the causal relationships found in Section 7.4.1. Therefore, before starting to present the results it is useful to recall the procedures which were suggested in Sections 5.3 and 5.3.1 and applied during the estimation process.

For each combination of pairs of indices¹¹¹ models (21) and (22) solved¹¹² rolling in respect of the descending window sizes, as discussed in Section 5.3, the causality test is performed on a joint basis in the Granger (1969) sense separately for the mean and variance for each possible direction of causality (from $X \rightarrow Y$, $Y \rightarrow X$) for both oil unadjusted and adjusted cases. All the outcomes of each solved equation and causality test are then recorded.

The non-causality HRF, using the consolidated statistics (Expression (23)), as suggested by Swanson (1998), is estimated by applying recorded outcomes of the causality test with respect to each window size separately for the mean and variance for each possible direction of causality (from $X \rightarrow Y$, $Y \rightarrow X$).

For each pair of indices the *non-causality HRF* vs. *rolling window size* diagrams are then constructed both for mean (oil unadjusted Table A.6-1 and oil adjusted Table A.6-2) and variance (oil unadjusted Table A.6-3 and oil adjusted Table A.6-4).

Further each diagram is interpreted using cases suggested in Table 5.3-2 and additional tables are organised by synthesizing the diagram form to the case marker form¹¹³. It is worth noting that four interpretational cases cannot fulfil all the possible patterns of non-causality HRF behaviour. Therefore, besides the four common cases (C1, C2, C3, C4) represented in Table 5.3-2, there some transitional cases (C1-C2, C4-C2, C4-C3), which are suited to the nonstandard patterns of non-causality HRF diagrams represented in Table A.6-1, Table A.6-2, Table A.6-3 and Table A.6-4.

¹¹¹ Note that oil price is also treated as an “index” in this sense.

¹¹² Note that in order to estimate models (21) and (22) the parameter c and f should be known. Therefore, the estimation of such models assumes estimation of the CCF causality test in order to derive maximum lag where cross-correlation coefficient is found to be significant in the s -statistics.

¹¹³ Mean causality in unadjusted form transmits from Table A.6-1 to Panel A of Table A.6-5

Mean causality in adjusted form transmits from Table A.6-2 to Panel B of Table A.6-5

Variance causality in unadjusted form transmits from Table A.6-3 to Panel C of Table A.6-5

Variance causality in adjusted form transmits from Table A.6-4 to Panel D of Table A.6-5

For the investigation of stability of the causal relationships, case markers from Table A.6-5 are then represented in Table 7.4-1 by attaching to the correspondent cell the results of the Granger causality test based on full sample estimation.

Having established the parameters of the table, it is now possible to start the discussion on the stability of the causal linkages.

7.4.1.1. Casual relationships between indices and the oil price (Panel A and C based on equation (21)).

Causality from the oil price to the index in mean

As a preliminary to the discussion, it is important to focus on the linkages between the oil price and other indices represented on panels A and C. The oil price had a causal effect only on Russia (EE) and the UK (DS), which stayed in line with their relatedness through the oil price. However, the same effect should also be observed in the case of oil self-sufficient Brazil (ES), but this result is not confirmed in the hypothesis testing outcome. It is possible to cautiously ascribe the existence of causality to the UK stock market index by the same closing time of the equity market and the snapshot of the oil price recorded in London, which gives the UK (DS) a synchronicity in relation to the oil price and a more beneficial position compared to the closing time of Brazil (ES).

The results for Russia and the UK is also confirmed by the combined case (C1-C2) of non-causality HRF, which suggests that on large sample sizes, the non-causality hypothesis for the given countries, that “oil price does not Granger cause index”, is likely to be rejected. Moreover, careful examination of corresponded diagrams of Table A.6-1 suggests that the results of the relationship between the oil price and Russia is stronger, compared to the oil price and the UK. This fact, confirms the strong net-oil exporting position of Russia.

Causality from the index to the oil price in mean

Another interesting result from Table 7.4-1 is the causal effect observed from the share indices to the oil price. The hypothesis of non-causality is rejected at 1% level of significance from Russia, France, and the UK to the oil price, while from Brazil and the US it is confirmed at 5% level. The comparison of Table 7.4-1 with Table 7.2-2 demonstrates that conditional volatility modelling may disclose more linkages in mean than a regression model.

However, the existence of the C3 case for France, Brazil and the US suggests that the result of the full sample estimation is unstable when the sample size is decreased. Therefore, one cannot rely on the outcome of full sample estimation, since such a result may provide spurious results for the

potential user. At the same time the (C1-C2) combined pattern is found in causality from Russia and the UK to the oil price, which confirms the existence of the large sample size stable bi-directional causality and in the case of Russia, the relationship is more stable than in the UK case.

Causality from the oil price to index in variance

As for the causality in variance, no effect is found from the oil price to the participating indices in the full sample estimation and the non-causality HRF revealed in the C2 pattern, where the causality is hardly visible in most of the sub-samples for each window sizes.

Causality from the index to the oil price in variance

The testing of the non-causality hypothesis in the full sample estimation demonstrated the existence of causality from Germany and France to the oil price, confirmed with the C1-C2 non-causality HRF pattern. Moreover, the pattern (C4-C2) is found for the UK oil price case, which demonstrates that even if the causality is not confirmed at the full sample, high rejection rates of non-causality HRF may still occur at certain window sizes inside the sample. At the same time, all other cases where the indices attempted to cause the oil price confirmed the C2 case, non-causality HRF confirmed the lack of causality inside the sample.

Overall the existence of the (C3) case in non-causality, HRF confirms that full sample hypothesis testing may provide dubious results, which could confuse the potential user of information regarding cross-market linkages. The C1-C2 case is more stable. However, the potential user of the information should take into account the sample size of the data. At the same time, the highest level of reliability of the results was achieved in the C1 case, where the non-causality HRF is strong for all window sizes. Examination of the different sample sizes should also be performed in the C4 case, since that non-causality hypothesis is not rejected in the full sample estimation only, while descending window sizes demonstrated high HRF.

7.4.1.2. Casual relationships between indices with and without oil price adjustment based on equation (21) (Panel A and C) and equation (22).

Cross-market causal linkages in mean

It is possible to begin an explanation of the cross-market causal linkages by referring to the similarities between Table 7.4-1 Panel A and causality testing using the regression estimation performed in Table 7.2-2. Almost all indices, except China, demonstrate a high degree of interdependence between each other in mean. The picture with China is more thorough in the case of causality tested in ARMA (m,n) - EGARCH(p,q), since causal linkages from other indices to China is

not confirmed after allowing for the moving average effect, the previous lag's own volatility and unexpected standardized innovations.

China had only region-wide mean causality to Japan and India, confirmed at 1% level of significance and causality to the US at the 5% level of significance, which is found to be insignificant after the inclusion of the oil price variable. This evidence conforms to the findings of other authors regarding the solitary position of the Chinese market (among the others Huang, *et al.*, 2000; Baur and Fry, 2009; Wang and Lee, 2009).

The case of China is confirmed by the C2 pattern of non-causality HRF, for most of the pairs. However, the causality from China to India and to the US is marked by the C3 pattern, which shows the contentious nature of using full sample estimation against rolling estimation, for descending window sizes.

All other indices are likely to have the C1 case confirming strong persistence in non-causality HRF, with some exceptions provided by the C1-C2 case, where emerging markets don't have trading overlaps with the correspondent developed market. This confirms that the time factor is one of the most important issues, when examining the cross-market linkages. The allocation of the index trading time on the day timeline predetermines its strong dependencies with the developed markets, approximately located in a similar time zone. This can be traced to a C1 pattern for Russia with the EU countries (including the C4 case), Brazil with the US and the EU countries, India with Japan, with China as the only exception.

Finally, comparison of Panel A and Panel B shows that adjustment for the oil price has little effect on the testing of the Granger Causality hypothesis on the joint bases, except the case of China to India and China to the US, where detected causal linkages disappeared after adjustment for the oil price, which can be seen on the correspondent cells of Panel B of Table 7.4-1.

The existence of C4 cases, supplied with the B mark in some pairs, suggests that on the full sample estimation convergence is not achieved. However, non-causality HRF examination shows that causal linkages are likely to exist when smaller sample sizes are applied.

Cross-market causal linkages in variance

As for the variance causality, it is possible to highlight the following:

It is possible to distinguish a block of bi-directional causality mostly with C1-C2 or C4-C2 cases that include Brazil, countries of EU and the US. The listed countries are likely to have full sample bi-directional causality confirmed, which are reliable at non-causality HRF to a certain window size.

The case of Japan is more puzzling. Japan is not causing other countries in variance, and it is also confirmed by the C2 case, suggesting that even on the smaller window size, a lack of causality exists. However, other countries do cause Japan with the similar HRF pattern (C1-C2) for India, Russia, France, the UK, the US, with the exception of Germany, where the unreliability in the non-causality HRF (C3 case) and full sample confirmed causality is found. Overall, the Japanese case demonstrates that this country is led by innovation from other developed markets or their reflection from the emerging markets (India, Russia and Brazil).

This structure of causality is not changed after adjustment for the oil price, which confirms that the oil price has an insignificant impact on the testing of the causality hypothesis on joint bases in the $ARMA(m,n)$ -EGARCH(p,q) model.

However, the adjustment for the oil price does cause changes on the rejection of the non-causality hypothesis in full sample estimation for India and Russia.

Before the adjustment for the oil price, India, in full sample estimation, had variance causality in the direction of Germany and the US, while after adjustment, the only causality that appeared is the causality to the UK (besides variance causality to Japan discussed in a previous paragraph). Nevertheless, the given variance causality holds the C3 case in the non-causality HRF, which means that there is instability in smaller sample sizes.

In the case of Russia, the variance causality is found from Russia to Brazil and the US, while the causality to the US disappeared after adjustment for the oil price, together with the appearance of the variance causality to India. This may indicate that the variance causal relationship of some BRIC countries with other developed and BRIC countries are affected by the adjustment in the oil price, unless the rolling estimation for the descending window sizes is performed. The rolling estimation (non-causality HRF) demonstrates that the Russia to India variance causality is of a C3 nature, while results in the same direction of variance causality in the oil price adjusted form are changed to the C4-C2 case confirming that the relationship is no longer found in the full sample estimation.

Regarding the Chinese equity market, it is possible to conclude that despite the lack of confirmation of a causal relationship in mean causality in variance causality the Chinese market has some linkages, which are also found in the oil adjusted case. The unidirectional causal linkages in variance are found from China to France and to the US. However, the China to France case is confirmed to be C3, which means that the causality is unstable.

8. Discussion

8.1. Discussion on consequences of ignoring non-synchronism problem and early/later closing market bias.

According to the research objective concerning the consequences of ignoring the non-synchronism problem (research objective 5: Section 1, page 5 and its discussion on page 74) in Section 7.2 a comparison was performed between classical and non-synchronism corrected causality, using a regression model, where the outcome is represented in matrices¹¹⁴ with stock market indices, which are sorted by the closing time sequence. The classic Granger Causality results demonstrate the existence of delimitation on the diagonal line, where the upper half shows strong evidence of causality, while the lower half depicts the lack of causality, with some exceptions located close to the diagonal line.

Results of the non-synchronism corrected causality demonstrate strong dependence between all indices except China, which demonstrated only intraregional dependencies. The oil price demonstrated low dependencies with the markets. However, it is found to be caused by the US and Brazil at lag 1 and Russia at lag 0.

Since markets were sorted by the sequence of their closing times, starting from early closing markets and ending with later closing markets, an attempt was made to prove that the factor of earlier/later closing markets may affect the causality structure. Further, by investigating the possible causality interactions between the US and Japan, it was found that on a standard GMT line, Japan's effect from the previous day needs 39 hours for the signal to affect the US closing value, while the US needs only 9 hours to affect the Japanese closing value.

This large difference in duration gave grounds for further investigation and this is discussed as a part of the research objective 6 (research objective 6: Section 1, page 6 and its discussion on page 76). The comparison of the standard and shifted GMT line's effect on the gap structure demonstrated the important role of the traditionally established GMT time structure on the measurement of the linkages between markets and it gave a favourable advantage to the later closing markets over the earlier closing ones.

In order to investigate the standard GMT line factor an attempt was made to simulate time shifts in the GMT line to examine how such shift induces changes in the structure and duration of the gaps between the US and Japan. It was found that the appearance of the US at the beginning of the day

¹¹⁴ See Table 7.2-1 for classic and Table 7.2-2 for non-synchronism corrected form.

induces the gap structure to reverse, the Japan-US gap is reduced to 15 hours, while the US-Japan is increased to 33 hours, still less than the shift of 39 hours from the Japanese to US closing values in the standard GMT line).

After choosing a 4 hours time shift, the research investigated how the structure of the returns is changed, due to the appearance of the US at the beginning of the day. It was found that the classic Granger Causality test, where the US attempts to cause Japan at lag 1 and vice versa, is reformulated to lag 2 or higher lag for the US to Japan case and lag 0 to Japan to the US case. So the time gap reversal and appearance of the US at the beginning of the day also affects the lag structure of causality. By applying the new lag structure into the regression model for the US, in relation to other indices, it was found that after imposing the earlier closing market condition, US behaviour started to be consistent with the behaviour of other earlier closing indices. The result raises the question of the US dominance in cross-market relationships, whose existence may partly be explained by the later closing market factor.

The result is also crucial for any pair of indices, when investigating the significance of linkages (spillover, information transmission, interdependence, lead-lag effects, etc.), since most econometric models are lag based. Therefore, it can be argued that it might be important to investigate the causality pattern for the markets, assuming both conditions (earlier/later close of the markets) to avoid the underestimation and overestimation in the measurement of linkages.

The problem can partially be resolved by using a non-synchronism correction technique or other techniques mentioned in Section 5.1. While in the case of the equation correction technique, the authors mainly investigate contemporaneous terms for early closing markets and the previous day effect for later closing markets. An investigation is not usually performed for later closing markets for the lag 2 effect whilst early closing markets are still applied at lag 1. As mentioned previously, the Gebka and Serwa (2007) study is a good example of the contemporaneous effect in causality, which can be developed into a higher lag for the equal measurement of the lag 1 causality (spillover) for early closing markets and lag 2 causality (spillover) for the later closing markets.

Overall, this study demonstrated the existence of the non-synchronism bias and the consequences of ignoring it. However, an attempt was also made to examine the problem of earlier/later closing markets, mainly observed in the study by Furstenberg, *et al.* (1989). This problem is a consequence of the non-synchronism problem, which reveals that one market has a beneficial position while

examining causality (spillover effect) over another market when observed in daily frequency, in models where the non-synchronism correction is not applied¹¹⁵.

Arguably the early/late closing market bias that occurs in the standard GMT line is possibly underestimated in the data with lower frequencies. The effect may exist on the non-aggregated data, e.g. weekly, “closing Wednesday”; monthly, closing values of the last day of the month (quarterly). Most authors suggest¹¹⁶ (see Table 4.1-1 in Section 4.1) that lower frequencies data are not exposed to the daily data non-synchronism a priori. However, as suggested above, the later closing market always stays in a beneficial position compared to the other markets for one day, since it absorbs all the current day’s innovations. Attention should be paid to the possible existence of certain disparities in the use of non-aggregated lower data frequencies, since they may still be exposed to the daily data non-synchronism effect. Thus, it is possible to suggest a virtual time shift, where the US market starts the day, instead of Japan. The hypothesis could be easily tested by taking the values of the US from the day ($t-1$) and recording that value together with other indices at a day t , ignoring the real day (t) value of the US. Thus, the “closing Wednesday” for weekly data will be replaced by the US “closing Tuesday”, while the US closing values of the last day of the month should be replaced by the US closing value for the day before the last day of the month. If a difference exists between the standard time for the US, which is usually applied in the relevant studies, and the virtual time shift example, then the difference could be due to the existence of the later closing market bias. Thus, the US “domination in causal effect” may also be explained by the fact that US is the latest market to close during the day. In the present thesis the problem is not empirically tested, but leaves open the opportunity for further research.

Nevertheless, the analysis in this section is based on the regression model which is suggested for the simplification of the explanation as carried out by Furstenberg, *et al.* (1989), Malliaris and Urrutia (1992a) or Peiró, *et al.* (1993, 1995). However, in the next sections, the relationship between the market linkages is observed with more complex models¹¹⁷, the application of stability analysis and

¹¹⁵ See Section 4.1 and 5.1 for the discussion.

¹¹⁶ For example, Furstenberg, *et al.* (1989, p. 147) stated that: “*Since weekly rates of change in the different national stock price indexes are calculated for periods, Wednesday to Wednesday, that are largely overlapping, information is shared both ways and stock price responses are mutual, flowing back and forth within the observation period. Hence, unlike daily correlations, weekly correlations should not show each market related most closely to its immediate predecessor in the order of closing*”. Further, by finding the evidence that daily correlation is higher compared to weekly correlation, the authors concluded that on weekly data there is less evidence with an immediate successor (Furstenberg, *et al.*, 1989, p. 147) assuming early and later closing market in the same day.

¹¹⁷ Application of the ARMA (m,n)-EGARCH (p,q) corrected to the non-synchronism for the Causality testing in the Granger (1969) sense showed in Section 7.4.1 in Table 7.4-1 (Panel A) demonstrates conformity with the results of the Table 7.2-2, at least for all participating indices (excluding oil price returns) with a more solitary position for China, since there is a lack of mean causality from other countries to China.

the more active role of the oil price. But non-synchronism correction techniques proposed in this section are applied at each stage of the estimation of the subsequent sections.

8.2. Discussion on significance and sign stability

The issue of stability testing runs through the whole paper. The analysis of the literature on cross-market linkages as well as the oil price effect on stock market demonstrated that stability testing is often used for the investigation (e.g. Smith, *et al.*, 1993; Anatolyev, 2005; Gorjaev and Zabolkin, 2006; Yang, *et al.*, 2006; Awokuse, *et al.*, 2009; Diebold and Yilmaz, 2009) of the results and the evolution of parameters (significance) over time.

During the research phase it was found that the stability of integration and gave rise to significant concerns regarding full sample estimation, the results validity and there is an active discussion regarding recursive and rolling estimation techniques. Therefore, Section 4.2.1 highlighted the necessity of parameter stability in integration and co-integration and discussed the application of recursive and rolling estimation, together with a critique of recursive estimation. Taking into account this critique, the decision was made to use the rolling estimation for stability testing in various tests inside the thesis.

However, rolling estimation by itself has a significant drawback, which is omitted most authors who apply rolling estimation. In Section 5.3, it was pointed out that no, or poor, grounds are usually given for choosing the window size, which is used in the rolling estimation. Therefore, in this thesis it was decided to use a set of windows with different sizes, sorted in descending order (in this paper “descending window sizes”), where each will be solved by a rolling approach. The contention is that the most detailed investigation may be achieved in window sizes sequence starting from the full sample (in this thesis this is 3130 for the series logged returns) and ending at the window size where the estimation is still relevant for the research objectives, with a window size changing in steps equal to 1 observation. However, such a scheme of estimation is very time consuming. Therefore, the decision is made to use 7 different window sizes (including the full sample) as suggested in Section 5.3 and in Table 5.3-1 in particular.

The use of the descending window size in the rolling approach generates a large amount of information that needs to be consolidated and thus is represented in compact form. For this purpose, a Hypothesis Rejection Frequency (HRF) was utilised, similar to the study by Swanson (1998), which also used it in non-stationarity and non-causality HRF. The HRF derived expression is also used for estimating Sign Prevalence (SP).

The main point of such an investigation is the comparison of the full sample estimation with the rolling estimation performed on a set of descending window sizes. Such comparison provides stronger evidence of the detected relationship or may detect misleading results of the full sample estimation.

Application of non-stationarity HRF

The task of the investigation of the stability of series non-stationarity is stated in Section 1, page 6 with a discussion on page 78 as research objective 7. The testing of the non-stationarity properties of the data is performed in Section 7.1. The non-stationarity HRF showed the existence of anomalies, where the rolling estimation at certain window sizes demonstrates the rejection of the non-stationarity hypothesis of the unit root test, performed on levels of the data, despite expected non-rejection. This example sheds light on potential concern about the utilisation of a full sample unit root test as a preliminary routine before the estimation of recursive or rolling co-integration tests. This concern arises from a preliminary condition of series non-stationarity before any co-integration test is applied. If in any recursive (rolling) sub-sample the unit root is not found, then on the given sub-samples, the co-integration test cannot be applied, since application of the co-integration tests on stationary sub-samples is meaningless.

Regarding the result of the rolling estimation on descending window size, it is possible to suggest that substantial anomalies do exist in rolling sub-samples, with severe disproportion detected for China (window size 2730) and Russia (window size 1930), where the stationarity of the sub-samples is confirmed in 27% and 21% of total number of subsamples (see Table 7.1-2). For other participating countries, significant anomalies are also found but on smaller window sizes.

Overall, the evidence raises concerns regarding the potential validity of using co-integration tests together with recursive and rolling estimations.

Further examination of the parameter (significance) stability is performed with respect to the non-causality test in the Granger (1969) sense. This issue is included in the fifth research objective (Section 1, page 7 with a discussion on page 79), which encompasses the application of the SP and non-causality HRF.

Application of the Sign Prevalence (SP)

Section 7.3.4 – 7.3.8 examined the oil price effect on stock market linkages between BRIC and developed countries. The investigation is performed using the CCF test, where the interest was in

the sign and magnitude of the percentage change that represent relationships between participating countries. Such a comparison is performed on a full sample basis.

However, to increase the robustness of the results, the stability of the sign was examined. Stability was represented in percentage change SP, observed for the causality at a certain lag, and which is represented as a compound of the SP derived for each of the descending window sizes (for examination of sign stability see study by Goriaev and Zabotkin, 2006). If at each window size (excluding full sample) positive (negative) sign prevails over or equal to negative (positive), than positive (negative) SP is confirmed and marked in tables as {+SP} {-SP}.

The comparison of the full sample estimation sign of the percentage change after adjustment for the oil price does not necessarily coincide with the results of the SP. Moreover, it may also contradict the sign of the full sample estimation, or detect an SP at lags where full sample estimation detected no linkages. In the thesis, the results of the SP were reported and it was given a high priority in interpretation, when it contradicted the full sample estimation.

The existence of the SP at a certain lag may be treated as the existence of a pattern in response to the linkage to oil price adjustment. Therefore, the application of the SP may give strong confirmation of the full sample estimation or unveil its instability.

Application of the non-causality HRF

The non-causality HRF was applied in Section 7.4.1 for the purpose of investigating the stability of causal relationships between two countries. As it was in non-stationarity HRF and SP, we also applied descending window sizes, and this allowed us to derive non-causality HRF for each participating window size. For the purpose of clarity and a compact form of result representing a *non-causality HRF vs. rolling window size* diagram was used, with the possibility of interpreting unusual cases (see Section 5.3.1).

Firstly, from the investors' point of view, it would be valuable to know how deep inside the sample Granger Causality can be confirmed. For them, confirmation of the existence of Causality for a different sub-sample might be important for forecasting purposes. (e.g. if it were possible to state that for a given pair of series in all sub-samples, with 150 observations, Granger Causality is confirmed at 5% level of significance, then the Granger Causality is likely to be confirmed in out-of sample, if no abnormal events occur during that period).

Secondly, if a full sample confirms Granger Causality and it is also found in sub-samples (Table 5.3-2, Case 1), then the confirmation of Granger Causality for the full sample will be robust, since it is based on sub-samples causality.

Thirdly, most articles confirm Granger Causality only for the full sample or a set of several sub-periods. Despite the benefits of simplicity, full sample analysis in some cases might be misleading, even if the data meets the pretesting conditions.

In this case the Smith technique applied for different sizes of window might be useful in detecting hidden weak persistence in non-causality HRF (Table 5.3-2, Case 3). If the full sample is confirmed Granger Causality but not confirmed using a different size of window in the Smith technique, then the full sample confirmed Granger Causality results might mislead the potential user. This is because there is a low probability that the existence of Granger Causality will be confirmed in a sub-sample inside and outside the full sample.

Finally, the technique provides additional information as to how different sample sizes affect causality statistics between given series. The advantage of the technique is that it can be of useful to researchers who are interested in the sample size sensitivity to hypothesis testing and parameter statistics.

8.3. Discussion on the oil price effect on stock market behaviour

Section 7.3.3 examines the relationship between the oil price and the participating stock market indices, with respect to research objective 4 (Section 1, page 5 with a discussion on page 69). The CCF GARCH Cheung and Ng (1996) causality test is applied to investigate the lead-lag relationship both causality-in-mean and causality-in-variance. Having summarised the results of the estimation, it is possible to provide the following interpretation and references to similar findings in studies by other authors.

Causality-in-mean between the oil price and participating countries, does not demonstrate any distinguishable trend between the developed and emerging countries. However, the magnitude of the relationship is seen to be dependent on the country's oil status, which can be traced to a high cross-correlation coefficient for Russia (0.094), the UK (0.0604). High positive estimates are also confirmed, both for emerging and developed net oil-producing countries (Section 3.2.4 for developed oil-producers, Section 3.2.5 for emerging oil producers and Section 3.2.6 for oil-exporting Russia). However, the exception is the mean causality at lag 1 for oil-importing US (0.0598) as shown in Table 7.3-3, which is also referred to in studies by Barsky and Kilian (2001, 2004), Kilian (2008b), Apegis and Miller (2009) where the oil price is assumed to be endogenous.

It was also not possible to confirm the negative relationships between oil-importers and the oil price despite the findings of other authors in Section 3.2.2 who examined developed oil-importers (Cobo-Reyes and Quirós, 2005; Park and Ratti, 2008; Chiou and Lee, 2009; Sariannidis, *et al.*, 2009). This may be partly explained by the application of the contemporaneous effect of the oil price and the application of different models in the studies mentioned above.

Another important point is the prominent difference between developed and emerging market interactions with the oil price observed in variance. Whereas due to the lack of linkages in volatility, BRIC countries are likely to express emerging market behaviour similar to that shown in Ramos and Veiga (2009; 2010). However, mature market countries generally are likely to have a causality in variance (except for the OIL-Japan case), and it is found to be bi-directional at the contemporaneous term (except for the OIL-US case), which may be explained by the fact that EU countries' stock markets' closing values and the oil price snap shot occur at approximately the same time.

The linkages of the developed countries are in line with the findings of Sadorsky (1999) who found evidence of a linkage between the stock market and oil price volatility for the US economy. However, it may also be suggested that these findings conform with the findings of a study by Ramos and Veiga (2009), where Oil & Gas companies were examined, and found that the oil price volatility effect is significant in the case of mature markets and insignificant in the case of emerging ones. Ramos and Veiga (2010) provide corroboration in this regard, where they found evidence that emerging markets do not have exposure to the oil price or oil price volatility and which suggests that the emerging markets are a separate asset class. This is distinct from the behaviour of the developed markets and it appears to be confirmed in related studies (e.g. Bekaert and Harvey, 1995; Bekaert, *et al.*, 2003). However, as suggested earlier, mean relationships are likely to be dependent on the oil status of the country and that linkages in mean do exist between emerging markets (represented by the BRIC countries) and the oil price.

8.4. Discussion cross-market linkages observed in CCF test

The examination of the cross-market linkages was performed as part of research objective 1 (Section 1, page 4 with a discussion on page 33) to examine linkages in mean and variance for BRIC and mature market countries. Therefore, in this section, it is possible to generalise the results of the equation outcome on cross-market linkage observed both in mean and in variance¹¹⁸.

¹¹⁸ Based on summary of results from Sections 7.3.5, 7.3.6, 7.3.7, 7.3.8.

Mean interactions

The value of the correlation coefficients are high for markets with trading time overlaps, which may be ascribed to the issue of geographical proximity, possibly strong trade ties and the approximate same time zone effect. The findings are in line with those of Furstenberg, *et al.* (1989), Malliaris and Urrutia (1992a), Peiró, *et al.* (1993, 1995), where they found that indices mainly have high correlation at lag 0 or 1. This is also confirmed in other studies on VAR and the GARCH models Bessler and Yang (2003), Wang and Firth (2004), Singh, *et al.* (2010).

There is also controversy in the high contemporaneous correlation that were found, usually the correlation at higher lags is less likely to be high, as found in the outcome of the CCF test and is also referred to in a studies by Peiró, *et al.* (1993, 1995) and Bracker, *et al.* (1999). This can be traced to the finding that European markets tend to demonstrate multiple correlations at higher lags found to be significant in *s*-statistics, although they are relatively low in magnitude. One other finding should also be mentioned: European market's correlations usually have high contemporaneous correlations, but low correlations at lag 1, while US correlation at lag 1 (next day effect) in interactions with European markets is still strong. This, on the one hand, may be ascribed to the dominant position of the US as the main source of innovations for the other international markets in line with various studies (among the others: Eun and Shim, 1989; Koch and Koch, 1991; Bessler and Yang, 2003). However, on the other hand, it may also be ascribed to the earlier/later closing market bias as discussed in Sections 7.2 and 8.1.

Mean interactions between emerging markets are also likely to appear in contemporaneous terms (also found in Fujii, 2005), but the values of the CCF coefficients, estimated on standardized residuals, are much smaller in magnitude compared to those which appear between developed markets. This finding conforms to those of Levich (1998, p. 233), Hashmi and Tay (2007), Gebka and Serwa (2007), where the causality pattern does not appeared to be strong in magnitude.

It is possible to state that the examination of the linkages among BRIC countries, performed in this section, demonstrates conformity with the previous studies. This current research is in line with the analysis of the causality (spillover) among emerging countries from different regions, including Brazil and Russia, in particular a study by Gebka and Serwa (2007) and for BRIC countries in a study by Aktan, *et al.* (2009).

The study by Gebka and Serwa (2007) demonstrated that linkages between Brazil and Russia are the highest in magnitude among the interregional linkages of these countries, but still lower than their intraregional linkages. The findings in this thesis suggest that the cross-correlation linkage between

Brazil and Russia is also the highest among the BRIC countries. This does not necessarily mean that Brazil and Russia have direct linkages, since it is impossible to exclude the possibility that these two countries are not simultaneously affected by a third external factor (e.g. world index¹¹⁹, regional index or the oil price).

India's causal relationships are also mainly described by the contemporaneous term with a magnitude higher for their relationship with Russia and Brazil, compared to neighbouring China. This finding conforms to a study by Aktan, *et al.* (2009) where the causality in VAR framework is confirmed from Brazil and the US, while India affected Brazil and Russia. However, the non-synchronism problem may raise some concern regarding the validity of the outcome, since daily data is applied into the VAR model without non-synchronism correction.

The isolated position of China, as suggested by a growing group of studies of market linkages (Huang, *et al.*, 2000; Bahng and Shin, 2003; Baur and Fry, 2009; Wang and Lee, 2009) regarding the low correlation of the Chinese market with those of other BRIC countries, makes it possible to conclude that some causality linkages exist between China and other BRIC countries, but they are less likely to appear from the Chinese market to other markets.

There are several aspects that explain these findings:

The first aspect is the orientation of emerging markets to internal or regional rather than global (world) trends (e.g. Bhar and Nikolova, 2009a, p. 211), while for spillovers it is mainly to regional trends, except China);

The second is that the time gap factor (Furstenberg, *et al.*, 1989) may be an important issue, when examining the reasons for relatively small cross-correlations coefficients between emerging markets. Needless to say, all factors are crucial when daily data non-synchronism problem is appropriately solved¹²⁰;

The third aspect is the mean interactions of the emerging and developed markets (based on Sections 7.3.6, 7.3.7) these are likely to be dependent on the factor of the time gap between the closing values of indices. The leader among all BRIC countries is Brazil, which has strong contemporaneous mean interactions with the participating EU countries and the US, while mean interactions with

¹¹⁹ The effect of the world index and regional index are examined in studies by Bhar and Nikolova (2007; 2009a), Beirne, *et al.* (2010). Gebka and Serwa (2007) who examined the markets indices after exempting the effect of the World index factor. Regarding the World index effect Bhar and Nikolova (2009a, p. 209) suggested that nearly fifty percent of the World index consists of US stocks it is possible to expect that the US has a significant effect on the indices around the world. As an example, the control for the US effect is also performed in a study by Fujii (2005, p. 324).

¹²⁰ See Section 5.1 for possible treatments of the problem of daily data non-synchronism.

Japan are at least 3 times smaller in magnitude compared to those found within the EU and 4 times smaller than those found within the US.

Russia has the second largest magnitude of cross-correlation coefficient, with the strongest interactions detected in its relationships with the EU countries. India's cross-correlation coefficients with developed countries markets are below those of Russia, despite the findings by Bhar and Nikolova (2009a, p. 217) where India was found to be the most integrated market. Finally, China has small cross-correlation coefficients, confirmed by s-statistics, and the lack of the causality-in-mean relationships to the developed markets; this finding suggests that the position of China is more detached from world markets.

As for the causal linkages of the oil-self-sufficient UK, it is possible to conclude that the UK's linkages have stronger correlations with Brazil and Russia, compared to India and China. However, it is difficult to distinguish the driver of these strong correlations. This may possibly be the oil price component in the UK, Brazil and Russia relationship and the dynamics of the stock market indices, plus the factor of same time zone, which allows these three countries to absorb EU and the US sources of innovations.

Overall, the CCF coefficients between emerging and developed markets are likely to be smaller compared to those between developed markets, which was also found in studies by Bekaert and Harvey (1995) and Bekaert, *et al.* (2003).

Variance interactions

CCF coefficients are likely to appear at the contemporaneous term and lag 1, this was also found in the study by Cheung and Ng (1996) regarding developed countries' interactions and Fujii (2005) regarding emerging countries.

CCF coefficients are also found to be stronger in the case of developed markets, compared to emerging ones, this finding is in line with the suggestion that developed and emerging economies express different asset class behaviour (Bekaert and Harvey, 1995; Bekaert, *et al.*, 2003; Gebka and Serwa, 2007; Bhar and Nikolova, 2009a).

8.5. Discussion on oil price effect on cross-market linkages observed in CCF test

This section of the discussion concerns the oil price effect on the linkages between BRIC and developed market countries as suggested in research objective 2 (Section 1, page 4 with a discussion on page 68). Patterns of response were also distinguished with respect to the oil status and

economic profile of the countries that participated in the observed pairs, regarding research objective 3 given in Section 1, page 5 with a discussion on page 69.

It was discovered that there was an oil price effect on the cross-market linkages both in causality-in-mean and causality-in-variance by means of CCF causality test.

A generalisation of the causal relationship, after adjustment for the oil price, is shown in Table 8.5-1. The rearrangement of participating countries into groups, regarding oil status and economic profile (as discussed in Section 7.3.2), allowed the relationships to be investigated in more the depth and scope. However, the oil price effect on causal relationships of certain types of pairs was not prominent.

It is difficult to make an interpretation of the relationships that were found, since there are a several problems, which prevent the reaching of an overall conclusion in some of the pairs.

1. The total number of participating series is small; some types of pairs have only a single country pair observation.
2. Even if the pair exists, there is the possibility that no causal relationships will be found.
3. If relationships are found in the group of participating pairs, the result of the oil price effect on the relationships might be mixed, which suggests that the result of the oil price effect on causal relationships is inconclusive.
4. It is difficult to find an interpretation even if the trend for a certain type of pairs is found.

A possible interpretation of the oil price effect on cross-market linkages is the concept that originated from the oil price effect on stock market behaviour. Evidence in the literature suggests that oil related countries are likely to demonstrate a high correlation with the oil price¹²¹. Jones, , *et al.* (2004, p. 24) pointed out that asset prices of oil related companies are to some extent, synchronised with oil price dynamics, since asset prices are the present discounted value of the future net earnings of the oil firm. Therefore, as suggested by Nandha and Faff (2008), oil price impacts should be quickly reflected in the dynamics of the stocks, and this should be true for both the short and long term behaviour of the oil price.

¹²¹ The summary of the literature on the oil price effect on the oil-exporting countries confirms this proposition (see Section 3.2.4 for the Developed Exporters response to the oil price, Section 3.2.5 and 3.2.6 for Emerging Exporters and BRIC countries response, and Section 3.2.6 for conclusive remarks).

This proposition allows assumptions to be made regarding the oil price component in stock market behaviour, with consequences for the cross-market linkages of countries with different oil status and economic profile. Oil price is interpreted as a distortion or complementary effect that is added to the countries' stock index to the extent of the countries' production/consumption profile (oil status). Thus, the results demonstrate that the adjustment for oil price can remove such a component and reveal the “real” linkage between any two countries. Therefore, the oil price affects the magnitude of the causal relationship, as is shown on Table 8.5-1 and the effect varies, depending on the status of the countries which are organised into pairs. Moreover, the effect also varies whether countries in the pairs are all emerging/developed or a mixture of both.

In other words, the oil related countries are likely to incorporate the reprocessed oil price dynamics into their stock market index dynamics. As a consequence of this, the prominent trend can be traced in the mean causality response in cross-market linkages of oil related countries (See EE-ES, EE-DS, ES-DS types of pairs). One remarkable fact is that causality is also decreased with confirmed SP, which demonstrates greater evidence of stability of the observed relationship. As for the oil price effect on variance causality the result is prominent for EE-ES and ES-DS, while the effect is positive in the case of EE-DS, but without SP.

This finding conforms to the idea that linkages between oil related countries are also due to the inclusion of the reprocessed oil price behaviour component in the stock market dynamics of the index. Thus, adjustment for the oil price of both indices in a pair leads to a decrease in magnitude of the CCF coefficient. Therefore, the filtering procedure might be useful for observing cross-market relationships without the oil price component bias, for the cases where the oil related countries are observed. However, in the majority of cases, the effect after the oil price adjustment is at the level of insignificant noise (close to 1% or less than 1% in absolute terms).

Following the same concept it is possible to suggest that oil-importers' linkages are to a lesser extent exposed by the inclusion of the oil price dynamics into the stock market index dynamics due to the rare SP appearance. Therefore, linkages between oil-importers after adjustment for the oil price do not make any significant changes. However, some differences can be detected between responses to the oil price adjustment in pairs with either emerging (EI-EI) or developed (DI-DI) markets participation, whereas pairs of oil importers with a different economic profile (EI-DI) demonstrate inconclusive results.

The Emerging Importers (EI-EI), represented by the intraregional interactions between China and India demonstrate a slight decrease in contemporaneous mean causality (-1.76%), while no relationship is found in variance. The detected link is also unstable, since SP is not confirmed.

Table 8.5-1

Summary of findings on oil price effect on cross-correlation coefficient, through the comparison of the oil unadjusted and adjusted cases

Pair combination with respect to oil status	Pair combination with respect to country's type: Emerging (EME) or developed (DEV) market.	The oil price effect on mean and variance causality relationships
Exporter-Self Sufficient	EME to EME (RU and BR)	Decrease in mean causality, less than 1% in contemporaneous term Decrease in variance causality, less than 1% in contemporaneous term
	EME to DEV (RU and UK)	Decrease in mean causality Increase in variance causality in contemporaneous term, increase from DS side at a higher lag
Exporter - Importer	EME to EME (RU and IN, CH)	Increase in mean at a higher lags from Exporter's side Inconclusive in variance
	EME to DEV (RU and JP, GE, FR, US)	Decrease in mean from DI side (except RU-GE) Inconclusive in variance
Self-sufficient Self-sufficient	EME to DEV (BR and UK)	Decrease in mean causality, less than 1% in contemporaneous term Decrease in variance causality, decrease from ES side at higher lag
Self-sufficient Importer	EME to EME (BR and IN, CH)	Inconclusive in mean Increase in variance from self-sufficient side at higher lag
	EME to DEV (BR and JP, GE, FR, US)	Decrease in contemporaneous mean for both (except GE), decrease at a higher lag from DI side (except FR) Increase in contemporaneous variance for both (except JP)
	DEV to EME (UK and IN, CH)	Inconclusive in mean Inconclusive in variance
	DEV to DEV (UK and JP, GE, FR, US)	Decrease at higher lag for both sides (except JP) Decrease at higher lag from DS side (except FR)
Importer Importer	EME to EME (IN and CH)	Decrease in contemporaneous mean causality Inconclusive in variance
	DEV to EME (JP, GE, FR, US and IN, CH)	Decrease in contemporaneous mean causality (except IN-JP, CH-US), for CH cases decrease is from the DI side. Decrease in higher lag variance causality from EI side (except CH-JP, CH-US)
	DEV to DEV (JP, GE, FR, US)	Decrease in contemporaneous mean (except US-GE, US-FR), but percentage change is under 1% in absolute terms (except FR-JP, US-JP) Decrease or no change in variance (except US-JP in contemporaneous term and US-FR at a higher lag)

As for the Developed (DI-DI) market interactions, evidence is found that they are also affected by the adjustment for the oil price. Both in mean and variance, a small decrease is detected. In mean, it is

found in contemporaneous terms (except US-GE, US-FR), while causality-in-variance shows a decrease or no change in magnitude of CCF coefficients (except US-JP in contemporaneous term and US-FR at a higher lag).

The decrease, at least in the mean relationship after oil price adjustment, contradicts the idea that the oil price dynamics is treated as a distortion effect for the oil importers. A possible explanation for this is that the oil importers' dynamics also hold the oil price dynamics component as a complementary effect, at least for the developed market, where the decrease in the CCF coefficient, after adjustment for the oil price, is confirmed in a greater number of cases and often with correspondent SP.

This current research cannot recommend applying the filtering procedure, since the effect is even smaller, compared to the oil exporters/self-sufficient cases (except in the contemporaneous term). However, the oil price effect on the cross-market linkages of oil importers of a similar economic profile does exist and it is found to be negative, with some exceptions.

In the case of the relationship between an oil Exporter (Self-sufficient) and an oil Importer, it is possible to suggest that the adjustment for the oil price removes the oil price dynamics component from the oil-exporter (self-sufficient) and a possible oil price dynamics distortion or complementary effect from the index of the oil-importing country. Therefore, it is also possible to expect a rise in mean causality. This was confirmed in EE-EI, while in DS-DI, EE-DI and ES-DI a decrease in relationships was detected.

The relationship in variance is also unclear since a decrease in CCF coefficients is found in EE-DI and DS-DI, while an increase is found in ES-DI pairs.

It is difficult to distinguish a prominent trend on the response of pairs with participation of oil importers, with either Self-sufficient or Exporter status. Therefore, it is suggested that further investigation of the topic is needed.

To summarise the effect of the observed relationships, it is possible to conclude that oil price affects the cross-market linkages both in mean and variance.

The result is more prominent between the countries with similar oil status, while for the oil importers, the economic profile of the countries is also important.

The oil price effect often has a small difference (less than 1%) which can be treated as an insignificant noise, but due to the fact that the effect is confirmed in different pairs of the same

profile (e.g. DI-DI) and often with the corresponding SP, it is possible to conclude that the effect does exist.

Since the effect is comparable to insignificant noise, it is possible to neglect it while examining cross-market linkages. However, closer examination of the higher lag s -statistics - significant CCF coefficients and their percentage change after oil price adjustment - demonstrates that this effect might be strong, but it is still attached to the relatively small magnitude of CCF coefficients.

The absence of the relationships and conflicting results often found in certain types of pairs allows suggests the possibility that there are other aspects which might be crucial while examining the oil price effect on the cross-market linkages. For example:

- the same time zone factor and geographical proximity of participating countries;
- the necessity of adjustment for exchange rate fluctuations;
- the necessity of adjustment for the regional and global factors;
- the necessity of the using different proxies of the oil price variable (i.e. net oil price increase suggested by Hamilton, 1996);
- the use of different equation specifications (oil price might be included in the variance equation; more than one lag can be applied),
- the difference in the use of the other oil price indicators (i.e. WTI, OPEC crude oil indices, see Driesprong, *et al.*, 2008) and
- the measurement of the variance causality, without mean causality adjustment¹²².

8.6. Discussion on oil price effect on cross-market linkages observed in EGARCH model using Granger causality test conducted in joint hypothesis

Cheung and Ng (1996, p. 36) suggested using the CCF GARCH causality test as a technique for detecting the causal lag structure of complex models. The authors suggested that the uncertainty regarding first and second moment dependencies may complicate the formulation of the multivariate model during the lag specification phase, especially when long causality patterns are expected.

The original paper by Cheung and Ng (1996) represents a procedure for implementation of the lags detected in CCF GARCH test into the GARCH model. Therefore, following the structure of the original

¹²² See, for instance, causality-in-mean examination in the presence of causality-in-variance (Constantinou, *et al.*, 2005).

study, in this thesis a causality test was applied in the Granger (1969) sense on ARMA(m,n)-EGARCH(p,q) model.

Besides the application of the EGARCH model by other authors (Kanas and Kouretas, 2002; Constantinou, *et al.*, 2005; Hamori, *et al.*, 2006; Inoue, 2008; Hanabusa, 2009), in order to implement lags found in CCF GARCH, a test was also performed on the robustness of the discovered relationships using the rolling window method. The application of 7 different window sizes (including full sample) gave more reliable results and disclosed potential weaknesses of the relationship when the sample size was decreased¹²³. Application of the rolling technique together with CCF GARCH test is also performed in the study by Fujii (2005) in order to examine the stability of the s -statistics of the found CCF correlation. The use of only one window size (240 observations) and its graphic representation shows the switch between tranquil and turmoil periods, which is useful for the purposes of the contagion investigation. However, such a method is less helpful when there are potential concerns regarding significance sensitivity to the different sizes of the rolling window. Therefore, application of the HRF in the sense of Swanson's (1998) *rejection rate* is more plausible.

Taking into account the specificity of the study regarding the oil price effect, the ARMA (m,n)-EGARCH(p,q) model is performed in order to examine the linkages: 1) between the stock market and the oil price (Section 7.4.1.1); 2) between two stock markets with and without oil price adjustment (Section 7.4.1.2).

Following the results of the Section 7.4.1.1 it is possible to highlight the following on oil price dependencies with stock markets:

Causal linkages between oil price and stock market (joint hypothesis).

First, joint test based mean causality from the oil price is likely to occur in oil related countries (i.e. Russia and the UK). Interestingly the relationships are not confirmed between the oil price and the Brazilian stock market.

Second, the oil price is found to be dependent in mean, not only with oil related countries, but also with France and the US. However, this result may be treated as weak evidence, since the causal relationship is confirmed on a C3 pattern of non-causality HRF.

Third, mature markets are likely to have causality in variance with the oil price, despite the lack of the variance spillovers from the emerging countries (see causal relationship from Germany, France

¹²³ See Section 5.3 for the application of the rolling window technique for descending window sizes; Section 5.3.1 for consolidating statistics, HRF diagrams and interpretational case of the *non-causality HRF vs. Window size* diagrams.

the oil price with C1-C2 pattern and UK with C4-C2 pattern; Table 7.4-1, Panel C). These findings are also confirmed in findings of CCF GARCH at hypothesis testing at the certain lags.

The conclusion of the cross-market linkages analysis and effect of adjustment for the oil price could be split into causal relationships in mean and in variance.

Cross-market causal linkages in mean (joint hypothesis).

The mean causality relationship is the obvious example of the global interdependence of stock markets, when correction for the non-synchronism is applied. Moreover, the existence of the C1 patterns of non-causality HRF found for the developed markets confirms that the relationship is stable even on the smaller sample sizes. This shows that the markets are interrelated and may be treated as a part of one global system.

If indices have a trading time overlap or there is no time gap between the indices' closing time, then those indices are likely to have strong causal dependencies in mean, sometimes independently from the country's economic profile, which can be seen in interdependence between Brazil in relation with the US and the EU, and Russia in relation to the EU with exception of the US.

Developed markets are likely to have a C1 case, even without trading time overlaps. This can be traced to the relationships of Japan with the markets of participating EU countries.

For the emerging markets, which don't have a trading time overlap, a C1-C2 case may occur. This could be traced to India, with the exception of France and the UK.

Finally, it is important to conclude that China has a lack of interdependencies with other markets. This suggests that Chinese stock market behaviour is driven by factors, other than those ruling developed markets dynamics.

Cross-market causal linkages in variance (joint hypothesis).

Regarding the discussion on the different oil price effects on the countries with different economic profiles (Section 3.3) the findings question the necessity of controlling the oil price effect, when relationships between indices are observed. However, the results of non-causality hypothesis testing, after adjustment for the oil price, are not necessarily stable on the smaller sample sizes. This can be traced to the finding that the adjustment for the oil factor in full sample estimation induces emerging markets to be dependent on each other and to be less dependent on mature markets (variance causality to other countries from India and Russia, and rejection of the hypothesis of no

causality between India and Russia after controlling for the oil price), while it is not confirmed in the non-causality HRF pattern.

Besides the expected influence of the oil price on cross-market linkages of the countries with oil exporting status, no influence is found for Brazil's cross-market linkages. This may be partly explained by the fact that the strong dependency of Brazil on developed markets demonstrates that the regional proximity factor and same zone factor have a much more significant impact on causality in variance and the pattern remains strong, even after controlling the oil price effect.

Developed markets are more likely to have causality in variance compared to emerging ones. Moreover, results of developed markets variance interactions are more stable compared to emerging ones. This can be traced to the more stable C1-C2 non-causality HRF pattern, despite C3 in cases of emerging ones.

No significant effect on causality in variance, after adjustment for the oil price, is found between developed countries.

Stability testing in variance causality revealed that a full sample outcome might be a delusion, which demonstrates the necessity of stability testing.

Finally, for both mean and variance causalities between stock market indices, adjustment for the oil price does not demonstrate any significant changes when the causality test is applied in the Granger (1969) sense on a joint basis. The effect is detected for the mean causality from China to the US, as well as in the disappearance of variance causality from India to Germany and the US, disappearance of causality from the Russia to the US and appearance from Russia to India. However, the effect is mainly weak, due to the existence of the C3 non-causality HRF pattern, which usually becomes C2 after adjustment (the opposite is found for the Russia-India variance causality).

The drastic difference between full sample estimation and the estimation on smaller sample sizes demonstrates that comparability of studies using full sample estimation only is rather questionable, meaning that C1 will have greater evidence of the causal linkage than C3.

9. Conclusion

The main research objective in this thesis was to examine the oil price impact on cross market linkages. For this purpose the CCF causality test proposed by Cheung and Ng (1996) was applied. The examination of the linkages was performed both in causality-in-mean and causality-in-variance, while the impact of the oil price on these linkages is observed through the percentage change in magnitude of s-statistics significant CCF coefficients of the oil price adjusted and unadjusted models. The estimation procedure was applied using the Bessler and Yang (2003) daily non-synchronism correction restriction, while stability of percentage change sign (SP – Sign Prevalance) was obtained using the rolling window approach.

The model is applied on the BRIC and mature markets countries, while the oil price is represented by the BRENT crude oil price.

The use of a mix of countries with different oil status (exporter/self-sufficient/importer) and economic profile (emerging/developed) allows the organisation of different types of pairs, assuming that each pair has its own inherent specificity in reaction to the oil price.

The findings of the research demonstrate that that causality-in-mean of pairs with oil producing countries (exporter, self-sufficient) participation has a prominently negative reaction to oil price adjustment, also confirmed in SP. However, the variance causality of the same set of countries is expresses a similar result to the mean causality reaction with the exception of an increase in the CCF coefficient magnitude for Russia and the UK case not being confirmed in SP.

Interestingly, a negative reaction is also detected in the causal relationships between oil importing country groups, separately within the pairs of Emerging or Developed Importers. The decrease in magnitude of causality-in-mean in pairs with Developed markets is also confirmed in causality-in-variance with no change or fall in the magnitude of the CCF coefficients, after adjustment for the oil price, often with SP. The emerging market importer also demonstrates a decrease in causality-in-mean, while the variance causality response to the oil price cannot be tested, since no variance causality is found between participating Emerging Importers (India and China).

The types of country pairs, with a mix of oil producing (Exporter/Self-sufficient) and oil importing countries, show conflicting results, which do not permit a firm conclusion regarding the regularity in the oil price effect on cross-market linkages inside country pairs. Therefore, these combinations of pairs need further investigation in future studies.

The understanding of the oil price effect on stock market behaviour is given through the perspective of a study by Jones, *et al.* (2004, p. 24), who pointed out that the asset prices of oil related companies are to some extent, synchronised with the oil price dynamics, since asset prices are the present discounted value of the future net earnings of the oil firm. Thus, as suggested by Nandha and Faff (2008), oil price impacts should be quickly reflected in the dynamics of stocks, and this should be true both for the short and long term behaviour of the oil price.

Therefore, it is assumed that oil producing countries have embedded oil price dynamics in their stock market behaviour, while for the oil importing countries, the oil price component is expected to be incorporated as an unnecessary distortion.

This explanation conforms to the causal linkages in pairs with oil producing countries, since after adjustment for the oil price, the magnitude is decreased (mean/variance causality), meaning that the linkages between two oil producers are also due to the inclusion of the oil price component in the market dynamics.

However, the magnitude of CCF is also decreased in the case of oil importers, despite the expected no change or rise in magnitude. It is possible that this might be ascribed to the use of the BRENT crude oil price index recorded at 16.30 London time daily from the Intercontinental Exchange (ICE), assuming full or partial synchronisation with the European and US innovations. Therefore, an application with other types of crude oil (i.e. WTI, OPEC), presumably, may give different results.

Nevertheless, most of the percentage changes after the oil price adjustment, especially in contemporaneous terms, are less than 1% in absolute terms. However, higher lag causal linkages are often changed drastically, especially when oil related countries are participating. This raises the question of the potential necessity of controlling for the oil price effect, when cross-market linkages are observed, even in low CCF coefficients cases.

Application of the lags detected in CCF tests to the $ARMA(m,n)$ -EGARCH(p,q) model in order to examine how the oil price affects the cross-market causality in the Granger (1969) sense observed on joint test bases, demonstrated no significant effect. In those cases where the full sample estimation non-causality hypothesis testing result did change the result, it was found to be unstable in non-causality HRF.

Besides the primary objective of the research, the thesis observed the traditional issue of the oil price effect on stock market linkages and examination of level of integration through analysis of cross market linkages.

The examination of the oil price impact in CCF causality test and $ARMA(m,n)$ -EGARCH(p,q) joint causality test on stock market behaviour performed in this thesis remains in line with previous studies, confirming that the oil status (exporter/importer) of a country predetermines the response to the oil price (exporter behaviour). Moreover, the oil price impact on stock market behaviour in variance conforms to the study by Ramos and Veiga (2009; 2010), where the authors detected small and insignificant differences in oil price volatility on the behaviour of emerging stock markets, despite a large and significant developed market case. The CCF coefficients revealed the lack of causality-in-mean between the oil price and emerging markets, while developed markets demonstrated multiple interactions at different lags.

At this point it is necessary to point out additional areas that may provide opportunities for future research within this subject area. These include:

- The examination of a larger number of series to determine what the oil price effect is on a cross-market linkages scheme of estimation using the CCF test.
- The application of additional economic variables might be applied together with the oil price impact, e.g. the exchange rate, regional and global indices.
- Attempting to identify factors other than crude oil that may have a strong effect on cross-market linkages.
- Identifying whether the codes used in this study might be easily used for a greater number of series and different influencing factors, together with a different non-synchronism correction matrix, in full sample or rolling estimation techniques.

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A. Appendices of schemes and equation outcomes

A.1. Oil production and consumption of participating countries.

Figure A.1-1

Oil production and consumption diagrams of Japan, Germany, France, UK and US.

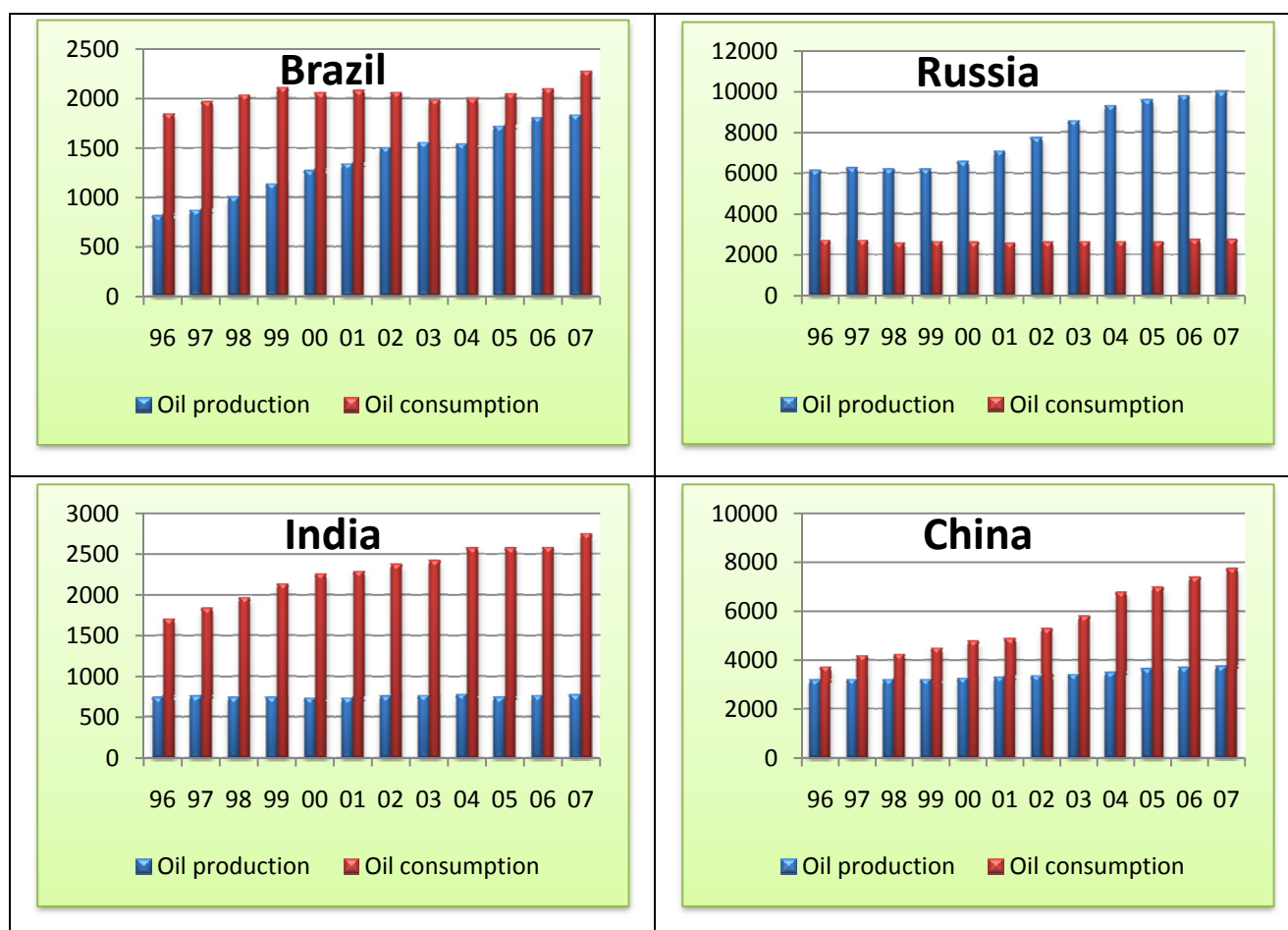


Note: Horizontal axis represent year and the vertical axis represents consumption/production oil in million tonnes.

Source: Graphs constructed using data gathered from BP Energy report data (Source: BP. Energy report 2008, data file).

Figure A.1-2

Oil production and consumption diagrams of Brazil, Russia, India and China.



Note: Horizontal axis represent year and the vertical axis represents oil in million tonnes.

Source: Graphs constructed using data gathered from BP Energy report data (Source: BP. Energy report 2008, data file).

A.2. Regression full sample output.

Table A.2-1

The output of the equations (4),(5) solved in full sample assuming classic form of Granger causality.

Test for direction	Relation	SIC lag	Constant	Alfa -1	Alfa -2	Alfa -3	Beta 0	Beta -1	Beta -2	Beta -3	Heteroscedasticity	NW correction	Wald test. All beta = 0
CH-->JP	N. day	1	-0.0106*	-0.0376			-0.0047						
JP-->CH	N. day	1	0.0779	-0.0069			0.0364				Rej. 5%	NW	
IN-->JP	N. day	1	-0.0158**	-0.0527**			0.0753**						Rej. 1%
JP-->IN	N. day	1	0.0550**	0.1096			-0.0242				Rej. 5%	NW	
IN-->CH	N. day	1	0.0757	-0.0067			0.0295				Rej. 5%	NW	
CH-->IN	N. day	1	0.0555**	0.1054			0.0003				Rej. 5%	NW	
RU-->JP	N. day	1	-0.0171**	-0.0530**			0.0554**						Rej. 1%
JP-->RU	N. day	1	0.0924**	0.1219			-0.0626				Rej. 5%	NW	Rej. 5%
RU-->CH	N. day	1	0.0756	-0.0053			0.0172				Rej. 5%	NW	
CH-->RU	N. day	1	0.0985**	0.1167			-0.0638				Rej. 5%	NW	
RU-->IN	N. day	1	0.0529**	0.0967**			0.0302**				Rej. 5%	NW	Rej. 1%
IN-->RU	N. day	1	0.0939**	0.117			-0.0051				Rej. 5%	NW	
GE-->JP	N. day	1	-0.0232**	-0.0859**			0.2651**						Rej. 1%
JP-->GE	N. day	1	0.0431	-0.0008			-0.0192				Rej. 5%	NW	
GE-->CH	N. day	1	0.0745	-0.0053**			0.0648**				Rej. 5%	NW	Rej. 1%
CH-->GE	N. day	1	0.0438	-0.0047			-0.0053				Rej. 5%	NW	
GE-->IN	N. day	1	0.0503**	0.0883**			0.1419**				Rej. 5%	NW	Rej. 1%
IN-->GE	N. day	1	0.043	-0.006			0.0082				Rej. 5%	NW	
GE-->RU	N. day	1	0.0923**	0.1092			0.0488				Rej. 5%	NW	
RU-->GE	N. day	1	0.0427	-0.0093			0.0089				Rej. 5%	NW	
FR-->JP	N. day	1	-0.0234**	-0.0916**			0.3085**						Rej. 1%
JP-->FR	N. day	1	0.0356	0.0366			-0.0365				Rej. 5%	NW	
FR-->CH	N. day	1	0.075	-0.0046**			0.0622**				Rej. 5%	NW	Rej. 1%
CH-->FR	N. day	1	0.0373	0.0275			-0.0122				Rej. 5%	NW	
FR-->IN	N. day	1	0.0517**	0.0891**			0.1256**				Rej. 5%	NW	Rej. 1%
IN-->FR	N. day	1	0.0366	0.0285			-0.004				Rej. 5%	NW	
FR-->RU	N. day	1	0.0922**	0.1082			0.0616				Rej. 5%	NW	
RU-->FR	N. day	1	0.0362	0.0264			0.0021				Rej. 5%	NW	
FR-->GE	N. day	1	0.0426**	-0.0927**			0.1223**				Rej. 5%	NW	Rej. 1%
GE-->FR	N. day	1	0.0352*	-0.0814**			0.1219**				Rej. 5%	NW	Rej. 1%
UK-->JP	N. day	1	-0.0216**	-0.0884**			0.3662**						Rej. 1%
JP-->UK	N. day	1	0.0261	0.021			-0.0238				Rej. 5%	NW	
UK-->CH	N. day	1	0.075	-0.0052**			0.0889**				Rej. 5%	NW	Rej. 1%
CH-->UK	N. day	1	0.0274	0.0134			-0.0107				Rej. 5%	NW	
UK-->IN	N. day	1	0.0517**	0.0850**			0.1855**				Rej. 5%	NW	Rej. 1%
IN-->UK	N. day	1	0.0273	0.0171			-0.0129				Rej. 5%	NW	
UK-->RU	N. day	1	0.0918**	0.1043*			0.1152*				Rej. 5%	NW	Rej. 5%
RU-->UK	N. day	1	0.0261	0.0085			0.0063				Rej. 5%	NW	
UK-->GE	N. day	1	0.0432	-0.0274			0.047				Rej. 5%	NW	
GE-->UK	N. day	1	0.0252*	-0.0683**			0.0821**				Rej. 5%	NW	Rej. 1%
UK-->FR	N. day	1	0.0364	0.0386			-0.0182				Rej. 5%	NW	
FR-->UK	N. day	1	0.0259	-0.0509*			0.0647*				Rej. 5%	NW	Rej. 5%
BR-->JP	N. day	1	-0.0200**	-0.0617**			0.1300**						Rej. 1%
JP-->BR	N. day	1	0.0602**	0.0873			-0.0075				Rej. 5%	NW	
BR-->CH	N. day	1	0.0751	-0.0054**			0.0336**				Rej. 5%	NW	Rej. 1%
CH-->BR	N. day	1	0.0625**	0.0869			-0.0278				Rej. 5%	NW	
BR-->IN	N. day	1	0.0504**	0.0877**			0.0927**				Rej. 5%	NW	Rej. 1%
IN-->BR	N. day	1	0.0609**	0.0876			-0.0104				Rej. 5%	NW	
BR-->RU	N. day	1	0.0847**	0.0778**			0.1934**				Rej. 5%	NW	Rej. 1%
RU-->BR	N. day	1	0.0604**	0.0868			-0.0004				Rej. 5%	NW	
BR-->GE	N. day	1	0.0397*	-0.0573**			0.0894**				Rej. 5%	NW	Rej. 1%
GE-->BR	N. day	1	0.0600**	0.0842			0.0125				Rej. 5%	NW	
BR-->FR	N. day	1	0.033	-0.0253**			0.0792**				Rej. 5%	NW	Rej. 1%
FR-->BR	N. day	1	0.0603**	0.0866			0.0005				Rej. 5%	NW	
BR-->UK	N. day	1	0.0234*	-0.0482**			0.0724**				Rej. 5%	NW	Rej. 1%
UK-->BR	N. day	1	0.0608**	0.0905			-0.027				Rej. 5%	NW	
US-->JP	N. day	1	-0.0266**	-0.0648**			0.4621**						Rej. 1%
JP-->US	N. day	1	0.0319	0.0109			-0.0276				Rej. 5%	NW	
US-->CH	N. day	1	0.0747	-0.0046*			0.0801*				Rej. 5%	NW	Rej. 5%
CH-->US	N. day	1	0.0329	0.0067			-0.0063				Rej. 5%	NW	
US-->IN	N. day	1	0.0485**	0.0945**			0.2328**				Rej. 5%	NW	Rej. 1%
IN-->US	N. day	1	0.0327	0.0076			-0.0053				Rej. 5%	NW	
US-->RU	N. day	1	0.0794**	0.0857**			0.5298**				Rej. 5%	NW	Rej. 1%
RU-->US	N. day	1	0.0328	0.0089			-0.0045				Rej. 5%	NW	
US-->GE	N. day	2	0.0340**	-0.1864**	-0.0699**		0.4750**		0.1302**		Rej. 5%	NW	Rej. 1%
GE-->US	N. day	1	0.0322	0.0009			0.0079				Rej. 5%	NW	
US-->FR	N. day	1	0.0277**	-0.1354**			0.4508**				Rej. 5%	NW	Rej. 1%
FR-->US	N. day	1	0.032	-0.0054			0.0191				Rej. 5%	NW	
US-->UK	N. day	3	0.0182**	-0.1914**	-0.0982**	-0.0883**	0.3969**		0.1073**	0.0709*	Rej. 5%	NW	Rej. 1%
UK-->US	N. day	1	0.0323	0.0048			0.0043				Rej. 5%	NW	
US-->BR	N. day	1	0.0580**	0.0637			0.1194				Rej. 5%	NW	
BR-->US	N. day	1	0.0325	0.0135			-0.0053				Rej. 5%	NW	
OIL-->JP	N. day	1	-0.0111*	-0.0379			0.0008						
JP-->OIL	N. day	1	0.0497*	0.0359			0.0537				Rej. 5%	NW	
OIL-->CH	N. day	1	0.0768	-0.0048			0.011				Rej. 5%	NW	
CH-->OIL	N. day	1	0.0485*	0.0371			0.0069				Rej. 5%	NW	
OIL-->IN	N. day	1	0.0556**	0.1054			-0.0019				Rej. 5%	NW	
IN-->OIL	N. day	1	0.0493*	0.037			-0.0046				Rej. 5%	NW	
OIL-->RU	N. day	1	0.0922**	0.1141			0.0332				Rej. 5%	NW	
RU-->OIL	N. day	1	0.0497*	0.0377			-0.0065				Rej. 5%	NW	
OIL-->GE	N. day	1	0.0431	-0.0048			0.0064				Rej. 5%	NW	
GE-->OIL	N. day	1	0.0470*	0.0368			0.0454				Rej. 5%	NW	
OIL-->FR	N. day	1	0.0363	0.0276			0.0007				Rej. 5%	NW	
FR-->OIL	N. day	1	0.0475*	0.0365			0.04				Rej. 5%	NW	
OIL-->UK	N. day	1	0.027	0.014			-0.007				Rej. 5%	NW	
UK-->OIL	N. day	1	0.0477*	0.036			0.0515				Rej. 5%	NW	
OIL-->BR	N. day	1	0.0597**	0.0865			0.0119				Rej. 5%	NW	
BR-->OIL	N. day	1	0.0467*	0.0361*			0.0356*				Rej. 5%	NW	Rej. 5%
OIL-->US	N. day	1	0.0324	0.0068			-0.0004				Rej. 5%	NW	
US-->OIL	N. day	1	0.0457*	0.0374*			0.0993*				Rej. 5%	NW	Rej. 5%

Table A.2-2

The output of the equations (8),(9) solved in full sample assuming correction for non-synchronism Table 5.1-2.

Test for direction	Relation	SIC lag	Constant	Alfa -1	Alfa -2	Alfa -3	Beta 0	Beta -1	Beta -2	Beta -3	Heteroscedasticity	NW correction	Wald test. All beta = 0
CH->JP	S.day	1	-0.0150*	-0.0397**			0.0520**						Rej. 1%
JP->CH	S.day	1	0.078	-0.0047**			0.0579**						Rej. 1%
IN->JP	S.day	2	-0.0255**	-0.0506**	-0.0503**			0.0573**			Rej. 5%	NW	Rej. 1%
JP->IN	S.day	1	0.0583**	0.0928**							Rej. 5%	NW	Rej. 1%
IN->CH	S.day	1	0.074	-0.0054**			0.0552**				Rej. 5%	NW	Rej. 1%
CH->IN	S.day	1	0.0516**	0.1039**			0.0524**				Rej. 5%	NW	Rej. 1%
RU->JP	N.day	1	-0.0171**	-0.0530**				0.0554**					Rej. 1%
JP->RU	S.day	1	0.0978**	0.1034**			0.2561**				Rej. 5%	NW	Rej. 1%
RU->CH	N.day	1	0.0756	-0.0053				0.0172			Rej. 5%	NW	
CH->RU	S.day	1	0.0930**	0.1163			0.0084				Rej. 5%	NW	
RU->IN	S.day	1	0.0446**	0.1024**			0.1052**				Rej. 5%	NW	Rej. 1%
IN->RU	S.day	1	0.0777**	0.1052**			0.2757**				Rej. 5%	NW	Rej. 1%
GE->JP	N.day	1	-0.0232**	-0.0859**				0.2651**					Rej. 1%
JP->GE	S.day	1	0.0476*	-0.0524**			0.1928**				Rej. 5%	NW	Rej. 1%
GE->CH	N.day	1	0.0745	-0.0053**				0.0648**			Rej. 5%	NW	Rej. 1%
CH->GE	S.day	1	0.0431	-0.005			0.0041				Rej. 5%	NW	
GE->IN	S.day	2	0.0444**	0.0878	-0.0078**		0.1561**	0.1430**			Rej. 5%	NW	Rej. 1%
IN->GE	S.day	1	0.0366	-0.0239**			0.1231**				Rej. 5%	NW	Rej. 1%
GE->RU	S.day	1	0.0719**	0.1125**			0.5112**				Rej. 5%	NW	Rej. 1%
RU->GE	S.day	1	0.0285	-0.0202**			0.1474**				Rej. 5%	NW	Rej. 1%
FR->JP	N.day	1	-0.0234**	-0.0916**				0.3085**					Rej. 1%
JP->FR	S.day	1	0.0402	-0.0235**			0.1791**				Rej. 5%	NW	Rej. 1%
FR->CH	N.day	1	0.075	-0.0046**				0.0622**			Rej. 5%	NW	Rej. 1%
CH->FR	S.day	1	0.037	0.0282			-0.0082				Rej. 5%	NW	
FR->IN	S.day	2	0.0447**	0.0901	-0.0027**		0.2071**	0.1201**			Rej. 5%	NW	Rej. 1%
IN->FR	S.day	1	0.029	0.0090**			0.1293**				Rej. 5%	NW	Rej. 1%
FR->RU	S.day	1	0.0722**	0.1131**			0.5810**				Rej. 5%	NW	Rej. 1%
RU->FR	S.day	1	0.0228	0.0110**			0.1335**				Rej. 5%	NW	Rej. 1%
FR->GE	S.day	3	0.0077**	-0.2157	-0.0401**	0.0397**	0.9089**	0.2109**	0.0730**		Rej. 5%	NW	Rej. 1%
GE->FR	S.day	3	0.0077**	-0.1804*	-0.0554**	-0.0551**	0.7258**	0.1987**	0.017		Rej. 5%	NW	Rej. 1%
UK->JP	N.day	1	-0.0216**	-0.0884**				0.3662**					Rej. 1%
JP->UK	S.day	1	0.0294	-0.0349**			0.1430**				Rej. 5%	NW	Rej. 1%
UK->CH	N.day	1	0.075	-0.0052**				0.0889**			Rej. 5%	NW	Rej. 1%
CH->UK	S.day	1	0.0265	0.0132			0.0009				Rej. 5%	NW	
UK->IN	S.day	2	0.0441**	0.0891	-0.0035**		0.2949**	0.1803**			Rej. 5%	NW	Rej. 1%
IN->UK	S.day	1	0.0204	-0.0099**			0.1107**				Rej. 5%	NW	Rej. 1%
UK->RU	S.day	1	0.0738**	0.1109**			0.7567**				Rej. 5%	NW	Rej. 1%
RU->UK	S.day	1	0.016	-0.0071**			0.1055**				Rej. 5%	NW	Rej. 1%
UK->GE	S.day	2	0.0177**	-0.1111	-0.0075**		1.0043**	0.1175**			Rej. 5%	NW	Rej. 1%
GE->UK	S.day	3	0.0063**	-0.0957	-0.0349**	-0.0534**	0.4826**	0.0974**	0.0129		Rej. 5%	NW	Rej. 1%
UK->FR	S.day	1	0.0108	-0.0063**			0.9933**				Rej. 5%	NW	Rej. 1%
FR->UK	S.day	1	0.0045	0.0013**			0.5984**				Rej. 5%	NW	Rej. 1%
BR->JP	N.day	1	-0.0200**	-0.0617**				0.1300**					Rej. 1%
JP->BR	S.day	1	0.0634**	0.0664**			0.1617**				Rej. 5%	NW	Rej. 1%
BR->CH	N.day	1	0.0751	-0.0054**				0.0336**			Rej. 5%	NW	Rej. 1%
CH->BR	S.day	1	0.0599**	0.0865			0.0061				Rej. 5%	NW	
BR->IN	N.day	1	0.0504**	0.0877**				0.0927**			Rej. 5%	NW	Rej. 1%
IN->BR	S.day	1	0.0506**	0.0691**			0.1757**				Rej. 5%	NW	Rej. 1%
BR->RU	S.day	2	0.0716**	0.0776	0.0018**		0.2241**	0.1741**			Rej. 5%	NW	Rej. 1%
RU->BR	S.day	1	0.0428*	0.0461**			0.1915**				Rej. 5%	NW	Rej. 1%
BR->GE	S.day	2	0.0289**	-0.0603	-0.0251**		0.1967**	0.0735**			Rej. 5%	NW	Rej. 1%
GE->BR	S.day	1	0.0384*	0.0417**			0.5784**				Rej. 5%	NW	Rej. 1%
BR->FR	S.day	3	0.027	-0.0245	-0.0293**	-0.0653**	0.1801**	0.0659**	-0.0124		Rej. 5%	NW	Rej. 1%
FR->BR	S.day	1	0.039	0.0376**			0.6587**				Rej. 5%	NW	Rej. 1%
BR->UK	S.day	3	0.0187	-0.0419	-0.0217**	-0.0696**	0.1368**	0.0612**	-0.0139		Rej. 5%	NW	Rej. 1%
UK->BR	S.day	1	0.0414	0.0317**			0.8377**				Rej. 5%	NW	Rej. 1%
US->JP	N.day	1	-0.0266**	-0.0648**				0.4621**					Rej. 1%
JP->US	S.day	1	0.034	-0.0211**			0.0620**				Rej. 5%	NW	Rej. 1%
US->CH	N.day	1	0.0747	-0.0046*				0.0801*			Rej. 5%	NW	Rej. 5%
CH->US	S.day	1	0.0328	0.0073			-0.0061				Rej. 5%	NW	
US->IN	N.day	1	0.0485**	0.0945**				0.2328**			Rej. 5%	NW	Rej. 1%
IN->US	S.day	1	0.0298	-0.0047**			0.0473**				Rej. 5%	NW	Rej. 1%
US->RU	N.day	1	0.0794**	0.0857**				0.5298**			Rej. 5%	NW	Rej. 1%
RU->US	S.day	1	0.0271	-0.0271**			0.0598**				Rej. 5%	NW	Rej. 1%
US->GE	S.day	3	0.0088**	-0.1940**	-0.0594	0.0097**	0.7516**	0.4757**	0.1406**		Rej. 5%	NW	Rej. 1%
GE->US	S.day	2	0.0209**	-0.1731*	-0.0523**		0.3667**	0.0767**			Rej. 5%	NW	Rej. 1%
US->FR	S.day	3	0.0086**	-0.1757**	-0.0699**	-0.0515**	0.6450**	0.4730**	0.1029**		Rej. 5%	NW	Rej. 1%
FR->US	S.day	2	0.0223**	-0.1922*	-0.0433**		0.3986**	0.0847**			Rej. 5%	NW	Rej. 1%
US->UK	S.day	3	0.0039**	-0.1895**	-0.0647**	-0.0531**	0.4620**	0.3920**	0.1011**		Rej. 5%	NW	Rej. 1%
UK->US	S.day	2	0.0247**	-0.1876*	-0.0520**		0.4864**	0.0962**			Rej. 5%	NW	Rej. 1%
US->BR	S.day	1	0.0196**	0.0901**			1.2410**				Rej. 5%	NW	Rej. 1%
BR->US	S.day	1	0.0208	-0.0315**			0.1936**				Rej. 5%	NW	Rej. 1%
OIL->JP	S.day	1	-0.0121*	-0.0391			0.0218						
JP->OIL	S.day	1	0.0495*	0.037			0.0447				Rej. 5%	NW	
OIL->CH	S.day	1	0.0779	-0.005			-0.0107				Rej. 5%	NW	
CH->OIL	S.day	1	0.0506*	0.0373			-0.021				Rej. 5%	NW	
OIL->IN	S.day	1	0.0554**	0.1054			0.003				Rej. 5%	NW	
IN->OIL	S.day	1	0.0487*	0.037			0.0052				Rej. 5%	NW	
OIL->RU	S.day	1	0.0884**	0.1168**			0.1017**				Rej. 5%	NW	Rej. 1%
RU->OIL	S.day	1	0.0419*	0.0339**			0.0689**				Rej. 5%	NW	Rej. 1%
OIL->GE	S.day	1	0.0432	-0.0049			0.0048				Rej. 5%	NW	
GE->OIL	S.day	1	0.0486*	0.037			0.0108				Rej. 5%	NW	
OIL->FR	S.day	1	0.0357	0.0271			0.0124				Rej. 5%	NW	
FR->OIL	S.day	1	0.0476*	0.037			0.0386				Rej. 5%	NW	
OIL->UK	S.day	1	0.0257	0.0123			0.0188				Rej. 5%	NW	
UK->OIL	S.day	1	0.0464*	0.0377			0.0964				Rej. 5%	NW	
OIL->BR	S.day	1	0.0593**	0.0859			0.0211				Rej. 5%	NW	
BR->OIL	S.day	1	0.0477*	0.0367			0.0202				Rej. 5%	NW	
OIL->US	S.day	1	0.0326	0.0073			-0.0042				Rej. 5%	NW	
US->OIL	S.day	1	0.0497*	0.037			-0.0219				Rej. 5%	NW	

Table A.2-3

The output of the equations (8),(9)

solved in full sample assuming correction after the shift in GMT line
presented in Table 7.2-5.

Pair direction	Relation	SIC lag	Constant	Alfa -1	Alfa -2	Alfa -3	Beta 0	Beta -1	Beta -2	Beta -3	Heteroscedasticity	NW correction	Wald test. All beta = 0
CH-->JP	N.day	1	-0.0106*	-0.0376				-0.0047					
JP-->CH	N.day	1	7.79E-02	-0.0069				0.0364			Rej. 5%	NW	
IN-->JP	N.day	1	-0.0158**	-0.0527**				.0753**					Rej. 1%
JP-->IN	N.day	1	0.0550**	0.1096				-0.0242			Rej. 5%	NW	
IN-->CH	N.day	1	7.57E-02	-0.0067				0.0295			Rej. 5%	NW	
CH-->IN	N.day	1	0.0555**	0.1054				0.0003			Rej. 5%	NW	
RU-->JP	N.day	1	-0.0171**	-0.0530**				.0554**					Rej. 1%
JP-->RU	N.day	1	0.0924**	0.1219				-0.0626			Rej. 5%	NW	Rej. 5%
RU-->CH	N.day	1	7.56E-02	-0.0053				0.0172			Rej. 5%	NW	
CH-->RU	N.day	1	0.0985**	0.1167				-0.0638			Rej. 5%	NW	
RU-->IN	N.day	1	0.0529**	0.0967**				.0302**			Rej. 5%	NW	Rej. 1%
IN-->RU	N.day	1	0.0939**	0.117				-0.0051			Rej. 5%	NW	
GE-->JP	N.day	1	-0.0232**	-0.0859**				.2651**					Rej. 1%
JP-->GE	N.day	1	4.31E-02	-0.0008				-0.0192			Rej. 5%	NW	
GE-->CH	N.day	1	7.45E-02	-0.0053**				.0648**			Rej. 5%	NW	Rej. 1%
CH-->GE	N.day	1	4.38E-02	-0.0047				-0.0053			Rej. 5%	NW	
GE-->IN	N.day	1	0.0503**	0.0883**				.1419**			Rej. 5%	NW	Rej. 1%
IN-->GE	N.day	1	4.30E-02	-0.006				0.0082			Rej. 5%	NW	
GE-->RU	N.day	1	0.0923**	0.1092				0.0488			Rej. 5%	NW	
RU-->GE	N.day	1	4.27E-02	-0.0093				0.0089			Rej. 5%	NW	
FR-->JP	N.day	1	-0.0234**	-0.0916**				.03085**					Rej. 1%
JP-->FR	N.day	1	3.56E-02	0.0366				-0.0365			Rej. 5%	NW	
FR-->CH	N.day	1	7.50E-02	-0.0046**				0.0622**			Rej. 5%	NW	Rej. 1%
CH-->FR	N.day	1	3.73E-02	0.0275				-0.0122			Rej. 5%	NW	
FR-->IN	N.day	1	0.0517**	0.0891**				.1256**			Rej. 5%	NW	Rej. 1%
IN-->FR	N.day	1	3.66E-02	0.0285				-0.004			Rej. 5%	NW	
RU-->FR	N.day	1	0.0922**	0.1082				0.0616			Rej. 5%	NW	
FR-->RU	N.day	1	3.62E-02	0.0264				0.0021			Rej. 5%	NW	
FR-->GE	N.day	1	0.0426**	-0.0927**				.1223**			Rej. 5%	NW	Rej. 1%
GE-->FR	N.day	1	0.0352*	-0.0814**				.1219**			Rej. 5%	NW	Rej. 1%
UK-->JP	N.day	1	-0.0216**	-0.0884**				.3662**					Rej. 1%
JP-->UK	N.day	1	2.61E-02	0.021				-0.0238			Rej. 5%	NW	
UK-->CH	N.day	1	7.50E-02	-0.0052**				.0889**			Rej. 5%	NW	Rej. 1%
CH-->UK	N.day	1	2.74E-02	0.0134				-0.0107			Rej. 5%	NW	
UK-->IN	N.day	1	0.0517**	0.0850**				.1855**			Rej. 5%	NW	Rej. 1%
IN-->UK	N.day	1	2.73E-02	0.0171				-0.0129			Rej. 5%	NW	
UK-->RU	N.day	1	0.0918**	0.1043*				0.1152*			Rej. 5%	NW	Rej. 5%
RU-->UK	N.day	1	2.61E-02	0.0085				0.0063			Rej. 5%	NW	
UK-->GE	N.day	1	4.32E-02	-0.0274				0.047			Rej. 5%	NW	
GE-->UK	N.day	1	0.0252*	-0.0683**				0.0821**			Rej. 5%	NW	Rej. 1%
UK-->FR	N.day	1	3.64E-02	0.0386				-0.0182			Rej. 5%	NW	
FR-->UK	N.day	1	2.59E-02	-0.0509*				0.0647*			Rej. 5%	NW	Rej. 5%
BR-->JP	N.day	1	-0.0200**	-0.0617**				0.1300**			Rej. 5%	NW	Rej. 1%
JP-->BR	N.day	1	0.0602**	0.0873				-0.0075			Rej. 5%	NW	
BR-->CH	N.day	1	7.51E-02	-0.0054**				0.0336**			Rej. 5%	NW	Rej. 1%
CH-->BR	N.day	1	0.0625**	0.0869				-0.0278			Rej. 5%	NW	
BR-->IN	N.day	1	0.0504**	0.0877**				0.0927**			Rej. 5%	NW	Rej. 1%
IN-->BR	N.day	1	0.0609**	0.0876				-0.0104			Rej. 5%	NW	
BR-->RU	N.day	1	0.0847**	0.0778**				0.1934**			Rej. 5%	NW	Rej. 1%
RU-->BR	N.day	1	0.0604**	0.0868				-0.0004			Rej. 5%	NW	
BR-->GE	N.day	1	0.0397*	-0.0573**				0.0894**			Rej. 5%	NW	Rej. 1%
GE-->BR	N.day	1	0.0600**	0.0842				0.0125			Rej. 5%	NW	
BR-->FR	N.day	1	3.30E-02	-0.0253**				0.0792**			Rej. 5%	NW	Rej. 1%
FR-->BR	N.day	1	0.0603**	0.0866				0.0005			Rej. 5%	NW	
BR-->UK	N.day	1	0.0234*	-0.0482**				0.0724**			Rej. 5%	NW	Rej. 1%
UK-->BR	N.day	1	0.0608**	0.0905				-0.027			Rej. 5%	NW	
US-->JP	Lag 2	1	-0.0136**	-0.0517**					0.0763**				Rej. 1%
JP-->US	S.day	1	3.40E-02	-0.0211**			0.0620**				Rej. 5%	NW	Rej. 1%
US-->CH	Lag 2	1	7.66E-02	-0.0052					0.0165		Rej. 5%	NW	
CH-->US	S.day	1	3.28E-02	0.0073			-0.0061				Rej. 5%	NW	
US-->IN	Lag 2	1	0.0541**	0.1002					0.0601		Rej. 5%	NW	
IN-->US	S.day	1	2.98E-02	-0.0047**			0.0473**				Rej. 5%	NW	Rej. 1%
US-->RU	Lag 2	1	0.0953**	0.1211					-0.0639		Rej. 5%	NW	
RU-->US	S.day	1	2.71E-02	-0.0271**			0.0598**				Rej. 5%	NW	Rej. 1%
US-->GE	Lag 2	1	4.24E-02	-0.0083					0.0213		Rej. 5%	NW	
GE-->US	S.day	2	0.0209**	-0.1731*	-0.0523**		0.3667**	0.0767**			Rej. 5%	NW	Rej. 1%
US-->FR	Lag 2	1	3.67E-02	0.0333					-0.0301		Rej. 5%	NW	
FR-->US	S.day	2	0.0223**	-0.1922*	-0.0433**		0.3986**	0.0847**			Rej. 5%	NW	Rej. 1%
US-->UK	Lag 2	1	2.65E-02	0.0129					0.0012		Rej. 5%	NW	
UK-->US	S.day	2	0.0247**	-0.1876*	-0.0520**		0.4864**	0.0962**			Rej. 5%	NW	Rej. 1%
US-->BR	Lag 2	1	0.0617**	0.0893					-0.1056		Rej. 5%	NW	
BR-->US	S.day	1	2.08E-02	-0.0315**			0.1936**				Rej. 5%	NW	Rej. 1%
OIL-->JP	N.day	1	-0.0111*	-0.0379				0.0008					
JP-->OIL	N.day	1	0.0497*	0.0359				0.0537			Rej. 5%	NW	
OIL-->CH	N.day	1	7.68E-02	-0.0048				0.011			Rej. 5%	NW	
CH-->OIL	N.day	1	0.0485*	0.0371				0.0069			Rej. 5%	NW	
OIL-->IN	N.day	1	0.0556**	0.1054				-0.0019			Rej. 5%	NW	
IN-->OIL	N.day	1	0.0493*	0.037				-0.0046			Rej. 5%	NW	
OIL-->RU	N.day	1	0.0922**	0.1141				0.0332			Rej. 5%	NW	
RU-->OIL	N.day	1	0.0497*	0.0377				-0.0065			Rej. 5%	NW	
OIL-->GE	N.day	1	4.31E-02	-0.0048				0.0064			Rej. 5%	NW	
GE-->OIL	N.day	1	0.0470*	0.0368				0.0454			Rej. 5%	NW	
OIL-->FR	N.day	1	3.63E-02	0.0276				0.0007			Rej. 5%	NW	
FR-->OIL	N.day	1	0.0475*	0.0365				0.04			Rej. 5%	NW	
OIL-->UK	N.day	1	2.70E-02	0.014				-0.007			Rej. 5%	NW	
UK-->OIL	N.day	1	0.0477*	0.036				0.0515			Rej. 5%	NW	
OIL-->BR	N.day	1	0.0597**	0.0865				0.0119			Rej. 5%	NW	
BR-->OIL	N.day	1	0.0467*	0.0361*				0.0356*			Rej. 5%	NW	Rej. 5%
OIL-->US	S.day	1	3.26E-02	0.0073			-0.0042				Rej. 5%	NW	
US-->OIL	Lag 2	1	0.0490*	0.0371					-0.006		Rej. 5%	NW	

A.3. CCF test output

Table A.3-1

Cheung and Ng (1996) causality in mean detected at a certain lag between series from standardized residuals extracted from equation (14).

Pair direction	Lead						Lag						
	X - Y	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
CH - JP							0.0591	0.0591	0.0372	-0.036			
IN - JP						0.0696	0.1719	0.1719					
IN - CH							0.0626	0.0626					
RU - JP						0.1191	NA	0.1498					
RU - CH				0.0417			NA		-0.0449				
RU - IN						0.0567	0.1769	0.1769					
GE - JP						0.2233	NA	0.2324		-0.0399			
GE - CH		0.0416				0.0621	NA						
GE - IN			0.0637			0.1216	0.1505	0.1505					
GE - RU						0.0642	0.2716	0.2716					
FR - JP					0.039	0.237	NA	0.2304	-0.0408	-0.0443			
FR - CH		0.0456				0.0521	NA						
FR - IN			0.0619	0.0428		0.1	0.1709	0.1709					
FR - RU						0.0672	0.2791	0.2791					
FR - GE						0.0588	0.7851	0.7851	0.0363	-0.0399	-0.048		
UK - JP						0.212	NA	0.2304					
UK - CH		0.0576				0.0554	NA						
UK - IN			0.0577			0.113	0.1717	0.1717					
UK - RU		0.0472	0.0351			0.0761	0.2798	0.2798					
UK - GE						0.0403	0.6677	0.6677			-0.0369	0.0419	
UK - FR	-0.0565			-0.0363			0.7266	0.7266				0.0378	
BR - JP				0.0367	0.2032	NA	0.1159					0.0362	
BR - CH	0.0428					0.0353	NA						
BR - IN			0.0821			0.1309	NA	0.1246					
BR - RU		0.0492	0.0376	0.0421	0.1843	0.2186	0.2186						
BR - GE						0.1315	0.3581	0.3581				0.0466	
BR - FR						0.1374	0.3493	0.3493					
BR - UK	-0.0351					0.1518	0.3449	0.3449					
US - JP				0.0592		0.315	NA	0.0974	-0.037				
US - CH		0.0378				0.0451	NA					-0.0388	
US - IN		0.0402	0.0685	0.0533	0.157	NA	0.0816		0.0482				
US - RU			0.0411			0.2263	NA	0.1656					
US - GE						0.2554	0.4671	0.4671					
US - FR						0.2549	0.4592	0.4592	0.0475				
US - UK						0.2651	0.4388	0.4388					-0.0493
US - BR			0.0363			0.0517	0.4966	0.4966					
OIL - JP							0.0368	0.0368					
OIL - CH													
OIL - IN										0.0353	0.0395		
OIL - RU				0.0374	0.0361	0.094	0.094						
OIL - GE													
OIL - FR							0.0354	0.0354					
OIL - UK							0.0604	0.0604			0.0357		
OIL - BR							0.0376	0.0376	0.0479				
OIL - US	-0.0373								0.0598				

Notes: Detection of causality involves estimation of the S-statistics (18) for causality in mean, which has asymptotic Chi-square distribution. Since, S-statistics significance of the CCF lags is tested separately then degrees of freedom ($k-j+1$) is derived knowing that $j=k$, which represent the lag number under investigation. Negative lag column represents causality from X to Y (X Lead) and positive lags represent causality from Y to X (X Lag) only significant values are displayed.

Table A.3-2

Cheung and Ng (1996) causality in variance detected at a certain lag between series from standardized residuals extracted from equation (14).

Pair direction	Lead						Lag					
	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
CH - JP												
IN - JP				0.1239								
IN - CH												0.0353
RU - JP					0.0536	NA						
RU - CH						NA						
RU - IN										0.06		
GE - JP					0.0412	NA	0.0563					
GE - CH						NA						0.0482
GE - IN					0.0409	0.0641	0.0641	0.043				
GE - RU	0.0533		0.0425	0.0506		0.0727	0.0727					
FR - JP					0.062	NA	0.0601					
FR - CH						NA					0.046	
FR - IN					0.0654			0.0803				
FR - RU	0.0421			0.0501		0.0473	0.0473					
FR - GE					0.0683	0.8614	0.8614	0.0938	0.0406		0.0451	
UK - JP		0.0528			0.0725	NA						
UK - CH						NA						
UK - IN						0.0419	0.0419	0.0855				
UK - RU	0.1208	0.0371	0.0672	0.0575		0.0537	0.0537					
UK - GE						0.4887	0.4887	0.0373		-0.049		
UK - FR				0.0571		0.6771	0.6771	0.0435	0.0748			
BR - JP		0.0467		0.0418	0.08	NA						
BR - CH		0.0434		0.0876		NA	0.0462					
BR - IN		0.0467		0.0356	0.0392	NA		0.0716				
BR - RU			0.0767	0.0537	0.0902	0.0888	0.0888					
BR - GE			0.0388	0.049	0.0859	0.1129	0.1129				0.0385	
BR - FR		0.0421		0.0569	0.0526	0.152	0.152					
BR - UK					0.0517	0.1817	0.1817					
US - JP	0.0611					NA						
US - CH						NA	0.0963				0.0852	
US - IN	0.0361				0.0474	NA		0.0561				
US - RU					0.1131	NA	0.0606					
US - GE				0.0386	0.1119	0.2156	0.2156	0.0384			0.1288	
US - FR				0.0575	0.0413	0.2225	0.2225				0.0822	
US - UK						0.2101	0.2101		0.0516		0.0859	
US - BR				0.0388		0.2447	0.2447		0.1		0.0743	
OIL - JP												
OIL - CH												
OIL - IN												
OIL - RU												
OIL - GE						0.0381	0.0381					
OIL - FR						0.0601	0.0601					
OIL - UK						0.0392	0.0392		0.0498			
OIL - BR												
OIL - US		0.0352										0.0388

Notes: Detection of causality involves estimation of the S-statistics (19) for causality in variance, which has asymptotic Chi-square distribution. Since, S-statistics significance of the CCF lags is tested separately then degrees of freedom ($k-j+1$) is derived knowing that $j=k$, which represent the lag number under investigation. Negative lag column represents causality from X to Y (X Lead) and positive lags represent causality from Y to X (X Lag) only significant values are displayed.

Table A.3-3

Cheung and Ng (1996) causality in mean detected at a certain lag between series from standardized residuals extracted from oil price adjusted equation (20).

Pair direction	Lead						Lag						
	X - Y	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
CH - JP							0.0591	0.0591	0.0381				
IN - JP						0.0701	0.1722	0.1722					
IN - CH							0.0615	0.0615					
RU - JP						0.1193	NA	0.1462					
RU - CH				0.0432			NA		-0.0448				
RU - IN					0.0576	0.1784	0.1784						
GE - JP					0.2225	NA	0.232		-0.0395				
GE - CH		0.0417			0.0616	NA				0.0353			
GE - IN			0.0635		0.1219	0.1502	0.1502						
GE - RU					0.0617	0.2718	0.2718						
FR - JP				0.0377	0.2359	NA	0.2277	-0.0434	-0.044				
FR - CH		0.0463			0.052	NA							
FR - IN			0.0614	0.0424	0.0998	0.1697	0.1697						
FR - RU					0.064	0.2774	0.2774						
FR - GE					0.0573	0.7846	0.7846		-0.0394	-0.0482			
UK - JP					0.2118	NA	0.2294						-0.0353
UK - CH		0.059			0.0549	NA							
UK - IN			0.0576		0.1134	0.1723	0.1723						
UK - RU		0.0451			0.0731	0.2768	0.2768						
UK - GE					0.0391	0.668	0.668				-0.0378	0.0409	
UK - FR	-0.0567			-0.0356		0.7257	0.7257					0.0372	
BR - JP				0.037	0.2026	NA	0.1136					0.0364	
BR - CH	0.0433				0.0357	NA							
BR - IN			0.0804		0.1301	NA	0.124						
BR - RU		0.0542	0.037	0.042	0.1797	0.2167	0.2167						
BR - GE					0.1291	0.3587	0.3587					0.0456	
BR - FR					0.1315	0.3487	0.3487						
BR - UK	-0.0364				0.1485	0.3431	0.3431						
US - JP				0.0581	0.3115	NA	0.0972	-0.0372					
US - CH		0.0373			0.0463	NA						-0.0375	
US - IN		0.0382	0.0686	0.0514	0.1569	NA	0.0808		0.05				
US - RU			0.0419		0.2229	NA	0.1683						
US - GE					0.2555	0.4682	0.4682						
US - FR					0.2486	0.4599	0.4599	0.0492					
US - UK					0.2619	0.441	0.441						-0.0489
US - BR			0.0351		0.0493	0.4962	0.4962						

Notes: Detection of causality involves estimation of the S-statistics (18) for causality in mean, which has asymptotic Chi-square distribution. Since, S-statistics significance of the CCF lags is tested separately then degrees of freedom ($k-j+1$) is derived knowing that $j=k$, which represent the lag number under investigation. Negative lag column represents causality from X to Y (X Lead) and positive lags represent causality from Y to X (X Lag) only significant values are displayed.

Table A.3-4

Cheung and Ng (1996) causality in variance detected at a certain lag between series from standardized residuals extracted from oil price adjusted equation (20).

Pair direction	Lead						Lag					
X - Y	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
CH - JP												
IN - JP				0.1254								
IN - CH												
RU - JP	0.0356				0.0542	NA						
RU - CH						NA						
RU - IN					0.0358					0.0641		
GE - JP					0.041	NA	0.0553					
GE - CH						NA						0.0473
GE - IN					0.0408	0.0634	0.0634	0.0425				
GE - RU	0.0518			0.0476		0.0703	0.0703					
FR - JP					0.0571	NA	0.0543					
FR - CH						NA					0.0456	
FR - IN					0.0663			0.0797				
FR - RU	0.0403		0.0351	0.0503		0.0487	0.0487					
FR - GE					0.065	0.8583	0.8583	0.0593	0.039		0.0475	
UK - JP		0.0518			0.067	NA						
UK - CH						NA						
UK - IN					0.037	0.0415	0.0415	0.0816				
UK - RU	0.1179		0.0648	0.0633		0.0549	0.0549					
UK - GE						0.4935	0.4935	0.0379		-0.0479		
UK - FR				0.0438		0.6881	0.6881		0.0616			
BR - JP		0.0459		0.0418	0.079	NA						
BR - CH		0.0467		0.0929		NA	0.043					
BR - IN		0.0497		0.036	0.0391	NA		0.0689				
BR - RU			0.0686	0.047	0.0703	0.088	0.088					
BR - GE			0.0366	0.0456	0.0817	0.1161	0.1161				0.0381	
BR - FR		0.0434		0.0585	0.0516	0.1533	0.1533					
BR - UK					0.0493	0.1783	0.1783					
US - JP	0.0576					NA						
US - CH						NA	0.0865				0.0925	
US - IN	0.0374				0.0484	NA		0.0398				
US - RU					0.1092	NA	0.0566					
US - GE				0.0398	0.1058	0.2087	0.2087				0.1265	
US - FR				0.0579	0.037	0.2244	0.2244				0.0825	
US - UK						0.206	0.206		0.053		0.0904	
US - BR				0.0405		0.2488	0.2488		0.1028		0.0843	

Notes: Detection of causality involves estimation of the S-statistics (19) for causality in variance, which has asymptotic Chi-square distribution. Since, S-statistics significance of the CCF lags is tested separately then degrees of freedom ($k-j+1$) is derived knowing that $j=k$, which represent the lag number under investigation. Negative lag column represents causality from X to Y (X Lead) and positive lags represent causality from Y to X (X Lag) only significant values are displayed.

A.4. Oil price effect stability on stock market linkages.

Table A.4-1

Sign stability of the of oil price effect on the CCF causality-in-mean between stock market linkages.

Notes: The table provides compound of the consolidated statistics of the percentage change sign between oil unadjusted and oil adjusted cross-correlation coefficients performed on standardized residuals (causality-in-mean). The estimation of each pair of participating indices is performed using the rolling window, with descending window sizes, as discussed in Section 5.3 and Table 5.3-1. Column 1 represents the pair to be observed in the window size (Column 2), each with a total number of rolling sub-samples (Column 3). Values in columns 4-15 for full sample (Column 2, window size 3130) represent a percentage change after comparison between the oil unadjusted and adjusted forms of estimation, while window sizes from 2730 to 150 are recorded in a shorter form, for the purpose of the space conservation. For example, the record at column 9, pair CH-JP (windows size 2730) has value “100% + 42/- 54” which is interpreted as follows: at lag 0 from China to Japan in 100% of observed cases the relationship exists in both oil adjusted and unadjusted estimations, of which 42% of derived percentage changes had a positive sign and 54% had a negative sign. If frequency of appearance of one sign prevails or is equal to the other one in all window sizes (2730-150), then SP verdict is recorded in full sample line in the same column with ^(+SP) and ^(-SP) representing positive and negative SP respectively.

X – Y	Window size	Number rolling sub-samples	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CH-JP	3130	1						0%{-SP}	0%{-SP}	2.42%{-SP}				
2730	401							100% + 42/- 54	100% + 42/- 54	100% + 40/- 55	86% + 7/- 89		6% + 82/- 14	
1930	1201		0%/- 100		0% + 40/- 60		1% + 83/- 12	57% + 22/- 75	57% + 22/- 75	50% + 31/- 66	55% + 17/- 80		12% + 51/- 43	
1130	2001				6% + 77/- 21		2% + 20/- 76	47% + 22/- 73	47% + 22/- 73	13% + 39/- 58	15% + 23/- 75		4% + 58/- 38	9% + 72/- 27
330	2801		0% + 33/- 50	0%/- 100	1% + 50/- 43	0% + 100	1% + 61/- 37	17% + 41/- 56	17% + 41/- 56	3% + 36/- 62	9% + 56/- 42		0% + 37/- 59	3% + 73/- 26
250	2881		1% + 32/- 67	1% + 44/- 55	2% + 61/- 38	0% + 9/- 90	2% + 71/- 27	12% + 45/- 52	12% + 45/- 52	1% + 29/- 70	8% + 54/- 45		3% + 38/- 61	3% + 65/- 33
150	2981		1% + 47/- 52	2% + 63/- 36	2% + 58/- 41	0% + 38/- 61	3% + 57/- 42	8% + 46/- 52	8% + 46/- 52	2% + 44/- 55	2% + 45/- 54	2% + 61/- 38	3% + 41/- 58	1% + 25/- 74
IN-JP	3130	1					.72%	.17%{+SP}	.17%{+SP}					
2730	401					1% + 25/- 62	100% + 80/- 16	100% + 55/- 38	100% + 55/- 38					1% + 42/- 57
1930	1201				6% + 71/- 13	4% + 45/- 43	84% + 84/- 12	100% + 82/- 14	100% + 82/- 14		10% + 23/- 75			0% + 66/- 16
1130	2001		4% + 2/- 97		4% + 2/- 97	3% + 98/- 1	56% + 23/- 75	100% + 73/- 22	100% + 73/- 22	9% + 10/- 85	8% + 1/- 98	0% + 90/- 9	0%/- 100	13% + 8/- 90
330	2801		1% + 71/- 28	1% + 34/- 62	8% + 56/- 43	0% + 58/- 41	29% + 31/- 68	74% + 55/- 43	74% + 55/- 43	8% + 43/- 55	2% + 39/- 60	0% + 72/- 27	0% + 9/- 90	5% + 63/- 35
250	2881		4% + 71/- 28	0% + 20/- 80	9% + 50/- 48	2% + 78/- 20	24% + 41/- 58	64% + 52/- 47	64% + 52/- 47	7% + 58/- 41	4% + 48/- 52	4% + 55/- 44	0% + 22/- 77	3% + 71/- 28
150	2981		3% + 47/- 52	1% + 25/- 75	5% + 44/- 54	1% + 62/- 37	13% + 50/- 49	51% + 50/- 49	51% + 50/- 49	10% + 54/- 44	3% + 64/- 35	4% + 48/- 50	1% + 46/- 53	3% + 54/- 45
IN-CH	3130	1						-1.76%	-1.76%					
2730	401							100% + 45/- 49	100% + 45/- 49					
1930	1201							42% + 59/- 37	42% + 59/- 37				14% + 43/- 55	0% + 50/- 50
1130	2001					7% + 27/- 72		28% + 52/- 45	28% + 52/- 45				28% + 39/- 58	1% + 84/- 15
330	2801		0% + 52/- 47	3% + 45/- 54	2% + 63/- 35	8% + 46/- 53	6% + 33/- 65	17% + 43/- 55	17% + 43/- 55	0%/- 100		7% + 38/- 61	13% + 37/- 61	9% + 50/- 47
250	2881		3% + 48/- 50	2% + 56/- 43	2% + 45/- 54	10% + 53/- 46	5% + 29/- 69	13% + 35/- 64	13% + 35/- 64	0% + 42/- 50	0% + 66/- 33	7% + 34/- 65	14% + 37/- 61	7% + 54/- 45
150	2981		2% + 38/- 60	3% + 61/- 37	3% + 58/- 41	6% + 44/- 55	3% + 59/- 38	12% + 41/- 58	12% + 41/- 58	1% + 55/- 44	0% + 80/- 20	5% + 40/- 58	9% + 46/- 52	5% + 50/- 49
RU-JP	3130	1					.17%{-SP}		-2.4%{-SP}					
2730	401		4% + 50/- 33				100% + 5/- 89		100% + 0/- 99					
1930	1201		28% + 50/- 47				100% + 17/- 80		100% + 14/- 85					
1130	2001		15% + 70/- 23			4% + 16/- 76	90% + 45/- 54		100% + 11/- 88	0% + 85/- 15				
330	2801		0% + 55/- 40	2% + 52/- 47		4% + 55/- 43	52% + 48/- 49		74% + 33/- 65	2% + 86/- 11	4% + 44/- 55	11% + 32/- 65	1% + 62/- 34	0% + 62/- 37
250	2881		3% + 65/- 32	1% + 83/- 16		3% + 65/- 34	42% + 47/- 51		62% + 34/- 65	2% + 43/- 54	5% + 46/- 53	6% + 39/- 60	3% + 45/- 53	2% + 44/- 55
150	2981		1% + 42/- 57	2% + 65/- 34	0% + 52/- 48	3% + 66/- 33	29% + 46/- 52		39% + 44/- 55	1% + 52/- 47	3% + 43/- 56	2% + 60/- 35	3% + 48/- 51	1% + 45/- 54
RU-CH	3130	1				3.6%{+SP}			-2.22%{+SP}					
2730	401			8% + 91/- 5		91% + 74/- 22			100% + 79/- 19	16% + 50/- 47				
1930	1201			0% + 50/- 50		23% + 53/- 42	0% + 20/- 80		1% + 42/- 52	41% + 64/- 34			12% + 9/- 90	
1130	2001			21% + 40/- 57		22% + 85/- 14			10% + 25/- 72	54% + 63/- 34	0% + 26/- 73		9% + 33/- 65	
330	2801			8% + 27/- 71	0% + 66/- 33	7% + 75/- 23	0% + 66/- 33		5% + 39/- 60	16% + 72/- 26	1% + 89/- 10	0% + 43/- 56	1% + 51/- 45	
250	2881			7% + 36/- 63	0% + 60/- 40	6% + 66/- 32	0% + 42/- 57		4% + 43/- 56	14% + 67/- 32	1% + 62/- 35	0% + 77/- 22	1% + 31/- 68	0% + 22/- 77
150	2981		0% + 57/- 42	6% + 45/- 54	0% + 80/- 20	2% + 53/- 46	1% + 46/- 53		2% + 60/- 39	9% + 54/- 44	0% + 57/- 42	3% + 61/- 38	0% + 44/- 56	0% + 50/- 50
RU-IN	3130	1				{-SP}	1.59%	.85%	.85%			{-SP}		
2730	401				1%/- 100	9% + 23/- 76	100% + 37/- 57	100% + 88/- 10	100% + 88/- 10		32% + 58/- 35	2%/- 100		

1930	1201			1% + 35/- 64	21% + 32/- 67	12% + 17/- 81	100% + 92/- 6	100% + 92/- 6	0% + 37/- 50	27% + 4/- 94		
1130	2001			0% + 20/- 80	3% + 34/- 61	21% + 49/- 43	100% + 79/- 18	100% + 79/- 18	0% + 90/- 10	22% + 20/- 77		13% + 89/- 10
330	2801	4% + 18/- 81	2% + 64/- 33	1% + 64/- 32	0% + 28/- 72	17% + 54/- 45	86% + 45/- 53	86% + 45/- 53	6% + 31/- 67	6% + 64/- 34	2% + 44/- 52	4% + 62/- 37
250	2881	5% + 34/- 63	3% + 51/- 47	0% + 73/- 21	0% + 20/- 73	16% + 53/- 46	73% + 45/- 54	73% + 45/- 54	6% + 41/- 58	6% + 74/- 24	1% + 23/- 76	3% + 88/- 11
150	2981	5% + 51/- 48	2% + 52/- 47	2% + 62/- 37	1% + 45/- 54	6% + 45/- 53	48% + 51/- 47	48% + 51/- 47	3% + 63/- 36	1% + 44/- 56	1% + 67/- 32	5% + 28/- 71
GE-JP	3130	1										
2730	401											
1930	1201											
1130	2001	1% + 32/- 64			0% + 100							
330	2801	4% + 29/- 70	0% + 85/- 14	0% + 50/- 50	0% + 35/- 65	82% + 24/- 74						
250	2881	3% + 55/- 44	0% + 85/- 14	0% + 70/- 30	2% + 60/- 39	76% + 28/- 70						
150	2981	3% + 64/- 34	0% + 40/- 59	1% + 39/- 60	3% + 50/- 50	64% + 40/- 59						
CH-GE	3130	1										
2730	401											
1930	1201											
1130	2001	7% + 53/- 43	0% + 66/- 33	1% + 30/- 69								
330	2801	4% + 32/- 63	4% + 84/- 15	0% + 50/- 50								
250	2881	6% + 33/- 65	5% + 61/- 36	1% + 38/- 61	1% + 55/- 42	9% + 61/- 37	3% + 47/- 52					
150	2981	5% + 43/- 56	3% + 55/- 43	1% + 59/- 40	2% + 46/- 53	4% + 69/- 30	3% + 44/- 55					
IN-GE	3130	1										
2730	401											
1930	1201											
1130	2001											
330	2801	2% + 33/- 64	0% + 100	0% + 83/- 16	3% + 51/- 46	14% + 48/- 50	70% + 47/- 51					
250	2881	1% + 60/- 39	0%/- 100	0% + 46/- 53	4% + 53/- 43	9% + 39/- 60	59% + 44/- 55					
150	2981	2% + 48/- 50	1% + 51/- 48	1% + 45/- 54	1% + 50/- 49	5% + 51/- 48	44% + 42/- 57					
RU-GE	3130	1										
2730	401											
1930	1201											
1130	2001	8% + 26/- 70	0%/- 100	1% + 58/- 37	0% + 75/- 25							
330	2801	12% + 43/- 55	5% + 77/- 21	4% + 65/- 32	3% + 53/- 40	5% + 23/- 74	96% + 56/- 42					
250	2881	10% + 64/- 35	6% + 68/- 31	2% + 54/- 43	2% + 41/- 58	2% + 24/- 73	88% + 50/- 48					
150	2981	5% + 64/- 35	4% + 64/- 34	2% + 66/- 33	2% + 56/- 43	1% + 27/- 72	71% + 46/- 53					
FR-JP	3130	1										
2730	401											
1930	1201											
1130	2001											
330	2801	0% + 35/- 64	0% + 37/- 62	4% + 52/- 46	3% + 52/- 47	91% + 26/- 72						
250	2881	3% + 64/- 35	0% + 52/- 47	0% + 33/- 66	4% + 48/- 51	87% + 29/- 69						
150	2981	3% + 67/- 32	1% + 56/- 40	2% + 48/- 50	4% + 56/- 43	66% + 42/- 57						
CH-FR	3130	1										
2730	401											
1930	1201											
1130	2001	1% + 31/- 68	1% + 43/- 51									
330	2801	7% + 46/- 51	2% + 49/- 49	1% + 45/- 52								
250	2881	10% + 27/- 72	2% + 50/- 50	3% + 42/- 57	0% + 70/- 29	4% + 64/- 34	10% + 56/- 42					
150	2981	3% + 40/- 59	2% + 55/- 44	4% + 65/- 34	1% + 41/- 58	3% + 58/- 41	7% + 47/- 52					
IN-FR	3130	1										
2730	401											
1930	1201											
1130	2001											
330	2801	0%/- 100	0% + 57/- 42	0% + 88/- 5	9% + 42/- 56	13% + 38/- 60	76% + 50/- 49					
250	2881	0% + 38/- 61	3% + 21/- 78	2% + 78/- 21	6% + 45/- 53	10% + 47/- 50	63% + 48/- 51					
150	2981	1% + 42/- 55	5% + 26/- 72	1% + 48/- 51	4% + 51/- 48	8% + 49/- 49	48% + 43/- 56					
RU-FR	3130	1										
2730	401											
1930	1201											
1130	2001	24% + 9/- 86	2% + 62/- 7									
330	2801	12% + 65/- 34	0% + 52/- 48	1% + 82/- 17	0% + 46/- 46	3% + 55/- 44	96% + 53/- 46					
250	2881	10% + 61/- 38	1% + 78/- 18	1% + 51/- 48	0% + 62/- 37	1% + 55/- 45	92% + 47/- 51					
150	2981	3% + 47/- 52	4% + 69/- 29	1% + 63/- 36	1% + 53/- 46	0% + 26/- 73	76% + 43/- 56					

FR-GE	3130	1						-2.55%	-.06%	-.06%	{-SP}	-1.25%	.42%		
2730	401							100% + 22/- 72	100% + 64/- 28	100% + 64/- 28	97% + 6/- 92	84% + 42/- 36	97% + 71/- 21		
1930	1201							50% + 30/- 68	100% + 65/- 30	100% + 65/- 30	88% + 30/- 68	46% + 56/- 37	66% + 42/- 50		
1130	2001							0% + 50/- 50	100% + 57/- 36	100% + 57/- 36	59% + 19/- 79	26% + 79/- 17	27% + 27/- 66		
330	2801							2% + 68/- 31	100% + 50/- 47	100% + 50/- 47	17% + 28/- 70	7% + 52/- 46	2% + 47/- 52	2% + 35/- 63	2% + 53/- 46
250	2881							3% + 76/- 23	100% + 47/- 51	100% + 47/- 51	12% + 34/- 64	3% + 61/- 38	1% + 50/- 50	3% + 27/- 69	4% + 40/- 59
150	2981							2% + 48/- 51	100% + 44/- 54	100% + 44/- 54	3% + 40/- 59	2% + 39/- 60	1% + 40/- 56	3% + 56/- 43	3% + 56/- 43
UK-JP	3130	1						-.09%{-SP}		-.43%{-SP}					
2730	401							100% + 1/- 98	100% + 10/- 86	100% + 2/- 97	4% + 100	37% + 3/- 96			2% + 100
1930	1201							100% + 10/- 86	100% + 38/- 60	100% + 8/- 89		7% + 3/- 95			
1130	2001							100% + 10/- 86	100% + 38/- 60	100% + 28/- 68	9% + 74/- 21	2% + 2/- 97			9% + 76/- 21
330	2801							6% + 51/- 47	2% + 63/- 36	89% + 33/- 65	5% + 70/- 29	6% + 45/- 51	3% + 42/- 57	0% + 73/- 21	5% + 17/- 81
250	2881							7% + 63/- 36	3% + 49/- 50	0% + 64/- 36	1% + 65/- 34	79% + 36/- 62	4% + 52/- 46	3% + 54/- 45	0% + 50/- 50
150	2981							4% + 56/- 43	1% + 48/- 51	1% + 48/- 51	3% + 51/- 48	58% + 45/- 54	59% + 40/- 59	4% + 48/- 51	2% + 49/- 49
CH-UK	3130	1													
2730	401														
1930	1201														
1130	2001														
330	2801														
250	2881														
150	2981														
IN-UK	3130	1													
2730	401														
1930	1201														
1130	2001														
330	2801														
250	2881														
150	2981														
RU-UK	3130	1													
2730	401														
1930	1201														
1130	2001														
330	2801														
250	2881														
150	2981														
UK-GE	3130	1													
2730	401														
1930	1201														
1130	2001														
330	2801														
250	2881														
150	2981														
UK-FR	3130	1													
2730	401														
1930	1201														
1130	2001														
330	2801														
250	2881														
150	2981														
BR-JP	3130	1													
2730	401														
1930	1201														
1130	2001														
330	2801														
250	2881														
150	2981														
BR-CH	3130	1													
2730	401														
1930	1201														
1130	2001														

	330	2801	3% + 34/- 64	0% + 18/- 81	4% + 78/- 21	3% + 46/- 53	4% + 41/- 55	20% + 44/- 54	0%/- 100	5% + 49/- 47	4% + 28/- 69	1% + 15/- 84	11% + 50/- 48		
	250	2881	2% + 33/- 63	0% + 42/- 57	3% + 77/- 22	2% + 61/- 36	6% + 43/- 55	14% + 51/- 46	0% + 25/- 75	4% + 47/- 51	2% + 19/- 80	2% + 44/- 55	9% + 26/- 73		
	150	2981	5% + 49/- 49	1% + 46/- 53	2% + 46/- 53	2% + 56/- 43	4% + 53/- 45	10% + 45/- 54	1% + 59/- 40	3% + 54/- 45	3% + 26/- 73	2% + 53/- 46	4% + 48/- 51		
BR-IN	3130	1	-2.07%{-SP}				-61%	-48%							
	2730	401	0% + 75	3%/- 100	100% + 29/- 66		100% + 69/- 27	100% + 83/- 13							
	1930	1201	0%/- 50	30% + 63/- 31	99% + 18/- 80	9% + 8/- 77	100% + 76/- 21	100% + 65/- 29							
	1130	2001	3% + 11/- 79	6% + 66/- 32	73% + 21/- 75	2% + 75/- 24	100% + 66/- 30	100% + 63/- 31	7% + 86/- 13	0% + 100	2% + 12/- 86		0% + 92/- 7		
	330	2801	10% + 53/- 45	16% + 51/- 47	26% + 39/- 60	2% + 62/- 34	58% + 46/- 52	49% + 49/- 49	15% + 72/- 26	1% + 27/- 70	12% + 26/- 72	2% + 22/- 77	7% + 50/- 49		
	250	2881	11% + 57/- 42	12% + 52/- 47	22% + 46/- 52	3% + 50/- 47	49% + 46/- 52	42% + 47/- 51	12% + 70/- 28	2% + 19/- 80	9% + 44/- 54	1% + 27/- 72	7% + 53/- 44		
	150	2981	7% + 48/- 51	7% + 44/- 54	12% + 46/- 53	1% + 45/- 54	32% + 44/- 55	27% + 41/- 58	8% + 54/- 44	1% + 73/- 26	3% + 62/- 37	1% + 70/- 29	4% + 39/- 60		
BR-RU	3130	1	10.16%{-SP}				-1.6%{+SP}	-2.24%	-2.5%{-SP}	-87%{-SP}					
	2730	401	54% + 9/- 85				60% + 90/- 7	76% + 36/- 61	100% + 1/- 98	100% + 2/- 97	100% + 2/- 97				
	1930	1201	20% + 28/- 70				36% + 94/- 4	2% + 62/- 31	100% + 31/- 65	100% + 8/- 89	100% + 8/- 89				
	1130	2001	0%/- 50	0% + 45/- 54	16% + 55/- 41	4% + 42/- 53	100% + 29/- 67	100% + 21/- 76	100% + 21/- 76						
	330	2801	2% + 66/- 30	4% + 48/- 48	3% + 89/- 10	8% + 63/- 35	83% + 25/- 74	84% + 41/- 58	1% + 43/- 53	0% + 100	1% + 62/- 35	2% + 62/- 35	2% + 57/- 39		
	250	2881	4% + 63/- 35	5% + 48/- 50	4% + 72/- 27	6% + 57/- 41	73% + 27/- 72	75% + 42/- 57	0% + 20/- 79	1% + 92/- 7	0% + 84/- 15	2% + 54/- 45	3% + 63/- 36		
	150	2981	0% + 44/- 55	5% + 45/- 54	0% + 57/- 42	2% + 36/- 61	48% + 38/- 61	63% + 44/- 54	3% + 51/- 48	2% + 73/- 26	1% + 56/- 44	1% + 57/- 42	1% + 34/- 65		
BR-GE	3130	1						-1.83%	.17%	.17%					
	2730	401						100% + 24/- 67	100% + 73/- 22	100% + 73/- 22					
	1930	1201					25% + 65/- 24	100% + 51/- 43	100% + 63/- 32	100% + 63/- 32					
	1130	2001					18% + 71/- 25	5% + 55/- 42	95% + 50/- 46	100% + 64/- 31	0% + 23/- 76	0% + 75/- 12	2% + 36/- 53	58% + 49/- 45	5% + 41/- 49
	330	2801	0% + 90/- 10		0% + 30/- 69	1% + 15/- 84	51% + 45/- 54	99% + 47/- 51	99% + 47/- 51	5% + 57/- 42	1% + 11/- 88	4% + 31/- 67	11% + 25/- 73	4% + 19/- 80	
	250	2881	2% + 93/- 6	0% + 57/- 42	2% + 31/- 68	1% + 20/- 80	43% + 39/- 59	98% + 53/- 45	98% + 53/- 45	5% + 50/- 48	2% + 41/- 54	2% + 44/- 54	10% + 34/- 64	3% + 36/- 62	
	150	2981	1% + 51/- 45	1% + 65/- 35	3% + 46/- 53	2% + 38/- 61	23% + 43/- 56	87% + 46/- 53	87% + 46/- 53	2% + 47/- 52	2% + 46/- 53	1% + 45/- 54	8% + 52/- 47	3% + 66/- 33	
BR-FR	3130	1						-4.29%	-1.7%{-SP}	-1.7%{-SP}					
	2730	401	12% + 31/- 68					100% + 3/- 95	100% + 40/- 51	100% + 40/- 51					
	1930	1201	5% + 41/- 50					100% + 28/- 68	100% + 30/- 64	100% + 30/- 64					
	1130	2001	8% + 15/- 80					100% + 28/- 68	100% + 36/- 58	5% + 14/- 81	0% + 72/- 18	35% + 24/- 72	7% + 36/- 55	8% + 68/- 26	
	330	2801	3% + 38/- 61	3% + 56/- 41	0%/- 100	0% + 88/- 11	71% + 53/- 46	98% + 38/- 61	98% + 38/- 61	5% + 29/- 70	8% + 75/- 23	9% + 48/- 51	6% + 27/- 70	3% + 21/- 73	
	250	2881	3% + 61/- 38	2% + 66/- 31	1% + 52/- 47	2% + 48/- 51	49% + 52/- 46	97% + 47/- 52	97% + 47/- 52	2% + 56/- 42	5% + 50/- 49	8% + 48/- 51	5% + 28/- 71	1% + 26/- 73	
	150	2981	2% + 54/- 45	4% + 56/- 43	2% + 52/- 47	2% + 53/- 46	21% + 54/- 45	88% + 45/- 54	88% + 45/- 54	2% + 42/- 57	4% + 46/- 53	8% + 36/- 63	3% + 44/- 55	3% + 68/- 31	
BR-UK	3130	1	3.7%					-2.17%	-52%{-SP}	-52%{-SP}					
	2730	401	0% + 100					100% + 4/- 95	100% + 11/- 85	100% + 11/- 85					
	1930	1201					0%/- 100	0%/- 75	100% + 17/- 80	100% + 17/- 78	100% + 17/- 78				
	1130	2001	4% + 89/- 9				3% + 35/- 60	19% + 75/- 21	100% + 37/- 59	100% + 21/- 75	100% + 21/- 75				
	330	2801	5% + 49/- 50	0% + 87/- 12	1% + 76/- 23	5% + 35/- 64	83% + 49/- 49	100% + 33/- 65	100% + 33/- 65	1% + 42/- 57	1% + 56/- 43	9% + 40/- 57	6% + 43/- 55	0% + 74/- 25	
	250	2881	4% + 56/- 42	0% + 64/- 35	2% + 72/- 25	4% + 52/- 47	69% + 45/- 54	97% + 41/- 57	97% + 41/- 57	2% + 40/- 59	1% + 39/- 60	8% + 42/- 57	6% + 51/- 48	0% + 37/- 62	
	150	2981	4% + 39/- 60	1% + 38/- 61	3% + 52/- 45	4% + 37/- 62	34% + 47/- 52	85% + 41/- 57	85% + 41/- 57	2% + 57/- 42	1% + 56/- 43	5% + 37/- 61	5% + 62/- 37	0% + 40/- 60	
US-JP	3130	1					-1.86%	-1.11%{-SP}	-21%						
	2730	401					100% + 80/- 17	100% + 4/- 95	100% + 72/- 24	54% + 98/- 0	33% + 9/- 81				
	1930	1201					77% + 94/- 4	100% + 2/- 97	100% + 80/- 15	28% + 44/- 44	12% + 35/- 50				
	1130	2001	14% + 3/- 95				27% + 76/- 21	100% + 8/- 89	80% + 67/- 28	4% + 35/- 60	10% + 53/- 42				
	330	2801	3% + 36/- 62	4% + 53/- 45	5% + 66/- 33	21% + 42/- 56	100% + 30/- 69	56% + 47/- 52	13% + 46/- 52	3% + 56/- 41	12% + 38/- 60	0% + 59/- 40	3% + 25/- 74		
	250	2881	3% + 33/- 65	3% + 24/- 73	5% + 66/- 33	16% + 43/- 56	98% + 34/- 65	50% + 38/- 60	11% + 38/- 60	3% + 47/- 51	10% + 37/- 62	0% + 36/- 54	3% + 13/- 86		
	150	2981	4% + 61/- 38	3% + 42/- 57	5% + 50/- 49	12% + 48/- 51	90% + 41/- 58	28% + 40/- 59	9% + 44/- 55	5% + 62/- 37	6% + 32/- 66	1% + 57/- 42	2% + 50/- 50		
CH-US	3130	1	-3.6%						2.66%						
	2730	401	3% + 68/- 31	3% + 53/- 46	39% + 51/- 44			44% + 48/- 42	44% + 48/- 42						
	1930	1201	23% + 36/- 57	0% + 25/- 75	1% + 55/- 44		0%/- 100	17% + 47/- 50	5% + 52/- 46	5% + 52/- 46					
	1130	2001	49% + 42/- 54	2% + 47/- 50	11% + 68/- 29			26% + 53/- 44	2% + 16/- 80	7% + 45/- 51	25% + 58/- 39	0%/- 100	8% + 32/- 65		
	330	2801	22% + 41/- 57	3% + 53/- 45	3% + 47/- 51	1% + 56/- 40	4% + 60/- 39	12% + 68/- 31	5% + 56/- 43	7% + 36/- 62	9% + 61/- 36	0% + 52/- 47	11% + 39/- 58		
	250	2881	21% + 44/- 55	1% + 55/- 42	4% + 58/- 40	0% + 57/- 42	3% + 63/- 36	10% + 64/- 35	5% + 48/- 51	5% + 47/- 52	6% + 52/- 47	1% + 70/- 29	7% + 44/- 54		
	150	2981	13% + 42/- 56	3% + 48/- 51	4% + 52/- 47	2% + 60/- 38	1% + 56/- 44	7% + 47/- 52	4% + 51/- 47	2% + 39/- 59	4% + 52/- 47	1% + 74/- 25	5% + 47/- 51		
IN-US	3130	1					3.73%	-98%	-06%						
	2730	401					79% + 41/- 50		100% + 29/- 57	100% + 56/- 37					
	1930	1201	14% + 84/- 14				3% + 31/- 66		94% + 26/- 68	100% + 85/- 13	69% + 27/- 69	100% + 42/- 49	32% + 66/- 28		
	1130	2001	33% + 63/- 29	0% + 52/- 47	10% + 24/- 72		5% + 76/- 22	4% + 56/- 39	58% + 21/- 76	98% + 71/- 24	25% + 44/- 53	93% + 45/- 49	5% + 89/- 9		
	330	2801	12% + 39/- 59	3% + 41/- 58	5% + 44/- 55	2% + 77/- 22	11% + 41/- 58	57% + 48/- 50	68% + 37/- 61	9% + 56/- 42	17% + 58/- 41	11% + 44/- 55	0% + 45/- 54		
	250	2881	9% + 48/- 51	6% + 26/- 72	3% + 67/- 31	3% + 63/- 36	10% + 41/- 58	45% + 49/- 49	56% + 38/- 60	10% + 58/- 41	13% + 59/- 39	10% + 50/- 49	3% + 44/- 56		
	150	2981	4% + 51/- 48	5% + 30/- 69	3% + 50/- 49	3% + 51/- 48	6% + 41/- 58	24% + 50/- 49	39% + 43/- 56	6% + 63/- 36	6% + 51/- 48	4% + 40/- 60	4% + 69/- 29		
RU-US	3130	1						1.63%	-1.5%{-SP}						
	2730	401						100% + 97/- 2	100% + 1/- 98						
									75% + 42/- 50						

1930	1201						100% + 92/- 6		100% + 37/- 60		4% + 28/- 67		
1130	2001			0% + 14/- 85			100% + 75/- 23		100% + 38/- 60	0% + 100	4% + 73/- 20		
330	2801	2% + 17/- 82	2% + 58/- 38	0% + 63/- 36	0% + 73/- 26	8% + 25/- 73	82% + 50/- 49		93% + 43/- 56	1% + 55/- 42	3% + 42/- 56	2% + 24/- 74	0% + 41/- 58
250	2881	3% + 32/- 62	5% + 58/- 41	1% + 46/- 53	0% + 67/- 32	7% + 24/- 75	74% + 45/- 54		82% + 40/- 59	1% + 25/- 74	1% + 46/- 51	3% + 30/- 67	1% + 60/- 40
150	2981	2% + 31/- 68	4% + 43/- 55	2% + 46/- 53	1% + 64/- 35	4% + 40/- 59	52% + 45/- 54		62% + 40/- 58	1% + 56/- 43	0% + 90/- 9	2% + 40/- 59	0% + 50/- 50
US-GE	3130	1				.04%	.24%	.24%					
2730	401					100% + 45/- 47	100% + 40/- 46	100% + 40/- 46					
1930	1201				32% + 50/- 47	100% + 58/- 36	100% + 40/- 51	100% + 40/- 51	6% + 51/- 43				10% + 49/- 46
1130	2001				10% + 11/- 88	100% + 55/- 42	100% + 50/- 45	100% + 50/- 45	8% + 38/- 58	2% + 28/- 67			31% + 71/- 25
330	2801	1% + 31/- 66	5% + 16/- 82	0% + 83/- 16	4% + 25/- 74	85% + 38/- 60	95% + 44/- 55	95% + 44/- 55	3% + 44/- 55	2% + 37/- 61	3% + 97/- 2		9% + 35/- 64
250	2881	1% + 48/- 51	4% + 10/- 89	1% + 50/- 50	9% + 47/- 51	77% + 39/- 59	92% + 43/- 56	92% + 43/- 56	2% + 48/- 49	1% + 58/- 41	3% + 69/- 30	1% + 7/- 92	5% + 37/- 62
150	2981	3% + 42/- 56	2% + 32/- 67	2% + 47/- 52	3% + 41/- 58	62% + 43/- 55	88% + 44/- 54	88% + 44/- 54	2% + 53/- 46	3% + 53/- 46	1% + 53/- 46	1% + 48/- 51	3% + 38/- 61
US-FR	3130	1				-2.47%{-SP}	.15%	.15%	3.58%				
2730	401					100% + 7/- 91	100% + 73/- 23	100% + 73/- 23	99% + 42/- 46				
1930	1201	0% + 100	0% + 11/- 88			100% + 32/- 65	100% + 72/- 22	100% + 72/- 22	55% + 56/- 34				
1130	2001		21% + 80/- 15		0% + 100	100% + 32/- 64	100% + 60/- 35	100% + 60/- 35	32% + 60/- 34			3% + 25/- 71	17% + 38/- 56
330	2801	1% + 69/- 30	10% + 47/- 51	0% + 50/- 50	1% + 30/- 67	100% + 42/- 56	100% + 44/- 54	100% + 44/- 54	14% + 64/- 35	2% + 54/- 42	0% + 50/- 50	0%/- 100	9% + 56/- 42
250	2881	2% + 62/- 36	8% + 45/- 54	0% + 75/- 25	0% + 19/- 76	98% + 41/- 58	100% + 44/- 55	100% + 44/- 55	9% + 60/- 39	1% + 37/- 62	0% + 41/- 58	1% + 17/- 82	7% + 55/- 43
150	2981	3% + 49/- 50	4% + 52/- 47	0% + 41/- 58	2% + 53/- 45	76% + 43/- 56	99% + 45/- 54	99% + 45/- 54	3% + 53/- 45	3% + 52/- 47	1% + 42/- 54	1% + 31/- 68	7% + 53/- 46
US-UK	3130	1				-1.21%{-SP}	.5%	.5%					-81%
2730	401					100% + 3/- 96	100% + 97/- 1	100% + 97/- 1					83% + 9/- 86
1930	1201					100% + 9/- 89	100% + 94/- 4	100% + 94/- 4		21%/- 100			55% + 15/- 82
1130	2001		0% + 80/- 10		2% + 18/- 76	100% + 26/- 72	100% + 79/- 19	100% + 79/- 19	7% + 33/- 61	17% + 20/- 75		9% + 71/- 27	37% + 29/- 67
330	2801	3% + 64/- 35	6% + 60/- 37	0% + 50/- 50	2% + 62/- 37	100% + 39/- 59	100% + 48/- 50	100% + 48/- 50	7% + 29/- 70	8% + 44/- 55	0% + 60/- 40	3% + 42/- 57	21% + 60/- 38
250	2881	4% + 61/- 38	5% + 48/- 51	0% + 25/- 75	3% + 80/- 19	99% + 37/- 62	98% + 44/- 54	98% + 44/- 54	3% + 27/- 72	2% + 37/- 62	1% + 36/- 63	2% + 34/- 65	14% + 64/- 34
150	2981	2% + 56/- 43	4% + 55/- 44	0% + 50/- 50	3% + 54/- 45	84% + 42/- 57	93% + 43/- 55	93% + 43/- 55	2% + 43/- 56	1% + 37/- 62	0% + 39/- 60	3% + 52/- 45	6% + 54/- 45
BR-US	3130	1					-.08%	-.08%	-4.64%{-SP}				-3.31%
2730	401					77% + 30/- 56	100% + 83/- 13	100% + 83/- 13	100% + 46/- 48		64% + 54/- 30		
1930	1201					8% + 69/- 24	100% + 69/- 24	100% + 69/- 24	46% + 46/- 47		50% + 50/- 40	29% + 13/- 81	
1130	2001					1% + 59/- 33	100% + 65/- 29	100% + 65/- 29	39% + 27/- 70	0% + 50/- 50	22% + 57/- 35	22% + 45/- 49	
330	2801	2% + 31/- 68	0% + 74/- 25	3% + 46/- 52	0% + 100	14% + 38/- 60	100% + 48/- 50	100% + 48/- 50	25% + 45/- 53	5% + 57/- 40	4% + 21/- 77	5% + 51/- 48	1% + 18/- 81
250	2881	2% + 40/- 59	1% + 61/- 38	3% + 48/- 50	1% + 37/- 62	10% + 41/- 57	100% + 47/- 51	100% + 47/- 51	17% + 43/- 56	4% + 50/- 48	2% + 54/- 44	6% + 43/- 56	2% + 56/- 43
150	2981	2% + 39/- 59	1% + 57/- 42	1% + 56/- 43	3% + 41/- 58	6% + 34/- 65	99% + 45/- 54	99% + 45/- 54	7% + 31/- 68	3% + 52/- 47	0% + 50/- 50	5% + 64/- 35	3% + 45/- 54

Table A.4-2

Sign stability of the of oil price effect on the CCF test causality-in-variance between stock market linkages.

Notes: The table provides compound of the consolidated statistics of the percentage change sign between oil unadjusted and oil adjusted cross-correlation coefficients performed on squared standardized residuals (causality-in-variance). The estimation of each pair of participating indices is performed the using rolling window with descending window sizes as discussed in Section 5.3 and Table 5.3-1. Column 1 represents the pair to be observed in the window size (Column 2), each with a total number of rolling sub-samples (Column 3). Values in columns 4-15 for full sample (Column 2, window size 3130) represent a percentage change after comparison between the oil unadjusted and adjusted forms of estimation, while window sizes from 2730 to 150 are recorded in a shorter form, for the purpose of the space conservation. For example, the record at column 8, pair IN-JP (windows size 2730) has value “23% + 10/- 89”, which is interpreted as follows: at lag 1 from India to Japan in 23% of observed cases the relationship exists in both oil adjusted and unadjusted estimations, of which 10% of derived percentage changes had a positive sign and 89% had a negative sign. If frequency of appearance of one sign prevails or is equal to the other one in all window sizes (2730-150), then SP verdict is recorded in full sample line in the same column with ^{+SP} and ^{-SP} representing positive and negative SP respectively.

X – Y	Window size	Number of sub-samples	Lag -5	Lag -4	Lag -3	Lag -2	Lag -1	Lag 0	Lag 0	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CH-JP	3130	1												
	2730	401					24% + 46/- 51						1% + 60/- 40	
	1930	1201					18% + 41/- 58						0% + 66/- 33	
	1130	2001					10% + 33/- 66	0% + 100	0% + 100				1% + 37/- 58	
	330	2801	1% + 63/- 34	5% + 47/- 52	2% + 20/- 79	3% + 36/- 63	8% + 50/- 48	0% + 61/- 38	0% + 61/- 38	7% + 46/- 53	0% + 45/- 54	0%/- 100	6% + 53/- 43	0% + 33/- 66
	250	2881	3% + 47/- 52	5% + 56/- 42	2% + 29/- 70	6% + 42/- 57	6% + 48/- 51	0% + 71/- 28	0% + 71/- 28	8% + 50/- 49	1% + 43/- 56	0% + 25/- 75	5% + 52/- 47	0% + 60/- 40
	150	2981	2% + 39/- 60	3% + 57/- 42	2% + 43/- 56	3% + 43/- 56	3% + 46/- 53	1% + 53/- 46	1% + 53/- 46	6% + 42/- 57	1% + 57/- 42	0% + 40/- 59	2% + 50/- 47	0% + 64/- 35
IN-JP	3130	1				1.21%	{-SP}							
	2730	401		0% + 100		100% + 61/- 37	23% + 10/- 89	3% + 38/- 61	3% + 38/- 61					12% + 33/- 60
	1930	1201		20% + 59/- 39		86% + 64/- 34	3% + 6/- 93	16% + 40/- 57	16% + 40/- 57		37% + 53/- 40			6% + 81/- 14
	1130	2001		18% + 76/- 22		47% + 51/- 47	4% + 9/- 89	2% + 21/- 76	2% + 21/- 76	18% + 30/- 67	26% + 38/- 59		3% + 31/- 68	25% + 41/- 57
	330	2801	1% + 77/- 20	4% + 54/- 45	9% + 67/- 30	14% + 43/- 56	6% + 32/- 68	11% + 62/- 37	11% + 62/- 37	9% + 59/- 39	7% + 56/- 43	0%/- 50	6% + 53/- 44	11% + 51/- 47
	250	2881	1% + 45/- 54	4% + 46/- 52	4% + 66/- 33	8% + 53/- 46	6% + 26/- 72	9% + 46/- 53	9% + 46/- 53	9% + 54/- 45	6% + 57/- 42	0% + 36/- 63	3% + 48/- 50	7% + 58/- 40
	150	2981	1% + 47/- 52	3% + 55/- 44	2% + 53/- 46	4% + 71/- 28	4% + 45/- 54	7% + 50/- 49	7% + 50/- 49	4% + 40/- 57	3% + 55/- 44	0% + 45/- 54	2% + 41/- 58	7% + 48/- 51
IN-CH	3130	1												
	2730	401	0% + 100			25% + 45/- 51						48% + 45/- 50		55% + 50/- 48
	1930	1201	0% + 100		0% + 50/- 50	24% + 52/- 45						65% + 51/- 45		65% + 44/- 53
	1130	2001	0%/- 100			4% + 49/- 48				2% + 60/- 40		37% + 50/- 45		39% + 29/- 68
	330	2801			5% + 23/- 76	11% + 60/- 39	0% + 25/- 75	0% + 100	0% + 100	3% + 57/- 42	0% + 26/- 73	10% + 24/- 75	2% + 32/- 66	5% + 46/- 51
	250	2881	0% + 44/- 55	0% + 50/- 50	3% + 35/- 64	6% + 48/- 51	1% + 43/- 56	0% + 28/- 71	0% + 28/- 71	4% + 54/- 45	0% + 25/- 75	8% + 28/- 71	3% + 35/- 64	1% + 50/- 49
	150	2981	2% + 44/- 55	0% + 40/- 60	2% + 38/- 61	4% + 44/- 55	1% + 43/- 56	0% + 47/- 52	0% + 47/- 52	1% + 52/- 47	0% + 76/- 23	5% + 47/- 52	3% + 41/- 57	1% + 45/- 54
RU-JP	3130	1					1.12%							
	2730	401	63% + 45/- 53	6% + 14/- 81			70% + 95/- 4			26% + 1/- 98				
	1930	1201	30% + 58/- 40	22% + 20/- 78			18% + 75/- 22			43% + 0/- 99				0% + 100
	1130	2001	23% + 18/- 80	5% + 51/- 47	1% + 38/- 50	3% + 77/- 21	32% + 41/- 58			49% + 7/- 92		37% + 6/- 93		0% + 100
	330	2801	17% + 44/- 54	8% + 43/- 56	1% + 16/- 84	11% + 65/- 34	8% + 41/- 57			18% + 31/- 67	0% + 25/- 75	11% + 55/- 44	0% + 35/- 50	5% + 57/- 42
	250	2881	13% + 46/- 52	8% + 48/- 51	1% + 35/- 64	8% + 57/- 42	5% + 44/- 55			14% + 37/- 62	0% + 55/- 44	9% + 65/- 34	1% + 26/- 73	6% + 34/- 65
	150	2981	4% + 50/- 50	3% + 48/- 51	2% + 45/- 54	4% + 53/- 46	4% + 42/- 57			9% + 39/- 60	0% + 50/- 50	5% + 59/- 40	1% + 50/- 50	0% + 69/- 30
RU-CH	3130	1												
	2730	401												
	1930	1201								5% + 97/- 2				5%/- 100
	1130	2001								9% + 63/- 36		0%/- 100		5% + 19/- 78
	330	2801	2% + 66/- 32	2% + 61/- 35	1% + 30/- 69	0% + 50/- 50	1% + 73/- 26			9% + 59/- 39	2% + 50/- 47	7% + 82/- 17	9% + 36/- 63	12% + 51/- 48
	250	2881	1% + 79/- 18	1% + 64/- 36	1% + 34/- 65	0% + 79/- 20	1% + 37/- 62			9% + 44/- 55	2% + 53/- 46	9% + 69/- 29	5% + 42/- 57	12% + 47/- 51
	150	2981	2% + 60/- 40	0% + 60/- 40	0% + 31/- 68	1% + 43/- 56	2% + 42/- 55			5% + 42/- 57	2% + 53/- 46	4% + 63/- 35	1% + 47/- 52	7% + 52/- 47
RU-IN	3130	1												
	2730	401												
	1930	1201	0% + 100				1% + 30/- 69	6% + 2/- 97	6% + 2/- 97				59% + 62/- 37	
	1130	2001			8%/- 100		13% + 11/- 88	1% + 36/- 63	1% + 36/- 63				21% + 62/- 37	
	330	2801	0% + 36/- 63	0% + 100	2% + 2/- 97	4% + 43/- 56	7% + 35/- 64	4% + 17/- 82	4% + 17/- 82	5% + 7/- 92	8% + 26/- 71	12% + 53/- 43		
	250	2881	2% + 35/- 64	0% + 58/- 41	1% + 30/- 69	5% + 50/- 50	3% + 43/- 55	3% + 50/- 49	3% + 50/- 49	1% + 26/- 71	10% + 93/- 6	11% + 49/- 50		0% + 60/- 40
										3% + 27/- 72	6% + 85/- 14	10% + 48/- 50	0% + 70/- 30	0% + 37/- 62

	150	2981	2% + 57/- 42	2% + 40/- 59	1% + 58/- 41	5% + 28/- 70	4% + 46/- 53	3% + 52/- 47	3% + 52/- 47	3% + 56/- 43	5% + 69/- 30	3% + 43/- 56	1% + 39/- 60	0% + 59/- 40
GE-JP	3130	1	-49%[-SP]						-1.78%					
	2730	401	6% + 37/- 55				0%/- 100		77% + 15/- 82					
	1930	1201	10% + 52/- 40	0% + 100	18% + 22/- 74		14% + 19/- 79		13% + 12/- 84		2% + 8/- 92			
	1130	2001	6% + 67/- 30	0% + 100	13% + 36/- 62		4% + 31/- 67		8% + 41/- 56		3% + 51/- 48	9% + 75/- 23		
	330	2801	3% + 59/- 40	1% + 39/- 60	9% + 41/- 56	2% + 21/- 78	2% + 23/- 76		3% + 51/- 48	0% + 50/- 50	8% + 60/- 39	6% + 42/- 57	4% + 26/- 72	1% + 56/- 43
	250	2881	4% + 44/- 55	3% + 43/- 56	7% + 47/- 52	3% + 17/- 82	3% + 26/- 73		6% + 44/- 55	0% + 58/- 41	6% + 65/- 34	4% + 35/- 64	2% + 28/- 70	3% + 42/- 57
	150	2981	3% + 44/- 55	3% + 50/- 49	4% + 48/- 51	3% + 38/- 61	3% + 37/- 61		4% + 55/- 44	1% + 52/- 47	2% + 54/- 45	1% + 49/- 50	0% + 35/- 64	2% + 49/- 50
CH-GE	3130	1	-1.87%[-SP]						{+SP}					
	2730	401	9% + 48/- 51				43% + 50/- 45	2% + 72/- 27					29% + 55/- 38	
	1930	1201	3% + 23/- 73				3% + 52/- 47	10% + 43/- 54					68% + 57/- 41	
	1130	2001	2% + 41/- 58			0%/- 100	1% + 58/- 38	6% + 50/- 50		0% + 100	2% + 42/- 57		41% + 52/- 45	12% + 58/- 41
	330	2801	4% + 35/- 64	10% + 51/- 48	0%/- 100	5% + 57/- 42	5% + 45/- 53	6% + 71/- 27		3% + 58/- 40	12% + 50/- 49	4% + 69/- 29	17% + 59/- 40	8% + 56/- 42
	250	2881	6% + 31/- 68	9% + 55/- 43	0% + 39/- 60	3% + 64/- 35	4% + 75/- 24	4% + 50/- 49		2% + 70/- 29	14% + 62/- 36	4% + 64/- 35	14% + 54/- 44	6% + 56/- 43
	150	2981	5% + 50/- 50	5% + 52/- 47	0% + 58/- 41	3% + 56/- 43	2% + 57/- 42	2% + 48/- 51		3% + 52/- 47	7% + 50/- 49	2% + 50/- 50	5% + 51/- 48	3% + 49/- 50
IN-GE	3130	1	-1.16%						-1.09%					
	2730	401		35% + 42/- 54			81% + 44/- 50	100% + 44/- 50	100% + 44/- 50	69% + 58/- 39		3% + 25/- 75		
	1930	1201		32% + 36/- 62			47% + 31/- 66	84% + 36/- 61	84% + 36/- 61	31% + 74/- 25		0% + 33/- 66	0% + 100	0%/- 100
	1130	2001		16% + 57/- 41		9% + 35/- 63	32% + 36/- 59	34% + 74/- 23	34% + 74/- 23	24% + 60/- 38		0% + 40/- 60	0% + 12/- 87	
	330	2801	3% + 70/- 28	5% + 43/- 55	4% + 70/- 28	7% + 18/- 80	16% + 44/- 55	10% + 47/- 51	10% + 47/- 51	11% + 30/- 69	0% + 25/- 75	2% + 34/- 65	1% + 57/- 42	2% + 82/- 17
	250	2881	1% + 67/- 32	1% + 51/- 48	3% + 52/- 46	4% + 40/- 59	12% + 52/- 47	7% + 42/- 57	7% + 42/- 57	8% + 40/- 59	0% + 55/- 44	3% + 40/- 59	2% + 58/- 39	3% + 68/- 31
	150	2981	2% + 55/- 44	0% + 66/- 33	2% + 45/- 53	2% + 34/- 65	6% + 56/- 42	5% + 63/- 36	5% + 63/- 36	4% + 41/- 58	1% + 38/- 61	2% + 45/- 54	1% + 48/- 51	2% + 55/- 44
RU-GE	3130	1	-3.3%						-3.3%					
	2730	401					100% + 51/- 45	100% + 51/- 45	100% + 51/- 45	1% + 80/- 20	35% + 16/- 82	21% + 84/- 15		63% + 0/- 99
	1930	1201			0% + 66/- 33	5% + 19/- 79	100% + 25/- 73	100% + 25/- 73	100% + 25/- 73	71% + 40/- 58	7% + 55/- 44	6% + 100	0% + 33/- 66	21% + 1/- 98
	1130	2001			2% + 64/- 35	5% + 16/- 83	87% + 33/- 65	87% + 33/- 65	87% + 33/- 65	38% + 17/- 82	3% + 57/- 42	13% + 92/- 7		12% + 10/- 88
	330	2801	8% + 82/- 17	0% + 50/- 50	1% + 53/- 46	2% + 45/- 55	0% + 33/- 66	34% + 46/- 52	34% + 46/- 52	14% + 66/- 33	1% + 60/- 40	20% + 70/- 29	4% + 32/- 67	5% + 48/- 51
	250	2881	10% + 60/- 39	0% + 50/- 25	1% + 54/- 45	2% + 23/- 76	0% + 66/- 33	24% + 51/- 47	24% + 51/- 47	11% + 59/- 40	4% + 51/- 48	17% + 55/- 44	4% + 53/- 46	1% + 54/- 45
	150	2981	5% + 38/- 61	0% + 65/- 35	1% + 55/- 44	2% + 54/- 45	15% + 53/- 46	15% + 53/- 46	15% + 53/- 46	5% + 50/- 50	3% + 42/- 57	9% + 52/- 46	3% + 52/- 47	0% + 34/- 65
FR-JP	3130	1	-7.9%[-SP]						-9.65%[-SP]					
	2730	401					98% + 31/- 68		100% + 23/- 76					
	1930	1201		0% + 100	0%/- 100		90% + 26/- 72		80% + 9/- 88					
	1130	2001			2% + 47/- 52		45% + 13/- 85		20% + 29/- 68	7% + 59/- 38				
	330	2801	2% + 65/- 33	5% + 42/- 56	8% + 36/- 63	3% + 50/- 48	9% + 29/- 70		6% + 36/- 62	3% + 59/- 40	0% + 60/- 40	0% + 37/- 62	0% + 84/- 15	0% + 57/- 42
	250	2881	3% + 46/- 53	5% + 47/- 52	7% + 37/- 61	3% + 42/- 57	8% + 40/- 58		3% + 44/- 55	2% + 54/- 45	0% + 62/- 37	0% + 21/- 78	0% + 63/- 36	1% + 51/- 48
	150	2981	3% + 60/- 38	3% + 50/- 49	4% + 44/- 55	2% + 43/- 56	5% + 45/- 54		3% + 48/- 51	1% + 55/- 41	0% + 40/- 60	1% + 40/- 56	0% + 66/- 33	1% + 47/- 52
CH-FR	3130	1	-6.5%[-SP]											
	2730	401		9% + 33/- 66			20% + 25/- 69							0% + 100
	1930	1201		3% + 45/- 54			11% + 43/- 55	14% + 54/- 44						0%/- 100
	1130	2001		16% + 41/- 58			19% + 38/- 60	10% + 50/- 48			0% + 100	0% + 50/- 50		25% + 36/- 63
	330	2801	1% + 30/- 69	14% + 38/- 61		13% + 58/- 41	12% + 52/- 46	6% + 68/- 31		7% + 75/- 23	3% + 37/- 62	4% + 39/- 58	0% + 33/- 66	13% + 56/- 42
	250	2881	2% + 46/- 53	8% + 43/- 55	0% + 50/- 50	13% + 53/- 46	9% + 58/- 40	5% + 58/- 41		7% + 63/- 35	4% + 50/- 50	3% + 53/- 46	1% + 50/- 50	6% + 52/- 47
	150	2981	2% + 57/- 42	4% + 42/- 57	0% + 61/- 38	8% + 50/- 48	5% + 43/- 56	2% + 51/- 48		3% + 48/- 50	3% + 57/- 42	1% + 51/- 48	1% + 52/- 48	3% + 46/- 53
IN-FR	3130	1	-7.5%						1.38%					
	2730	401					100% + 25/- 72	0%/- 100	0%/- 100	100% + 44/- 51		6% + 33/- 66		
	1930	1201					86% + 41/- 56			42% + 67/- 32		0% + 54/- 45		
	1130	2001		3% + 21/- 72		1% + 80/- 20	50% + 28/- 71	6% + 34/- 63	6% + 34/- 63	53% + 79/- 20	0%/- 100		5% + 24/- 74	
	330	2801	1% + 38/- 61	0% + 41/- 58	0% + 80/- 20	6% + 45/- 54	24% + 45/- 54	8% + 35/- 63	8% + 35/- 63	12% + 43/- 55	0% + 52/- 47	1% + 36/- 63	5% + 59/- 40	2% + 82/- 17
	250	2881	1% + 52/- 47	0% + 27/- 72	0% + 25/- 75	4% + 66/- 33	16% + 48/- 50	3% + 35/- 64	3% + 35/- 64	11% + 45/- 54	0% + 43/- 56	3% + 37/- 61	4% + 58/- 41	2% + 46/- 53
	150	2981	1% + 49/- 50	1% + 65/- 34	0% + 50/- 50	3% + 52/- 47	8% + 56/- 43	4% + 55/- 44	4% + 55/- 44	5% + 36/- 63	1% + 55/- 43	3% + 45/- 54	1% + 43/- 56	3% + 48/- 52
RU-FR	3130	1	2.96%						2.96%					
	2730	401					92% + 36/- 61		92% + 36/- 61		42% + 23/- 75	14% + 93/- 6		63% + 5/- 94
	1930	1201			0% + 33/- 66		69% + 16/- 82		69% + 16/- 82	44% + 20/- 79	2% + 35/- 64	17% + 85/- 14		21% + 10/- 89
	1130	2001			1% + 9/- 90		4% + 14/- 85	63% + 41/- 57	63% + 41/- 57	34% + 5/- 94		13% + 87/- 12	0% + 62/- 37	12% + 13/- 86
	330	2801	2% + 76/- 23	0% + 40/- 60	8% + 34/- 65	8% + 39/- 60	2% + 50/- 49	24% + 65/- 34	24% + 65/- 34	10% + 43/- 56	5% + 51/- 47	16% + 83/- 16	5% + 52/- 47	11% + 17/- 82
	250	2881	4% + 48/- 50	0% + 28/- 71	8% + 41/- 58	7% + 45/- 54	3% + 55/- 44	19% + 64/- 35	19% + 64/- 35	8% + 47/- 52	5% + 60/- 39	12% + 72/- 27	5% + 61/- 38	9% + 26/- 73
	150	2981	3% + 35/- 64	0% + 62/- 37	2% + 51/- 48	4% + 49/- 49	0% + 28/- 72	16% + 49/- 50	16% + 49/- 50	5% + 41/- 58	3% + 54/- 45	7% + 73/- 26	3% + 48/- 51	4% + 35/- 64
FR-GE	3130	1	-4.83%[-SP]						-3.6%					
	2730	401		9% + 32/- 67		13% + 42/- 57	41% + 1/- 98	100% + 79/- 20	100% + 79/- 20	58% + 19/- 80	26% + 46/- 53	4% + 41/- 58	19% + 17/- 79	
	1930	1201		13% + 52/- 47		13% + 66/- 30	31% + 30/- 68	100% + 66/- 33	100% + 66/- 33	56% + 21/- 77	0% + 40/- 60		24% + 28/- 71	

	1130	2001	0% + 56/- 43	13% + 38/- 61		10% + 30/- 69	11% + 44/- 55	100% + 57/- 41	100% + 57/- 41	40% + 29/- 69	4% + 46/- 53	0% + 20/- 80	38% + 44/- 55	1% + 35/- 64
	330	2801	0% + 40/- 60	7% + 39/- 60	4% + 28/- 69	8% + 29/- 70	2% + 40/- 59	100% + 52/- 46	100% + 52/- 46	6% + 58/- 41	2% + 41/- 58	1% + 38/- 61	13% + 44/- 55	2% + 31/- 68
	250	2881	0% + 35/- 64	4% + 43/- 56	3% + 33/- 66	6% + 40/- 59	3% + 39/- 60	98% + 50/- 48	98% + 50/- 48	5% + 70/- 29	4% + 44/- 54	1% + 47/- 50	8% + 44/- 55	1% + 51/- 48
	150	2981	1% + 50/- 50	1% + 52/- 47	2% + 40/- 60	2% + 57/- 42	3% + 40/- 59	92% + 48/- 51	92% + 48/- 51	4% + 54/- 45	1% + 34/- 65	1% + 42/- 57	3% + 44/- 55	2% + 50/- 49
UK-JP	3130	1	-1.89%{-SP}		{-SP}		-7.59%{-SP}							
	2730	401	100% + 11/- 88		0% + 25/- 75		100% + 1/- 98							
	1930	1201	55% + 13/- 85		1% + 27/- 72		99% + 3/- 95							
	1130	2001	28% + 40/- 58		14% + 39/- 58		55% + 10/- 89		2%/- 100					
	330	2801	2% + 56/- 42	16% + 49/- 50	6% + 32/- 67	3% + 74/- 25	20% + 25/- 73		6% + 57/- 42	1% + 56/- 43	0% + 20/- 80	0% + 76/- 17	3% + 70/- 29	0%/- 100
	250	2881	3% + 67/- 32	11% + 47/- 52	5% + 37/- 62	3% + 64/- 34	13% + 36/- 63		3% + 52/- 47	0% + 37/- 62	0% + 36/- 63	0% + 25/- 75	0% + 14/- 85	0% + 25/- 75
	150	2981	2% + 48/- 51	7% + 47/- 52	4% + 46/- 53	1% + 47/- 50	9% + 46/- 53		2% + 50/- 49	0% + 28/- 71	0% + 70/- 30	0% + 38/- 61	0% + 44/- 55	0% + 57/- 42
CH-UK	3130	1												
	2730	401	1% + 16/- 66				53% + 54/- 44						90% + 56/- 40	
	1930	1201	0% + 100				17% + 51/- 47						85% + 59/- 39	
	1130	2001	0% + 23/- 76				10% + 54/- 44						52% + 52/- 46	
	330	2801	1% + 23/- 76	6% + 47/- 51	0% + 28/- 71	4% + 52/- 47	4% + 67/- 32	7% + 50/- 49		9% + 40/- 57			0%/- 100	
	250	2881	2% + 45/- 55	8% + 48/- 50	1% + 42/- 57	4% + 55/- 44	2% + 42/- 57	7% + 52/- 47		11% + 69/- 30	10% + 31/- 67	0% + 60/- 40	13% + 60/- 38	0% + 47/- 52
	150	2981	1% + 58/- 41	3% + 41/- 57	1% + 46/- 53	4% + 46/- 53	2% + 48/- 50	3% + 46/- 53		9% + 69/- 30	8% + 50/- 50	0% + 33/- 66	8% + 55/- 44	0% + 50/- 50
IN-UK	3130	1					-4.56%		-95%{-SP}		-95%{-SP}			
	2730	401			0% + 100		100% + 13/- 86		30% + 19/- 78		30% + 19/- 78		16% + 48/- 46	
	1930	1201			0% + 33/- 66		86% + 22/- 76		10% + 14/- 84		16% + 58/- 38		5% + 90/- 9	
	1130	2001					0% + 93/- 6		52% + 24/- 74		7% + 17/- 82		23% + 82/- 15	
	330	2801	2% + 67/- 32		3% + 51/- 47	3% + 50/- 50	21% + 45/- 54	8% + 15/- 84		7% + 17/- 82	22% + 86/- 12	0%/- 100	6% + 64/- 33	0%/- 100
	250	2881	3% + 59/- 40	0% + 50/- 50	1% + 39/- 60	2% + 53/- 44	15% + 52/- 46	9% + 17/- 82	8% + 15/- 84	14% + 44/- 54	6% + 35/- 64	2% + 47/- 52	13% + 55/- 44	1% + 61/- 38
	150	2981	1% + 51/- 48	1% + 60/- 39	1% + 31/- 65	3% + 43/- 56	6% + 54/- 45	9% + 43/- 56	9% + 17/- 82	12% + 31/- 68	3% + 38/- 61	1% + 43/- 56	11% + 51/- 48	2% + 61/- 38
RU-UK	3130	1					2.23%		2.23%		10.09%		-3.57%{+SP}	
	2730	401					100% + 35/- 62		100% + 35/- 62		35% + 73/- 25		100% + 90/- 8	
	1930	1201	35% + 20/- 75		9% + 5/- 92		77% + 17/- 81		77% + 17/- 81	0%/- 100	2% + 72/- 25	65% + 93/- 6	2% + 75/- 16	100% + 15/- 84
	1130	2001	1% + 42/- 52		5% + 26/- 72	13% + 19/- 79	70% + 29/- 70		70% + 29/- 70	16% + 3/- 96	0%/- 100	43% + 79/- 20	52% + 43/- 54	
	330	2801	0% + 80/- 20	6% + 45/- 54	4% + 23/- 76	9% + 30/- 68	2% + 25/- 70	29% + 60/- 39	29% + 60/- 39	4% + 55/- 43	9% + 51/- 48	23% + 65/- 34	3% + 63/- 36	22% + 17/- 82
	250	2881	0% + 14/- 85	5% + 34/- 65	3% + 36/- 63	8% + 39/- 60	3% + 37/- 62	26% + 60/- 39	26% + 60/- 39	4% + 44/- 55	11% + 55/- 44	16% + 58/- 41	3% + 44/- 55	18% + 19/- 80
	150	2981	1% + 65/- 34	1% + 43/- 55	1% + 45/- 54	5% + 43/- 56	2% + 47/- 52	19% + 45/- 54	19% + 45/- 54	3% + 50/- 49	6% + 55/- 44	8% + 60/- 39	2% + 44/- 55	7% + 33/- 66
UK-GE	3130	1					.98%{+SP}		.98%{+SP}		1.61%{-SP}		-2.24%	
	2730	401			0%/- 100		100% + 79/- 20		100% + 79/- 20		99% + 29/- 70		39% + 28/- 71	
	1930	1201	1% + 64/- 35		0% + 60/- 40		100% + 76/- 23		100% + 76/- 23	96% + 32/- 66	11% + 8/- 91	5% + 6/- 93	13% + 28/- 71	
	1130	2001	8% + 33/- 64	0% + 18/- 81	11% + 69/- 30	4% + 28/- 71	100% + 59/- 39		100% + 59/- 39	72% + 47/- 51	1% + 42/- 57	10% + 21/- 77	0% + 22/- 77	
	330	2801	2% + 53/- 46	3% + 34/- 63	7% + 49/- 50	8% + 41/- 58	0% + 27/- 72	93% + 62/- 37	93% + 62/- 37	11% + 49/- 49	4% + 41/- 57	1% + 21/- 75	3% + 26/- 73	1% + 54/- 45
	250	2881	1% + 54/- 43	3% + 50/- 49	3% + 60/- 39	6% + 27/- 72	2% + 56/- 43	91% + 58/- 41	91% + 58/- 41	9% + 43/- 56	3% + 64/- 35	1% + 44/- 56	3% + 38/- 61	0% + 46/- 53
	150	2981	1% + 51/- 48	3% + 59/- 40	1% + 51/- 48	4% + 45/- 54	0% + 42/- 57	85% + 51/- 48	85% + 51/- 48	5% + 45/- 54	1% + 53/- 44	0% + 51/- 48	3% + 45/- 54	1% + 46/- 53
UK-FR	3130	1			-23.29%		1.62%		1.62%		-17.65%			
	2730	401			73% + 27/- 72		0% + 100		100% + 72/- 27		100% + 72/- 27		25% + 38/- 61	
	1930	1201	1% + 47/- 47	5% + 54/- 45	3% + 60/- 36	70% + 23/- 75	0% + 54/- 45	100% + 62/- 37	100% + 62/- 37	64% + 39/- 57	35% + 52/- 45		71% + 38/- 58	
	1130	2001	13% + 68/- 30	0% + 46/- 53	11% + 63/- 34	33% + 47/- 51	0%/- 100	100% + 51/- 47	100% + 51/- 47	28% + 35/- 63	23% + 37/- 60	0% + 100	73% + 46/- 51	
	330	2801	3% + 43/- 54	1% + 52/- 44	12% + 55/- 44	6% + 41/- 58	0% + 71/- 28	100% + 51/- 47	100% + 51/- 47	8% + 47/- 51	16% + 51/- 48	0% + 16/- 83	38% + 67/- 31	0% + 50/- 50
	250	2881	2% + 43/- 56	4% + 28/- 71	7% + 40/- 59	6% + 42/- 56	0% + 53/- 46	100% + 46/- 52	100% + 46/- 52	7% + 50/- 48	8% + 50/- 48	0% + 29/- 70	1% + 46/- 53	2% + 44/- 53
	150	2981	2% + 44/- 55	2% + 55/- 44	4% + 48/- 51	3% + 60/- 39	0% + 47/- 52	99% + 46/- 53	99% + 46/- 53	2% + 53/- 46	3% + 56/- 44	1% + 60/- 39	1% + 58/- 41	1% + 51/- 44
BR-JP	3130	1	-1.71%		0%		-1.25%							
	2730	401			99% + 44/- 51		100% + 51/- 45		100% + 23/- 73					
	1930	1201			90% + 55/- 42		79% + 54/- 43		100% + 26/- 71					
	1130	2001	8% + 38/- 60	49% + 62/- 35	0% + 66/- 33	39% + 68/- 30	66% + 31/- 67			11% + 87/- 12	0% + 27/- 63	0% + 54/- 45	0% + 75/- 25	
	330	2801	17% + 44/- 55	20% + 57/- 42	5% + 56/- 43	15% + 66/- 33	14% + 45/- 54			17% + 53/- 43	1% + 79/- 20		0% + 84/- 15	
	250	2881	11% + 42/- 57	16% + 57/- 42	4% + 51/- 48	9% + 56/- 43	7% + 50/- 49		1% + 72/- 27	4% + 41/- 58	5% + 53/- 46	4% + 61/- 37	1% + 80/- 20	2% + 54/- 45
	150	2981	4% + 54/- 45	7% + 53/- 46	2% + 42/- 57	5% + 48/- 51	5% + 37/- 62		1% + 63/- 36	3% + 48/- 51	5% + 48/- 51	3% + 39/- 60	3% + 77/- 22	2% + 71/- 28
BR-CH	3130	1	7.6%		6.05%				-6.93%					
	2730	401			70% + 65/- 34		87% + 51/- 48		54% + 50/- 48					
	1930	1201			19% + 57/- 42		65% + 50/- 48		18% + 46/- 52					
	1130	2001			12% + 52/- 46		48% + 49/- 49		11% + 44/- 55				0% + 100	
	330	2801	1% + 74/- 25	6% + 11/- 87	0% + 20/- 80	33% + 43/- 56	0% + 64/- 36		12% + 55/- 43		1% + 52/- 47	3% + 58/- 41	1% + 25/- 75	1% + 87/- 12
	250	2881	2% + 42/- 56	6% + 22/- 77	0% + 42/- 57	23% + 42/- 57	1% + 52/- 47		11% + 51/- 48	0% + 50/- 50	1% + 65/- 34	6% + 77/- 22	0% + 36/- 64	2% + 51/- 48
	150	2981	2% + 47/- 52	2% + 50/- 49	1% + 48/- 51	12% + 41/- 58	0% + 72/- 27		7% + 47/- 52	0% + 55/- 44	4% + 58/- 41	2% + 77/- 22	2% + 49/- 50	1% + 61/- 38
BR-IN	3130	1	6.42%		1.12%		-26%{+SP}				-3.77%			

[illegible]

	330	2801	4% + 48/- 50	0% + 33/- 66	18% + 29/- 70	17% + 55/- 42	0% + 69/- 30	14% + 46/- 53		17% + 47/- 52	3% + 74/- 25	6% + 70/- 28		3% + 67/- 31
	250	2881	2% + 47/- 51	0% + 14/- 85	14% + 42/- 57	15% + 46/- 53	1% + 72/- 24	13% + 36/- 63		11% + 43/- 55	5% + 64/- 35	4% + 63/- 36		3% + 77/- 22
	150	2981	3% + 48/- 51	0% + 47/- 52	7% + 48/- 51	8% + 50/- 49	1% + 63/- 36	6% + 34/- 64		6% + 41/- 58	3% + 67/- 31	4% + 58/- 41	0% + 37/- 62	3% + 57/- 42
US-GE	3130	1				3.11%	-5.45%	-3.2%[-SP]	-3.2%[-SP]					-1.79%
	2730	401				13% + 55/- 41	100% + 54/- 44	100% + 46/- 51	100% + 46/- 51	90% + 35/- 63			100% + 37/- 61	
	1930	1201				1% + 33/- 61	48% + 47/- 51	100% + 37/- 61	100% + 37/- 61	68% + 58/- 39			100% + 63/- 36	
	1130	2001				4% + 30/- 66	32% + 45/- 53	87% + 37/- 62	87% + 37/- 62	21% + 46/- 52	9% + 50/- 45	0% + 33/- 66	56% + 67/- 31	
	330	2801	1% + 41/- 58	0%/- 100	0% + 56/- 43	2% + 26/- 73	11% + 60/- 39	62% + 38/- 60	62% + 38/- 60	3% + 39/- 59	10% + 59/- 40	2% + 30/- 69	12% + 47/- 51	1% + 56/- 40
	250	2881	2% + 47/- 51	1% + 28/- 71	1% + 42/- 57	2% + 44/- 55	8% + 56/- 43	56% + 41/- 58	56% + 41/- 58	2% + 57/- 42	7% + 55/- 43	2% + 53/- 46	10% + 53/- 45	1% + 44/- 55
	150	2981	3% + 47/- 52	1% + 43/- 54	2% + 56/- 43	5% + 50/- 50	4% + 44/- 55	45% + 45/- 53	45% + 45/- 53	4% + 42/- 57	4% + 50/- 50	0% + 45/- 54	6% + 47/- 53	1% + 42/- 57
US-FR	3130	1				.7%	-10.41%	.85%[-SP]	.85%[-SP]					.36%
	2730	401				99% + 35/- 58	39% + 13/- 86	100% + 37/- 60	100% + 37/- 60				100% + 76/- 23	
	1930	1201			0% + 66/- 33	31% + 15/- 82	1% + 60/- 40	100% + 32/- 67	100% + 32/- 67	33% + 65/- 32			100% + 72/- 27	
	1130	2001			0% + 50/- 45	15% + 45/- 51	12% + 39/- 59	100% + 37/- 61	100% + 37/- 61	11% + 72/- 27	0% + 57/- 36		56% + 83/- 15	
	330	2801	2% + 40/- 59	1% + 31/- 65	1% + 52/- 47	11% + 50/- 49	10% + 55/- 44	69% + 43/- 55	69% + 43/- 55	2% + 38/- 60	2% + 50/- 49	0% + 40/- 60	11% + 44/- 55	0% + 50/- 50
	250	2881	2% + 46/- 53	1% + 33/- 66	1% + 42/- 57	11% + 55/- 44	7% + 60/- 39	61% + 45/- 54	61% + 45/- 54	1% + 45/- 52	0% + 68/- 31	0% + 50/- 50	8% + 43/- 56	1% + 62/- 37
	150	2981	1% + 62/- 37	1% + 53/- 46	1% + 59/- 40	6% + 61/- 38	4% + 54/- 45	42% + 50/- 50	42% + 50/- 50	2% + 47/- 52	1% + 38/- 61	0% + 61/- 38	5% + 41/- 58	1% + 46/- 53
US-UK	3130	1						-1.95%	-1.95%		2.71%[-SP]			5.24%
	2730	401					2% + 41/- 58	100% + 34/- 64	100% + 34/- 64	6% + 53/- 42	86% + 26/- 71	52% + 93/- 6	100% + 89/- 9	
	1930	1201		0% + 100			27% + 52/- 45	100% + 36/- 62	100% + 36/- 62	38% + 77/- 21	38% + 33/- 65	19% + 95/- 4	100% + 85/- 13	
	1130	2001	3% + 89/- 8	11% + 25/- 73		0% + 100	14% + 30/- 68	100% + 38/- 61	100% + 38/- 61	34% + 71/- 28	26% + 49/- 50	16% + 87/- 12	56% + 80/- 18	0% + 50/- 50
	330	2801	7% + 41/- 58	3% + 51/- 47	2% + 55/- 44	1% + 28/- 71	13% + 64/- 35	74% + 47/- 52	74% + 47/- 52	0% + 56/- 44	12% + 43/- 56	6% + 60/- 39	11% + 35/- 63	0% + 82/- 17
	250	2881	7% + 50/- 50	3% + 48/- 51	2% + 40/- 59	2% + 41/- 56	9% + 51/- 48	66% + 49/- 50	66% + 49/- 50	1% + 44/- 55	10% + 49/- 49	3% + 58/- 41	8% + 43/- 56	2% + 39/- 57
	150	2981	4% + 48/- 51	3% + 55/- 44	1% + 48/- 51	2% + 44/- 55	7% + 39/- 60	47% + 50/- 49	47% + 50/- 49	1% + 57/- 42	6% + 43/- 56	4% + 47/- 52	5% + 50/- 49	1% + 43/- 56
BR-US	3130	1		13.46%[+SP]		2.8%		1.68%	1.68%		4.38%			
	2730	401		100% + 74/- 24		100% + 64/- 33		100% + 69/- 29	100% + 69/- 29		76% + 35/- 62			
	1930	1201		100% + 78/- 21		59% + 53/- 44		100% + 68/- 30	100% + 68/- 30		32% + 10/- 87			
	1130	2001	2% + 37/- 60	56% + 73/- 26	1% + 17/- 79	39% + 43/- 56		100% + 54/- 44	100% + 54/- 44		7% + 38/- 61		0%/- 100	0% + 11/- 77
	330	2801	1% + 47/- 52	14% + 52/- 46	2% + 60/- 40	15% + 51/- 48	1% + 52/- 47	78% + 42/- 57	78% + 42/- 57	0% + 75/- 25	11% + 55/- 43	2% + 65/- 32		0% + 47/- 52
	250	2881	1% + 54/- 45	9% + 64/- 35	3% + 53/- 46	11% + 48/- 51	3% + 50/- 49	67% + 44/- 55	67% + 44/- 55	1% + 58/- 41	9% + 50/- 48	2% + 80/- 19	2% + 66/- 33	0% + 46/- 53
	150	2981	0% + 30/- 69	5% + 50/- 49	2% + 60/- 39	6% + 53/- 46	3% + 48/- 51	44% + 50/- 49	44% + 50/- 49	2% + 40/- 59	3% + 55/- 44	1% + 56/- 43	1% + 43/- 56	1% + 31/- 68

A.5. Testing non-causality hypothesis on joint test basis in ARMA(m,n)-EGARCH(p,q) in full sample estimation.

Table A.5-1 (Page 1 out of 9)

Application of ARMA(m,n)-EGARCH(p,q) for testing non-causality hypothesis on joint test basis without oil price adjustment (Equation (21)).

Pair direction	CH-->JP	JP-->CH	IN-->JP	JP-->IN	IN-->CH	CH-->IN	RU-->JP	JP-->RU	RU-->CH	CH-->RU
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Same day	Same day	Same day	Same day	Same day	Same day	Next day	Same day	Next day	Same day
Equation state	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
lags of X in mean equation	(0...0)	(0...-2)	(0...-1)	(0...0)	(0...0)	(0...0)	(-1...-1)	(0...0)	(-1...-2)	(0...-1)
lags of AR	No AR	No AR	No AR	AR(1)	No AR	AR(1)	No AR	No AR	No AR	No AR
lags of MA	No MA	MA(3)	No MA	MA(2)	MA(3)	MA(2)	No MA	MA(1)	MA(3)	MA(1)
lags of ARCH	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(1)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X ² in variance equation	No Caus. in variance	No Caus. in variance	(0...-2)	No Caus. in variance	No Caus. in variance	No Caus. in variance	(-1...-1)	No Caus. in variance	No Caus. in variance	No Caus. in variance
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α_0 (Constant)	-0.022035	1.75E-05	-0.031008	0.110664 **	0.000122	0.099799 **	-0.026618	0.165174 **	0.000137	0.165049 **
λ_0	0.043497 **	0.000153	0.148383 **	0.133903 **	-5.11E-05	0.034550 **		0.179014 **		0.030635 *
λ_1		3.00E-05	0.032627 *				0.045629 **		0.000102	-0.001587
λ_2		-0.000125							-5.15E-07	
λ_3										
λ_4										
λ_5										
AR(1)				0.893513 **		0.899561 **				
AR(2)										
AR(3)										
MA(1)		-0.005400		-0.780255 **	-0.004735	-0.783461 **		0.058614 **	-0.006586	0.068631 **
MA(2)		0.001656		-0.070615 **	0.003276	-0.072273 **			0.003061	
MA(3)		0.007571			0.011933				0.013420	
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ω_0 (Constant)	-0.096864 **	-0.147923 **	-0.117247 **	-0.143891 **	-0.148004 **	-0.139077 **	-0.109298 **	-0.144703 **	-0.133656 **	-0.145225 **
ARCH(1)	0.013016	0.288796 **	-0.042450	0.251300 **	0.288472 **	0.254454 **	-0.019047	0.255125 **	0.250598 **	0.258448 **
ARCH(2)	0.130167 **		0.209524 **				0.175110 **			
γ (Assymmentric effect)	-0.058264 **	-0.040220 *	-0.064609 **	-0.088877 **	-0.041721 *	-0.100744 **	-0.059587 **	-0.017658	-0.034972 *	-0.015839
GARCH(1)	0.978836 **	0.946972 **	0.972891 **	0.940208 **	0.946536 **	0.933138 **	0.975544 **	0.974130 **	0.955860 **	0.974027 **
GARCH(2)										
μ_0			0.017426 **							
μ_1			-0.017578 **				0.000814 **			
μ_2			0.002194							
μ_3										
μ_4										
μ_5										
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No X mean Causality ($H_0: \lambda_{1X,Y} = \dots = \lambda_{gY} = 0$)	Rej. 1%		Rej. 1%	Rej. 1%		Rej. 1%	Rej. 1%	Rej. 1%		
No X variance Causality ($H_0: \mu_{1X,Y} = \dots = \mu_{wY} = 0$)			Rej. 1%				Rej. 1%			
---	---	---	---	---	---	---	---	---	---	---
LB Q-stat(10)	7.7364	16.635	10.706	20.742 *	15.913	20.004 *	10.479	39.171 **	16.037	40.036 **
LB Q2-stat(10)	9.5064	3.1168	12.957	6.7952	3.0968	5.9028	6.5392	7.4918	3.7647	8.4996
LM-test(10)										
LogLikelihood	-5506.016	-5349.513	-5453.575	-5533.440	-5354.916	-5567.968	-5494.757	-6755.793	-5351.641	-6785.213

Table A.5-1 (Page 2 out of 9)

Pair direction	RU-->IN	IN-->RU	GE-->JP	JP-->GE	GE-->CH	CH-->GE	GE-->IN	IN-->GE	GE-->RU	RU-->GE
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Same day	Same day	Next day	Same day	Next day	Same day	Same day	Same day	Same day	Same day
Equation state	OK	OK	OK	OK	OK	OK	OK	OK	No convergance (B)	OK
lags of X in mean equation	(0...-1)	(0...0)	(-1...-1)	(0...-2)	(-1...-4)	No Caus. in mean	(0...-3)	(0...0)		(0...0)
lags of AR	AR(1)	No AR	No AR	No AR	No AR	No AR	AR(1)	No AR		No AR
lags of MA	MA(2)	MA(1)	No MA	No MA	MA(3)	No MA	MA(2)	No MA		No MA
lags of ARCH	ARCH(1)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)		ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)		GARCH(1)
lags of X ² in variance equation	No Caus. in variance	(0...-3)	(-1...-1)	(0...0)	No Caus. in variance	(0...-5)	(0...-1)	(0...-1)		(0...0)

α_0 (Constant)	0.088578 **	0.146967 **	-0.029889	0.057675 **	0.000214	0.066506 **	0.091790 **	0.053537 **		0.052268 **
λ_0	0.072831 **	0.198393 **		0.200960 **			0.134521 **	0.109723 **		0.105261 **
λ_1	0.019594 *		0.232884 **	-0.030358 *	0.000158		0.114994 **			
λ_2				-0.019595	0.000115		0.048502 **			
λ_3					-1.22E-05		0.044835 **			
λ_4					0.000266					
λ_5										
AR(1)	0.871545 **						0.817376 **			
AR(2)										
AR(3)										
MA(1)	-0.755149 **	0.075026 **			-0.006405		-0.729167 **			
MA(2)	-0.068266 **				0.003603		-0.051106 *			
MA(3)					0.014329					

ω_0 (Constant)	-0.145442 **	-0.144658 **	-0.108720 **	-0.110761 **	-0.142204 **	-0.113280 **	-0.156302 **	-0.108158 **		-0.108172 **
ARCH(1)	0.266856 **	0.241421 **	-0.038266	0.148987 **	0.270668 **	0.152486 **	0.277042 **	0.142879 **		0.143740 **
ARCH(2)			0.188685 **							
γ (Assymmentric effect)	-0.100626 **	-0.009647	-0.056701 **	-0.066546 **	-0.039442 *	-0.067174 **	-0.094023 **	-0.060921 **		-0.062464 **
GARCH(1)	0.927027 **	0.975774 **	0.974480 **	0.984211 **	0.949867 **	0.983548 **	0.926353 **	0.984706 **		0.981814 **
GARCH(2)										
μ_0		0.006406		6.76E-05		9.92E-05	0.014649	0.012391 *		0.000275
μ_1		0.001650	0.003739 **			0.006181	-0.013292	-0.011750 *		
μ_2		-0.005451				-0.007767				
μ_3		-0.000775				0.000764				
μ_4						0.005787				
μ_5						-0.005005 *				

No X mean Causality ($H_0: \lambda_{1X,Y} = \dots = \lambda_{5Y} = 0$)	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%			Rej. 1%	Rej. 1%		Rej. 1%
No X variance Causality ($H_0: \mu_{1X,Y} = \dots = \mu_{5W} = 0$)			Rej. 1%					Rej. 5%		

LB Q-stat(10)	18.283 *	29.567 **	27.771 **	16.861	15.944	13.464	18.888 *	16.356		18.236
LB Q2-stat(10)	5.6701	6.9482	9.7637	13.326	3.2842	7.9749	6.2365	7.6311		7.7271
LM-test(10)										
LogLikelihood	-5540.341	-6741.596	-5425.367	-5019.005	-5344.376	-5112.800	-5510.404	-5088.400		-5048.479

Table A.5-1 (Page 3 out of 9)

Pair direction	FR-->JP	JP-->FR	FR-->CH	CH-->FR	FR-->IN	IN-->FR	FR-->RU	RU-->FR	FR-->GE
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Next day	Same day	Next day	Same day	Same day	Same day	Same day	Same day	Same day
Equation state	OK	OK	OK	OK	OK	OK	OK	OK	OK
lags of X in mean equation	(-1...-2)	(0...-2)	(-1...-4)	No Caus. in mean	(0...-3)	(0...0)	(0...-1)	(0...0)	(0...-1)
lags of AR	No AR	No AR	No AR	No AR	AR(1)	No AR	No AR	No AR	No AR
lags of MA	No MA	No MA	MA(3)	No MA	MA(2)	No MA	MA(1)	No MA	No MA
lags of ARCH	ARCH(2)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X^2 in variance equation	(-1...-1)	(0...0)	No Caus. in variance	(0...-4)	(0...-1)	(0...-1)	(0...-5)	(0...0)	(0...-1)

α_0 (Constant)	-0.021877	0.052625 **	-5.27E-05	0.054164 **	0.097868 **	0.045487 *	0.156945 **	0.035749	0.019064 *
λ_0		0.180861 **			0.159895 **	0.112269 **	0.395684 **	0.101757 **	0.947516 **
λ_1	0.260420 **	-0.035432 **	0.000507		0.111319 **		0.086292 **		0.018639 *
λ_2	0.035387	-0.023241	0.000192		0.046356 **				
λ_3			-0.000184		0.062379 **				
λ_4			0.001146						
λ_5									
AR(1)					0.725220 **				
AR(2)									
AR(3)									
MA(1)			-0.005728		-0.633371 **		0.066076 **		
MA(2)			0.003337		-0.037465				
MA(3)			0.012186						

ω_0 (Constant)	-0.130055 **	-0.098818 **	-0.139343 **	-0.087289 **	-0.156073 **	-0.090746 **	-0.143415 **	-0.089743 **	-0.100175 **
ARCH(1)	0.061173	0.128536 **	0.264305 **	0.115355 **	0.274280 **	0.115157 **	0.227222 **	0.116952 **	0.110197 **
ARCH(2)	0.117783 *								
γ (Assymmentric effect)	-0.052758 **	-0.053208 **	-0.038158 *	-0.058641 **	-0.092705 **	-0.053698 **	-0.005238	-0.052925 **	-0.005437
GARCH(1)	0.966937 **	0.984073 **	0.952036 **	0.985042 **	0.924919 **	0.986366 **	0.982388 **	0.983532 **	0.993371 **
GARCH(2)									
μ_0		0.000829		-0.004201	0.004720	0.011050	0.020138	0.000226	0.039751 **
μ_1	0.006827 **			0.007115	-0.001459	-0.010025	0.007220		-0.034459 **
μ_2				0.006796			-0.022434		
μ_3				-0.013203 *			0.020299		
μ_4				0.004030			-0.037040 *		
μ_5							0.011545		

No X mean Causality ($H_0: \lambda_{ix,y} = \dots = \lambda_g = 0$)	Rej. 1%	Rej. 1%			Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%
No X variance Causality ($H_0: \mu_{ix,y} = \dots = \mu_w = 0$)	Rej. 1%			Rej. 5%			Rej. 1%		Rej. 1%

LB Q-stat(10)	30.245 **	18.680 *	16.302	20.484 *	20.330 *	22.078 *	28.667 **	22.119 *	70.818 **
LB Q2-stat(10)	10.544	13.114	3.4267	12.169	6.7030	14.637	9.1471	17.384	29.213 **
LM-test(10)									Rej. 1%
LogLikelihood	-5417.739	-4789.294	-5344.272	-4873.207	-5508.531	-4848.713	-6645.826	-4808.993	-3204.336

Table A.5-1 (Page 4 out of 9)

Pair direction	GE-->FR	UK-->JP	JP-->UK	UK-->CH	CH-->UK	UK-->IN	IN-->UK	UK-->RU	RU-->UK	UK-->GE
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Same day	Next day	Same day	Next day	Same day	Same day	Same day	Same day	Same day	Same day
Equation state	OK	OK	OK	OK	No sig. CCF detected (A)	OK	OK	OK	OK	OK
lags of X in mean equation	(0...-3)	(-1...-1)	(0...0)	(-1...-4)	No Caus. in mean	(0...-3)	(0...0)	(0...-4)	(0...0)	(0...-1)
lags of AR	No AR	No AR	No AR	No AR	No AR	AR(1)	No AR	No AR	No AR	No AR
lags of MA	No MA	No MA	MA(1)	MA(3)	MA(1)	MA(2)	MA(1)	MA(1)	MA(1)	No MA
lags of ARCH	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X ² in variance equation	(0...-4)	(-1...-4)	No Caus. in variance	No Caus. in variance	No Caus. in variance	(0...0)	(0...-1)	(0...-5)	(0...0)	(0...0)
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α_0 (Constant)	-0.001177	-0.032775	0.037960 **	-0.000121		0.088531 **	0.034242 *	0.142696 **	0.026257	0.018990
λ_0	0.818502 **		0.141477 **			0.252192 **	0.085990 **	0.535187 **	0.081662 **	0.924420 **
λ_1	0.012917	0.300761 **		0.000922		0.159539 **		0.134534 **		0.015298
λ_2	-0.028111 **			0.000256		0.063454 **		0.012939		
λ_3	-0.024090 **			0.000114		0.076588 **		0.047809		
λ_4				0.001704				0.040496		
λ_5										
AR(1)						0.808204 **				
AR(2)										
AR(3)										
MA(1)			-0.017292	-0.005163		-0.711231 **	0.003035	0.055219 **	0.007423	
MA(2)				0.003577		-0.049406				
MA(3)				0.012270						
---	---	---	---	---	---	---	---	---	---	---
ω_0 (Constant)	-0.074265 **	-0.115330 **	-0.119061 **	-0.163191 **		-0.173452 **	-0.108465 **	-0.176969 **	-0.119229 **	-0.109700 **
ARCH(1)	0.090442 **	-0.030193	0.142474 **	0.334935 **		0.291206 **	0.124905 **	0.296300 **	0.139035 **	0.127922 **
ARCH(2)		0.189812 **								
γ (Assymmentric effect)	-0.025329 *	-0.056416 **	-0.081460 **	-0.053290 *		-0.096941 **	-0.079255 **	-0.011749	-0.083674 **	-0.046128 **
GARCH(1)	0.997105 **	0.978756 **	0.973788 **	0.925088 **		0.917381 **	0.973540 **	0.970027 **	0.968513 **	0.988792 **
GARCH(2)										
μ_0	0.044241 **					0.013063 *	0.009933	0.062061 **	0.000216	0.006334 **
μ_1	-0.017907 *	0.052021 **					-0.008959	-0.034716		
μ_2	-0.018265 *	-0.044480						-0.040664		
μ_3	0.012468	-0.006774						0.072999 **		
μ_4	-0.019828 **	0.004500						-0.065285 **		
μ_5								0.008016		
---	---	---	---	---	---	---	---	---	---	---
No X mean Causality ($H_0: \lambda_{1X,Y} = \dots = \lambda_{gY} = 0$)	Rej. 1%	Rej. 1%	Rej. 1%			Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%
No X variance Causality ($H_0: \mu_{1X,Y} = \dots = \mu_{wY} = 0$)	Rej. 1%	Rej. 1%				Rej. 5%		Rej. 1%		Rej. 1%
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LB Q-stat(10)	75.050 **	22.760 *	15.352	15.888		18.477 *	21.150 *	27.539 **	22.092 *	20.102 *
LB Q2-stat(10)	26.354 **	10.941	12.586	2.6046		7.6142	10.453	7.8530	6.6871	7.6559
LM-test(10)	Rej. 1%									
LogLikelihood	-2941.497	-5417.183	-4023.423	-5342.983		-5497.169	-4075.037	-6624.497	-4026.800	-4061.001

Table A.5-1 (Page 5 out of 9)

Pair direction	GE-->UK	UK-->FR	FR-->UK	BR-->JP	JP-->BR	BR-->CH	CH-->BR	BR-->IN	IN-->BR	BR-->RU
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Same day	Same day	Same day	Next day	Same day	Next day	Same day	Next day	Same day	Same day
Equation state	OK	No convergance (B)	OK	OK	OK	OK	OK	OK	OK	OK
lags of X in mean equation	(0...-4)		(0...-4)	(-1...-2)	(0...-4)	(-1...-5)	No Caus. in mean	(-1...-3)	(0...0)	(0...-4)
lags of AR	No AR		No AR	No AR	AR(2)	No AR	AR(2)	AR(1)	AR(2)	No AR
lags of MA	MA(1)		MA(1)	No MA	No MA	MA(3)	No MA	MA(2)	No MA	MA(1)
lags of ARCH	ARCH(1)		ARCH(1)	ARCH(2)	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(1)
lags of GARCH	GARCH(1)		GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X ² in variance equation	(0...-3)		(0...-2)	(-1...-4)	No Caus. in variance	(-1...-4)	(0...0)	(-1...-4)	(0...-1)	(0...-3)

α_0 (Constant)	0.016325		0.009442	-0.027652	0.116175 **	0.000416	0.112900 **	0.094340 **	0.103924 **	0.123336 **
λ_0	0.502936 **		0.622299 **		0.126727 **				0.134084 **	0.171023 **
λ_1	0.026662 **		0.020290 *	0.124107 **	-0.018833	0.000477		0.070860 **		0.115318 **
λ_2	-0.006107		0.010775	0.006884	0.020696	-2.57E-05		0.000452		0.016503
λ_3	-0.022263 **		0.008967		0.026424	-0.000121		0.032746 **		0.023101
λ_4	0.006635		0.021453 *		0.033633	-4.42E-05				0.027074 *
λ_5						6.10E-05				
AR(1)					0.086198 **		0.098568 **	0.848226 **	0.086640 **	
AR(2)					-0.027953		-0.030402		-0.030287	
AR(3)										
MA(1)	-0.054901 **		-0.047721 **			-0.006889		-0.745678 **		0.048667 **
MA(2)						0.002901		-0.059621 **		
MA(3)						0.013884				

ω_0 (Constant)	-0.291954 **		-0.073639 **	-0.103786 **	-0.074902 **	-0.120601 **	-0.057364 **	-0.142975 **	-0.078014 **	-0.150136 **
ARCH(1)	0.207312 **		0.080967 **	0.005937	0.102060 *	0.230327 **	0.072567	0.257245 **	0.094548	0.251763 **
ARCH(2)				0.138224 **	0.131688 **		0.158529 **	0.137758 **		
γ (Assymmentric effect)	-0.031190		-0.020841 *	-0.045332 **	-0.138786 **	-0.032680	-0.145118 **	-0.099638 **	-0.139147 **	-0.012653
GARCH(1)	0.891293 **		0.991576 **	0.977065 **	0.930268 **	0.962904 **	0.924913 **	0.929766 **	0.928996 **	0.974970 **
GARCH(2)										
μ_0	0.045303 **		0.052756 **				-0.002153		0.002648	0.007034 *
μ_1	-0.007135		-0.022118 *	0.007216 **		0.001665		0.003492	-0.000725	-0.002547
μ_2	-0.020492		-0.029452 **	-0.004912		0.005342		-0.000789		-0.001501
μ_3	0.001438			-6.08E-05		-0.008572 *		-0.002839		-0.002901
μ_4				-0.000966		0.000646		0.000583		
μ_5										

No X mean Causality (H ₀ : $\lambda_{1xy} = \dots = \lambda_{gy} = 0$)	Rej. 1%		Rej. 1%	Rej. 1%	Rej. 1%			Rej. 1%	Rej. 1%	Rej. 1%
No X variance Causality (H ₀ : $\mu_{1xy} = \dots = \mu_{wy} = 0$)	Rej. 1%		Rej. 1%	Rej. 1%		Rej. 5%				Rej. 1%

LB Q-stat(10)	26.271 **		33.111 **	13.087	12.143	17.239	9.7324	19.135 *	9.6665	25.037 **
LB Q2-stat(10)	11.497		14.768	10.170	11.810	5.0671	11.989	5.9587	11.950	11.328
LM-test(10)										
LogLikelihood	-3123.395		-2788.852	-5427.146	-6767.522	-5338.517	-6788.781	-5538.144	-6772.197	-6665.987

Table A.5-1 (Page 6 out of 9)

Pair direction	RU-->BR	BR-->GE	GE-->BR	BR-->FR	FR-->BR	BR-->UK	UK-->BR	US-->JP	JP-->US	US-->CH
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Same day	Same day	Same day	Same day	Same day	Same day	Same day	Next day	Same day	Next day
Equation state	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
lags of X in mean equation	(0...0)	(0...-1)	(0...-4)	(0...-1)	(0...0)	(0...-5)	(0...0)	(-1...-2)	(0...-1)	(-1...-4)
lags of AR	AR(2)	No AR	AR(2)	No AR	AR(2)	No AR	AR(2)	No AR	No AR	No AR
lags of MA	No MA	No MA	No MA	No MA	No MA	MA(1)	No MA	No MA	No MA	MA(3)
lags of ARCH	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(2)	ARCH(2)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X ² in variance equation	(0...0)	(0...-3)	(0...-4)	(0...-4)	(0...0)	(0...-1)	(0...0)	(-1...-5)	No Caus. in variance	No Caus. in variance
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α_0 (Constant)	0.083435 *	0.031584	0.046855	0.019184	0.078759 *	0.021812	0.088771 **	-0.035742	0.038443 **	9.67E-05
λ_0	0.160343 **	0.198966 **	0.569250 **	0.181212 **	0.599696 **	0.133333 **	0.786901 **		0.052391 **	
λ_1		0.053082 **	0.097518 **	0.053425 **		0.052455 **		0.456383 **	-0.021707 *	8.57E-05
λ_2			0.023174			-0.000885		0.079080 **		0.000386
λ_3			0.030040			0.004444				0.000109
λ_4			0.068389 **			-0.010542				0.000373
λ_5						-0.014342 *				
AR(1)	0.080993 **		0.044954 **		0.051486 **		0.032868			
AR(2)	-0.035271		-0.041845 *		-0.026971		-0.020344			
AR(3)										
MA(1)						-0.041832 *				-0.006137
MA(2)										0.003267
MA(3)										0.012231
---	---	---	---	---	---	---	---	---	---	---
ω_0 (Constant)	-0.068119 **	-0.116542 **	-0.055653 **	-0.095294 **	-0.049074 *	-0.106587 **	-0.085495 **	-0.119596 **	-0.093540 **	-0.153890 **
ARCH(1)	0.085417	0.149685 **	0.073348	0.118189 **	0.047178	0.110659 **	0.135283 **	0.087502	-0.005399	0.307412 **
ARCH(2)	0.123100 *		0.144942 **		0.147025 **		0.098481	0.070918	0.114536 *	
γ (Assymmentric effect)	-0.130806 **	-0.064061 **	-0.149730 **	-0.047926 **	-0.133067 **	-0.076841 **	-0.123458 **	-0.050408 **	-0.120608 **	-0.048003 *
GARCH(1)	0.929785 **	0.984388 **	0.886549 **	0.983389 **	0.901729 **	0.971000 **	0.912456 **	0.974538 **	0.972911 **	0.935729 **
GARCH(2)										
μ_0	0.001511 **	0.004273 *	0.022038 **	0.004763 *	0.020791 **	0.010133 **	0.027105 **			
μ_1		0.002199	-0.005569	0.001681		-0.008907 **		0.026276 *		
μ_2		-0.000671	0.006373	-0.002641				-0.005011		
μ_3		-0.005292 *	-0.009619	-0.004810 *				-0.006773		
μ_4			0.007193	0.001839				-0.012482		
μ_5								0.010111		
---	---	---	---	---	---	---	---	---	---	---
No X mean Causality ($H_0: \lambda_{t_{X,Y}} = \dots = \lambda_g = 0$)	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	
No X variance Causality ($H_0: \mu_{t_{X,Y}} = \dots = \mu_w = 0$)	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%		
---	---	---	---	---	---	---	---	---	---	---
LB Q-stat(10)	10.097	30.659 **	13.930	30.508 **	11.875	29.230 **	8.6417	20.766 *	14.625	16.109
LB Q2-stat(10)	14.770	7.9753	7.4719	15.499	9.4181	17.992	8.3683	6.0846	4.0878	2.7866
LM-test(10)										
LogLikelihood	-6719.754	-4868.815	-6542.873	-4641.533	-6582.748	-3885.150	-6568.626	-5330.270	-3923.785	-5343.226

Table A.5-1 (Page 7 out of 9)

Pair direction	CH-->US	US-->IN	IN-->US	US-->RU	RU-->US	US-->GE	GE-->US	US-->FR	FR-->US	US-->UK
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Same day	Next day	Same day	Next day	Same day	Same day	Same day	Same day	Same day	Same day
Equation state	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
lags of X in mean equation	(0...-4)	(-1...-4)	(0...-2)	(-1...-3)	(0...0)	(0...-1)	(0...0)	(0...-1)	(0...-1)	(0...-1)
lags of AR	No AR	AR(1)	No AR	No AR	No AR	No AR	No AR	No AR	No AR	No AR
lags of MA	No MA	MA(2)	No MA	MA(1)	No MA	No MA	No MA	No MA	No MA	MA(1)
lags of ARCH	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X ² in variance equation	(0...-4)	(-1...-5)	(0...-1)	(-1...-1)	(0...0)	(0...-2)	(0...-4)	(0...-2)	(0...-4)	(0...0)
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α_0 (Constant)	0.038270 **	0.098618 **	0.032893 *	0.139876 **	0.031346 *	0.010406	0.003777	0.010156	0.008882	0.009324
λ_0	0.010026		0.036613 **		0.037583 **	0.667868 **	0.333238 **	0.634131 **	0.347595 **	0.462179 **
λ_1	-0.014197	0.197318 **	-0.013762	0.348290 **		0.303762 **		0.310411 **	0.023113 *	0.268020 **
λ_2	0.006763	0.067956 **	0.014847	0.018794						
λ_3	-0.015193 *	0.077982 **		0.021519						
λ_4	-0.010641	0.071686 **								
λ_5										
AR(1)		0.431939								
AR(2)										
AR(3)										
MA(1)		-0.336876		0.037082 *						-0.176880 **
MA(2)		-0.009825								
MA(3)										
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ω_0 (Constant)	-0.088129 **	-0.139534 **	-0.086370 **	-0.146635 **	-0.096508 **	-0.086161 **	-0.102962 **	-0.089946 **	-0.126840 **	-0.172927 **
ARCH(1)	-0.041347	0.244313 **	-0.061489	0.259269 **	-0.016423	0.093636 **	0.111854 *	0.102301 **	0.055563	0.131845 **
ARCH(2)	0.142507 **		0.160990 **		0.124625 **		-0.005058		0.052024	
γ (Assymmentric effect)	-0.119771 **	-0.086644 **	-0.118674 **	-0.015850	-0.124517 **	-0.041936 **	-0.111068 **	-0.022492	-0.129618 **	-0.059917 **
GARCH(1)	0.976435 **	0.938395 **	0.975376 **	0.971745 **	0.970636 **	0.975096 **	0.976521 **	0.981427 **	0.956714 **	0.924021 **
GARCH(2)										
μ_0	0.009456 **		0.010423 *		0.000521 *	0.028310 *	0.045797 **	0.040337 *	0.053073 **	0.032224 **
μ_1	-0.011682 *	0.034661	-0.009480 *	0.002895		0.048412 **	-0.031206 **	0.007858	-0.036380 *	
μ_2	0.003273	-0.012559				-0.065213 **	-0.005559	-0.038668 *	-0.003530	
μ_3	-0.003005	-0.012700					-0.005002		-0.009112	
μ_4	0.003212	0.003373					-0.001299		0.006748	
μ_5		-0.012235								
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No X mean Causality ($H_0: \lambda_{1xy} = \dots = \lambda_{5y} = 0$)	Rej. 5%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%
No X variance Causality ($H_0: \mu_{1xy} = \dots = \mu_{5y} = 0$)	Rej. 1%		Rej. 5%		Rej. 5%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%
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LB Q-stat(10)	15.809	21.187 *	15.868	40.157 **	14.914	104.63 **	62.022 **	113.03 **	77.106 **	24.891 **
LB Q2-stat(10)	5.1798	7.1427	7.6622	7.1779	5.5182	21.656 *	4.2167	11.548	9.9159	13.023
LM-test(10)						Rej. 5%				
LogLikelihood	-3928.014	-5530.457	-3928.783	-6729.827	-3919.071	-4638.248	-3509.922	-4361.621	-3555.080	-3595.108

Table A.5-1 (Page 8 out of 9)

Pair direction	UK-->US	US-->BR	BR-->US	OIL-->JP	JP-->OIL	OIL-->CH	CH-->OIL	OIL-->IN	IN-->OIL	OIL-->RU
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Same day	Same day	Same day	Same day	Same day	Same day	Same day	Same day	Same day	Same day
Equation state	OK	OK	OK	OK	OK	No sig. CCF detected (A)	No sig. CCF detected (A)	No sig. CCF detected (A)	OK	OK
lags of X in mean equation	(0...-5)	(0...-3)	(0...0)	(0...0)	(0...0)	No Caus. in mean	No Caus. in mean	No Caus. in mean	(0...-4)	(0...-2)
lags of AR	No AR	AR(2)	No AR	No AR	No AR	No AR	No AR	AR(1)	No AR	No AR
lags of MA	No MA	No MA	No MA	No MA	MA(1)	MA(3)	MA(1)	MA(2)	MA(1)	MA(1)
lags of ARCH	ARCH(2)	ARCH(2)	ARCH(2)	ARCH(2)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X ² in variance equation	(0...-4)	(0...-2)	(0...-4)	No Caus. in variance	No Caus. in variance	No Caus. in variance	No Caus. in variance	No Caus. in variance	No Caus. in variance	No Caus. in variance
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α_0 (Constant)	0.010995	0.047527	0.016273	-0.017839	0.089203 *				0.072137	0.159081 **
λ_0	0.405993 **	1.205751 **	0.194000 **	0.015626	0.038422				0.022858	0.075668 **
λ_1	0.009710	0.212463 **							0.013956	0.034242 **
λ_2	-0.017483	-0.062192							0.000477	0.019573
λ_3	0.016298	0.072351 *							0.027060	
λ_4	0.006398								0.051309 *	
λ_5	-0.026044									
AR(1)		0.059501 **								
AR(2)		-0.010306								
AR(3)										
MA(1)					0.029162				0.032540	0.069314 **
MA(2)										
MA(3)										
---	---	---	---	---	---	---	---	---	---	---
ω_0 (Constant)	-0.093832 **	-0.095168 **	-0.091323 **	-0.110102 **	-0.051116 **				-0.028604 *	-0.148503 **
ARCH(1)	0.038938	0.167390 **	0.038462	-0.012662	0.133234 **				0.088472 **	0.258439 **
ARCH(2)	0.046098	0.031353	0.060075	0.177425 **						
γ (Assymmentric effect)	-0.117076 **	-0.094688 **	-0.082161 **	-0.063096 **	-0.030035 **				-0.030454 **	-0.013994
GARCH(1)	0.969734 **	0.923636 **	0.984301 **	0.977263 **	0.964872 **				0.974210 **	0.975267 **
GARCH(2)										
μ_0	0.078143 **	0.039497 *	0.011862 **							
μ_1	-0.042875	-0.024495	-0.008950 **							
μ_2	-0.010647	0.018681	0.002096							
μ_3	-0.002986		-0.005590 *							
μ_4	-0.010273		0.001555							
μ_5										
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No X mean Causality ($H_0: \lambda_{1X,Y} = \dots = \lambda_g = 0$)	Rej. 1%	Rej. 1%	Rej. 1%							Rej. 1%
No X variance Causality ($H_0: \mu_{1X,Y} = \dots = \mu_w = 0$)	Rej. 1%	Rej. 1%	Rej. 1%							
---	---	---	---	---	---	---	---	---	---	---
LB Q-stat(10)	59.264 **	9.7177	16.671	6.5808	7.0514				6.4607	34.689 **
LB Q2-stat(10)	17.400	11.673	10.583	6.0134	9.0555				16.453	8.9290
LM-test(10)										
LogLikelihood	-3599.960	-6308.413	-3478.802	-5510.572	-6850.918				-6838.472	-6765.817

Table A.5-1 (Page 9 out of 9)

Pair direction	RU-->OIL	OIL-->GE	GE-->OIL	OIL-->FR	FR-->OIL	OIL-->UK	UK-->OIL	OIL-->BR	BR-->OIL	OIL-->US	US-->OIL
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Same day	Same day	Same day	Same day	Same day	Same day	Same day	Same day	Same day	Same day	Same day
Equation state	OK	OK	OK	OK	OK	OK	OK	No convergence (B)	OK	OK	OK
lags of X in mean equation	(0...0)	No Caus. in mean	No Caus. in mean	(0...0)	(0...0)	(0...0)	(0...-4)		(0...-1)	(0...-5)	(0...-1)
lags of AR	No AR	No AR	No AR	No AR	No AR	No AR	No AR		No AR	No AR	No AR
lags of MA	MA(1)	No MA	MA(1)	No MA	MA(1)	MA(1)	MA(1)		MA(1)	No MA	MA(1)
lags of ARCH	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)		ARCH(1)	ARCH(2)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)		GARCH(1)	GARCH(1)	GARCH(1)
lags of X^2 in variance equation	No Caus. in variance	(0...0)	(0...0)	(0...0)	(0...0)	(0...0)	(0...-2)		No Caus. in variance	(0...-4)	(0...-5)
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α_0 (Constant)	0.080101 *	0.063292 **	0.088440 *	0.057216 **	0.083505 *	0.039647 **	0.087623 *		0.079088 *	0.039242 **	0.083164 *
λ_0	0.065805 **			0.014157	0.085592 **	0.020662 **	0.146830 **		0.021965	0.001291	0.026849
λ_1							0.034762		0.030645 *	-0.000125	0.092622 *
λ_2							-0.026621			-0.009348	
λ_3							0.023464			-0.001208	
λ_4							0.046601			-0.005630	
λ_5										-0.009007	
AR(1)											
AR(2)											
AR(3)											
MA(1)	0.030950		0.030233		0.029894	0.024203	0.034807		0.030777		0.031486
MA(2)											
MA(3)											
---	---	---	---	---	---	---	---	---	---	---	---
ω_0 (Constant)	-0.025156 *	-0.113428 **	-0.029772	-0.083377 **	-0.032444	-0.107406 **	0.013253		-0.033805 *	-0.098169 **	-0.035319 *
ARCH(1)	0.077718 **	0.153603 **	0.110704 **	0.108278 **	0.115586 **	0.133151 **	0.109288 **		0.111298 **	0.006213	0.104795 **
ARCH(2)										0.106399 *	
γ (Assymmentric effect)	-0.023016 **	-0.069258 **	-0.030056 *	-0.063742 **	-0.028718 *	-0.085700 **	-0.040437 **		-0.031875 **	-0.128256 **	-0.029465 **
GARCH(1)	0.974641 **	0.982798 **	0.961871 **	0.984275 **	0.960461 **	0.974424 **	0.935469 **		0.967094 **	0.972216 **	0.970671 **
GARCH(2)											
μ_0		-1.76E-05	0.002282 *	0.000288	0.003301 *	-0.000574	0.019238			0.003247	0.023078
μ_1							-0.005346			0.000810	-0.000893
μ_2							-0.011801			-0.007951	0.006691
μ_3										0.001810	-0.036703
μ_4										0.002617	0.008214
μ_5											0.000232
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No X mean Causality ($H_0: \lambda_{1x,y} = \dots = \lambda_{5y} = 0$)	Rej. 1%				Rej. 1%	Rej. 1%	Rej. 1%		Rej. 5%		Rej. 5%
No X variance Causality ($H_0: \mu_{1x,y} = \dots = \mu_{5y} = 0$)			Rej. 5%		Rej. 5%						
---	---	---	---	---	---	---	---	---	---	---	---
LB Q-stat(10)	6.9067	12.685	6.9076	18.836 *	6.4523	18.616 *	7.3071		6.8558	15.006	7.1835
LB Q2-stat(10)	21.985 *	7.5705	12.030	17.197	11.720	8.4937	18.166		12.054	2.4983	12.971
LM-test(10)	Rej. 5%										
LogLikelihood	-6850.156	-5125.330	-6847.592	-4891.904	-6842.912	-4109.008	-6831.731		-6844.246	-3932.360	-6832.789

Table A.5-2

Application of ARMA(m,n)-EGARCH(p,q) for testing non-causality hypothesis on joint test basis with oil price adjustment (Equation (22)).

Table A.5-2 (Page 1 out of 8)

Pair direction	CH-->JP	JP-->CH	IN-->JP	JP-->IN	IN-->CH	CH-->IN	RU-->JP	JP-->RU	RU-->CH	CH-->RU
Sample Relation	FS Same day	FS Same day	FS Same day	FS Same day	FS Same day	FS Same day	FS Next day	FS Same day	FS Next day	FS Same day
Equation state	OK	OK	OK	OK	No convergance (B)	OK	OK	OK	OK	OK
lags of X in mean equation	(0...0)	(0...-1)	(0...-1)	(0...0)		(0...0)	(-1...-1)	(0...0)	(-1...-2)	(0...-1)
lags of AR	No AR	AR(2)	No AR	AR(1)		AR(1)	No AR	No AR	AR(2)	No AR
lags of MA	No MA	No MA	No MA	MA(2)		MA(2)	No MA	MA(1)	No MA	MA(1)
lags of ARCH	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(1)		ARCH(1)	ARCH(2)	ARCH(2)	ARCH(1)	ARCH(2)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)		GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X^2 in variance equation	No Caus. in variance	No Caus. in variance	(0...-2)	No Caus. in variance		No Caus. in variance	(-1...-5)	No Caus. in variance	No Caus. in variance	No Caus. in variance

α_0 (Constant)	-0.025755	0.000107	-0.034662	0.114457 **		0.101006 **	-0.025990	0.161860 **	0.000110	0.169461 **
θ_1 (Oil price returns)	0.015682	4.49E-05	0.014113	-0.009638		-0.006627	0.018432	0.069191 **	2.80E-05	0.071081 **
λ_0	0.044063 **	8.79E-05	0.151798 **	0.132309 **		0.034758 **		0.177702 **		0.029978
λ_1		4.47E-05	0.029878 *				0.046588 **		5.39E-05	0.001609
λ_2									5.04E-05	
λ_3										
λ_4										
λ_5										
AR(1)		-0.007135		0.900053 **		0.899435 **			-0.003815	
AR(2)		-6.80E-05							-6.07E-05	
AR(3)										
MA(1)				-0.788642 **		-0.785564 **		0.057190 **		0.069431 **
MA(2)				-0.070864 **		-0.069335 **				
MA(3)										

ω_0 (Constant)	-0.106082 **	-0.101821 **	-0.115091 **	-0.144744 **		-0.143114 **	-0.104867 **	-0.145838 **	-0.134260 **	-0.137585 **
ARCH(1)	0.023579	0.168994 **	0.028744	0.252530 **		0.259160 **	-0.049580	0.299187 **	0.229357 **	0.275856 **
ARCH(2)	0.133301 **		0.129418 **				0.199648 **	-0.045677		-0.050738
γ (Assymmentric effect)	-0.060530 **	-0.014799	-0.057611 **	-0.088843 **		-0.101013 **	-0.057485 **	-0.014296	-0.026774	-0.009278
GARCH(1)	0.979850 **	0.982034 **	0.978236 **	0.939932 **		0.933302 **	0.976543 **	0.975561 **	0.971057 **	0.982227 **
GARCH(2)										
μ_0			0.013656 **							
μ_1			-0.012418				0.001972			
μ_2			0.001413				-0.001745			
μ_3							0.001515			
μ_4							0.000134			
μ_5							-0.001103			

No X mean Causality ($H_0: \lambda_{ix,y} = \dots = \lambda_g = 0$)	Rej. 1%		Rej. 1%	Rej. 1%		Rej. 1%	Rej. 1%	Rej. 1%		
No X variance Causality ($H_0: \mu_{ix,y} = \dots = \mu_w = 0$)			Rej. 1%				Rej. 5%			

LB Q-stat(10)	7.7728	19.757 *	11.198	20.969 *		20.542 *	11.063	36.547 **	18.573 *	35.270 **
LB Q2-stat(10)	6.8946	12.385	11.818	6.7018		5.7542	5.8550	6.8835	4.5869	8.6148
LM-test(10)										
LogLikelihood	-5503.942	-5358.285	-5450.235	-5533.016		-5567.760	-5482.372	-6740.025	-5347.964	-6769.445

Table A.5-2 (Page 2 out of 8)

Pair direction	RU-->IN	IN-->RU	GE-->JP	JP-->GE	GE-->CH	CH-->GE	GE-->IN	IN-->GE	GE-->RU	RU-->GE
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Same day	Same day	Next day	Same day	Next day	Same day	Same day	Same day	Same day	Same day
Equation state	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
lags of X in mean equation	(0...-1)	(0...0)	(-1...-1)	(0...-2)	(-1...-4)	(0...-3)	(0...-3)	(0...0)	(0...-1)	(0...0)
lags of AR	AR(1)	No AR	No AR	No AR	AR(2)	No AR	AR(1)	No AR	No AR	No AR
lags of MA	MA(2)	MA(1)	No MA	No MA	No MA	No MA	MA(2)	No MA	MA(1)	No MA
lags of ARCH	ARCH(1)	ARCH(2)	ARCH(2)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(2)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X ² in variance equation	(0...-1)	(0...-3)	(-1...-1)	(0...0)	No Caus. in variance	(0...-5)	(0...-1)	(0...-1)	(0...-5)	(0...0)
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α_0 (Constant)	0.091832 **	0.144533 **	-0.034052	0.056925 **	4.41E-05	0.060022 **	0.430448	0.052645 **	0.147222 **	0.050283 **
θ_1 (Oil price returns)	-0.011861	0.081747 **	0.013986	0.003742	2.55E-05	0.006055	-0.004417	0.007096	0.084058 **	-0.006372
λ_0	0.077283 **	0.197069 **		0.200083 **		0.015162	0.135103 **	0.109334 **	0.327939 **	0.105953 **
λ_1	0.018737 *		0.233793 **	-0.030984 *	2.89E-05	0.005612	0.112656 **		0.083209 **	
λ_2				-0.020229	2.17E-05	-0.006193	0.048934 **			
λ_3					2.75E-05	0.022139 *	0.046980 **			
λ_4					5.33E-05					
λ_5										
AR(1)	0.868930 **				-0.002830		0.999568 **			
AR(2)					-3.14E-05					
AR(3)										
MA(1)	-0.751925 **	0.067502 **					-0.918611 **		0.069545 **	
MA(2)	-0.069083 **						-0.079344 **			
MA(3)										
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ω_0 (Constant)	-0.152368 **	-0.142225 **	-0.114601 **	-0.114218 **	-0.131417 **	-0.113152 **	-0.159199 **	-0.108353 **	-0.145970 **	-0.106377 **
ARCH(1)	0.269300 **	0.290368 **	0.000326	0.153972 **	0.236004 **	0.152535 **	0.279236 **	0.143251 **	0.292255 **	0.141888 **
ARCH(2)		-0.063894	0.159260 **						-0.055360	
γ (Assymmentric effect)	-0.099706 **	-0.005896	-0.055895 **	-0.065717 **	-0.031147	-0.068534 **	-0.083230 **	-0.061615 **	-0.002008	-0.062600 **
GARCH(1)	0.915294 **	0.979476 **	0.974514 **	0.983929 **	0.963582 **	0.983694 **	0.928524 **	0.984603 **	0.979805 **	0.981843 **
GARCH(2)										
μ_0	0.000403	0.020178 *		6.31E-05		0.001361	0.015234	0.012189 *	0.035866 **	0.000259
μ_1	0.001238	-0.015610	0.003678 **			0.003164	-0.013583	-0.011543 *	-0.005930	
μ_2		-0.009556				-0.008085			-0.026815 *	
μ_3		0.007020				0.003926			0.004662	
μ_4						0.005528			-0.006416	
μ_5						-0.005855 *			-0.000733	
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No X mean Causality ($H_0: \lambda_{ix,y} = \dots = \lambda_g = 0$)	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%			Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%
No X variance Causality ($H_0: \mu_{ix,y} = \dots = \mu_w = 0$)	Rej. 5%		Rej. 1%						Rej. 1%	
---	---	---	---	---	---	---	---	---	---	---
LB Q-stat(10)	17.792	29.035 **	27.594 **	16.940	18.260	13.974	21.154 *	16.548	28.683 **	18.036
LB Q2-stat(10)	6.2664	6.4437	7.9914	12.989	4.2303	8.8573	6.0533	7.7384	10.647	7.7800
LM-test(10)										
LogLikelihood	-5534.911	-6725.362	-5423.783	-5018.845	-5341.332	-5108.913	-5508.384	-5088.101	-6644.195	-5048.165

Table A.5-2 (Page 3 out of 8)

Pair direction	FR-->JP	JP-->FR	FR-->CH	CH-->FR	FR-->IN	IN-->FR	FR-->RU	RU-->FR	FR-->GE	GE-->FR
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Next day	Same day	Next day	Same day	Same day	Same day	Same day	Same day	Same day	Same day
Equation state	OK	OK	OK	OK	OK	OK	No convergance (B)	OK	OK	OK
lags of X in mean equation	(-1...-2)	(0...-2)	(-1...-4)	No Caus. in mean	(0...-3)	(0...-0)		(0...-0)	(0...-1)	(0...-3)
lags of AR	No AR	AR(1)	AR(2)	AR(1)	AR(1)	AR(1)		AR(1)	No AR	AR(1)
lags of MA	No MA	No MA	No MA	No MA	MA(2)	No MA		No MA	No MA	No MA
lags of ARCH	ARCH(2)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)		ARCH(1)	ARCH(1)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)		GARCH(1)	GARCH(1)	GARCH(1)
lags of X ² in variance equation	(-1...-1)	(0...0)	No Caus. in variance	(0...-4)	(0...-1)	(0...-1)		(0...0)	(0...-1)	(0...-4)

α_0 (Constant)	-0.025751	0.054170 **	2.48E-05	0.054877 **	0.800370	0.042970 *		0.031564	0.021505 *	-0.002145
θ_1 (Oil price returns)	0.012277	0.008640	3.54E-05	0.011465	-0.009644	0.013369		0.003856	-0.023074 **	0.022512 **
λ_0		0.188671 **			0.161526 **	0.113389 **		0.103943 **	0.952726 **	0.820706 **
λ_1	0.260214 **	-0.035818 **	6.07E-05		0.108592 **				0.018502 *	0.004633
λ_2	0.035092	-0.025466 *	1.68E-05		0.045974 **					-0.026436 **
λ_3			-3.96E-05		0.061779 **					-0.022907 **
λ_4			0.000110							
λ_5										
AR(1)		-0.039137 *	-0.000759	0.006917	0.999743 **	-0.010734		0.003521		-0.147296 **
AR(2)			-3.94E-05							
AR(3)										
MA(1)					-0.917100 **					
MA(2)					-0.080691 **					
MA(3)										

ω_0 (Constant)	-0.139538 **	-0.104854 **	-0.148414 **	-0.089391 **	-0.158690 **	-0.093044 **		-0.079172 **	-0.099675 **	-0.115771 **
ARCH(1)	0.019726	0.136885 **	0.273269 **	0.117332 **	0.276666 **	0.118847 **		0.099352 **	0.115396 **	0.142609 **
ARCH(2)	0.171556 **									
γ (Assymmentric effect)	-0.054733 **	-0.054752 **	-0.038025 *	-0.057114 **	-0.082206 **	-0.051835 **		-0.059287 **	-0.004256	-0.033622 **
GARCH(1)	0.969337 **	0.981113 **	0.953677 **	0.985483 **	0.926481 **	0.986141 **		0.984972 **	0.994667 **	0.996600 **
GARCH(2)										
μ_0		0.001001		-0.004173	0.004889	0.011812		0.000292	0.051052 **	0.036435 **
μ_1	0.006422 **			0.007455	-0.001181	-0.010678			-0.047210 **	-0.023254 **
μ_2				0.006454						-0.011767 **
μ_3				-0.013941 *						0.013500
μ_4				0.004919						-0.014490 *
μ_5										

No X mean Causality ($H_0: \lambda_{tx,y} = \dots = \lambda_g = 0$)	Rej. 1%	Rej. 1%			Rej. 1%	Rej. 1%		Rej. 1%	Rej. 1%	Rej. 1%
No X variance Causality ($H_0: \mu_{tx,y} = \dots = \mu_w = 0$)	Rej. 1%			Rej. 5%					Rej. 1%	Rej. 1%

LB Q-stat(10)	31.361 **	20.205 *	17.673	19.854 *	22.243 *	23.191 **		22.133 *	72.555 **	16.670
LB Q2-stat(10)	7.5258	12.440	3.3072	12.367	6.3859	14.382		19.420 *	24.068 **	8.1630
LM-test(10)								Rej. 5%	Rej. 1%	
LogLikelihood	-5416.259	-4778.957	-5339.488	-4872.092	-5505.770	-4847.297		-4808.039	-3185.895	-2902.308

Table A.5-2 (Page 4 out of 8)

Pair direction	UK-->JP	JP-->UK	UK-->CH	CH-->UK	UK-->IN	IN-->UK	UK-->RU	RU-->UK	UK-->GE	GE-->UK
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Next day	Same day	Next day	Same day	Same day	Same day	Same day	Same day	Same day	Same day
Equation state	OK	OK	OK	No sig. CCF detected (A)	OK	OK	OK	OK	OK	OK
lags of X in mean equation	(-1...-1)	(0...-5)	(-1...-4)	No Caus. in mean	(0...-3)	(0...0)	(0...-4)	(0...0)	(0...-1)	(0...-4)
lags of AR	No AR	AR(1)	AR(2)	AR(1)	AR(1)	AR(1)	No AR	AR(1)	No AR	AR(1)
lags of MA	No MA	No MA	No MA	No MA	MA(2)	No MA	MA(1)	No MA	No MA	No MA
lags of ARCH	ARCH(2)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(1)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X^2 in variance equation	(-1...-4)	No Caus. in variance	No Caus. in variance	No Caus. in variance	(0...-1)	(0...-1)	(0...-5)	(0...0)	(0...0)	(0...-3)
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α_0 (Constant)	-0.029998	0.043993 **	0.000126		0.092967 **	0.030130 *	0.143259 **	0.027175	0.022879	0.013424
θ_1 (Oil price returns)	0.010487	0.019639 **	7.19E-05		-0.009996	0.020348 **	0.072465 **	0.011546	-0.025915 **	0.021172 **
λ_0		0.140731 **			0.253011 **	0.086318 **	0.515341 **	0.080736 **	0.935778 **	0.502622 **
λ_1	0.303508 **	-0.016996	0.000152		0.156834 **		0.116365 **		0.017308	0.024895 **
λ_2		-0.010492	-9.09E-05		0.061491 **		0.007625			-0.005880
λ_3		-0.001705	4.71E-05		0.071599 **		0.036723			-0.021697 *
λ_4		0.008844	0.000413				0.049435			0.006014
λ_5		-0.021851 *								
AR(1)		-0.017829	-0.002091		0.879691 **	0.003082		0.007509		-0.052157 **
AR(2)			-8.73E-05							
AR(3)										
MA(1)					-0.781879 **		0.056562 **			
MA(2)					-0.059657 **					
MA(3)										
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ω_0 (Constant)	-0.095129 **	-0.125449 **	-0.133566 **		-0.168934 **	-0.113803 **	-0.145996 **	-0.117760 **	-0.108721 **	-0.295935 **
ARCH(1)	-0.033450	0.146670 **	0.246744 **		0.283213 **	0.131012 **	0.316727 **	0.136123 **	0.126486 **	0.212809 **
ARCH(2)	0.166611 **						-0.082854			
γ (Assymmentric effect)	-0.054145 **	-0.088108 **	-0.032847		-0.095808 **	-0.081914 **	-0.006868	-0.084689 **	-0.042571 **	-0.035253
GARCH(1)	0.981209 **	0.969113 **	0.959681 **		0.922481 **	0.972425 **	0.981750 **	0.968223 **	0.988991 **	0.893216 **
GARCH(2)										
μ_0					0.039359 *	0.012706 *	0.042875	0.000245	0.006976 **	0.044797 **
μ_1	0.054444 **				-0.028506	-0.011263 *	-0.025177			-0.004044
μ_2	-0.048113 *						-0.013524			-0.023733 *
μ_3	0.012704						0.049357 *			0.003089
μ_4	-0.014702						-0.059743 **			
μ_5							0.005922			
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No X mean Causality ($H_0: \lambda_{1xy} = \dots = \lambda_{xy} = 0$)	Rej. 1%	Rej. 1%			Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%
No X variance Causality ($H_0: \mu_{1xy} = \dots = \mu_{xy} = 0$)	Rej. 1%				Rej. 1%	Rej. 5%	Rej. 1%		Rej. 1%	Rej. 1%
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LB Q-stat(10)	23.068 **	15.963	18.145		18.033	21.232 *	24.963 **	22.141 *	19.236 *	27.815 **
LB Q2-stat(10)	14.000	10.663	3.9159		7.7026	8.8854	12.207	6.7296	7.4419	9.2947
LM-test(10)										
LogLikelihood	-5415.426	-4011.555	-5339.799		-5494.844	-4069.946	-6605.418	-4024.613	-4052.949	-3113.787

Table A.5-2 (Page 5 out of 8)

Pair direction	UK-->FR	FR-->UK	BR-->JP	JP-->BR	BR-->CH	CH-->BR	BR-->IN	IN-->BR	BR-->RU	RU-->BR
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Same day	Same day	Next day	Same day	Next day	Same day	Next day	Same day	Same day	Same day
Equation state	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
lags of X in mean equation	(0...-5)	(0...-4)	(-1...-2)	(0...-4)	(-1...-5)	No Caus. in mean	(-1...-5)	(0...0)	(0...-4)	(0...0)
lags of AR	AR(1)	AR(1)	No AR	No AR	AR(2)	No AR	AR(2)	No AR	No AR	No AR
lags of MA	No MA	No MA	No MA	MA(1)	No MA	MA(1)	No MA	MA(1)	MA(1)	MA(1)
lags of ARCH	ARCH(1)	ARCH(1)	ARCH(2)	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(2)	ARCH(2)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X ² in variance equation	(0...-2)	(0...-2)	(-1...-4)	No Caus. in variance	(-1...-4)	(0...0)	(-1...-4)	(0...-1)	(0...-3)	(0...0)
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α_0 (Constant)	0.009011	0.007914	-0.028635	0.108677 **	7.79E-05	0.107232 **	8.20E-05	0.086360 *	0.126692 **	0.078816 *
θ_1 (Oil price returns)	-0.010059	0.015088 **	0.008113	0.017102	2.84E-05	0.020264	5.34E-05	0.023398	0.076790 **	0.015603
λ_0	0.965894 **	0.620726 **		0.123543 **				0.135938 **	0.161456 **	0.160703 **
λ_1	-0.000391	0.019651 *	0.124147 **	-0.022543	0.000138		0.000145		0.117610 **	
λ_2	-0.021027	0.010425	0.006818	0.017591	-3.35E-05		-2.19E-06		0.011727	
λ_3	0.001767	0.008997		0.024736	1.60E-05		2.62E-05		0.023058	
λ_4	-0.008424	0.019773 *		0.032536	8.86E-06		-3.46E-06		0.022066	
λ_5	0.001256				3.90E-06		1.68E-05			
AR(1)	-0.037998 *	-0.042330 *			-0.001583		-0.001722			
AR(2)					-4.85E-05		-4.05E-05			
AR(3)										
MA(1)				0.089323 **		0.102150 **		0.089632 **	0.048140 **	0.086713 **
MA(2)										
MA(3)										
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ω_0 (Constant)	-0.065285 **	-0.072244 **	-0.104051 **	-0.076274 **	-0.114406 **	-0.067567 **	-0.114400 **	-0.071361 **	-0.146868 **	-0.068111 **
ARCH(1)	0.083072 **	0.079593 **	0.005540	0.102674 *	0.215075 **	0.060842	0.215050 **	0.087667	0.276129 **	0.097642
ARCH(2)			0.139035 **	0.127957 *		0.173793 **		0.137185 **	-0.039796	0.162041 **
γ (Assymmentric effect)	-0.012711	-0.021928 *	-0.045313 **	-0.139994 **	-0.028907	-0.146258 **	-0.028903	-0.141602 **	-0.006222	-0.158961 **
GARCH(1)	0.998686 **	0.991922 **	0.976994 **	0.932645 **	0.967260 **	0.928874 **	0.967270 **	0.929376 **	0.978835 **	0.900624 **
GARCH(2)										
μ_0	0.060218 **	0.052879 **				-0.001852		0.002562	0.007925 **	0.001902 **
μ_1	-0.052892 *	-0.022290 *	0.007207 **		0.001007		0.001006	-0.000732	-0.000125	
μ_2	-0.007380	-0.029390 **	-0.004903		0.004780		0.004779		-0.003116	
μ_3			2.97E-05		-0.010289 **		-0.010289 **		-0.004049 *	
μ_4			-0.001053		0.003601		0.003603			
μ_5										
---	---	---	---	---	---	---	---	---	---	---
No X mean Causality ($H_0: \lambda_{1xy} = \dots = \lambda_{gy} = 0$)	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%				Rej. 1%	Rej. 1%	Rej. 1%
No X variance Causality ($H_0: \mu_{1xy} = \dots = \mu_{wy} = 0$)	Rej. 1%	Rej. 1%	Rej. 1%		Rej. 1%		Rej. 1%		Rej. 1%	Rej. 1%
---	---	---	---	---	---	---	---	---	---	---
LB Q-stat(10)	25.825 **	34.546 **	13.182	11.125	19.651 *	8.5195	19.660 *	9.1105	23.760 **	9.9639
LB Q2-stat(10)	17.499	13.581	9.7264	12.297	6.3727	11.573	6.3739	12.602	13.183	10.028
LM-test(10)										
LogLikelihood	-3458.216	-2782.949	-5426.778	-6771.548	-5334.618	-6796.387	-5334.645	-6777.300	-6646.888	-6730.194

Table A.5-2 (Page 6 out of 8)

Pair direction	BR-->GE	GE-->BR	BR-->FR	FR-->BR	BR-->UK	UK-->BR	US-->JP	JP-->US	US-->CH	CH-->US
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Same day	Same day	Same day	Same day	Same day	Same day	Next day	Same day	Next day	Same day
Equation state	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
lags of X in mean equation	(0...-1)	(0...-4)	(0...-1)	(0...-0)	(0...-5)	(0...-0)	(-1...-2)	(0...-1)	(-1...-4)	(0...-4)
lags of AR	No AR	No AR	AR(1)	No AR	AR(1)	No AR	No AR	No AR	AR(2)	No AR
lags of MA	No MA	MA(1)	No MA	MA(1)	No MA	MA(1)	No MA	No MA	No MA	No MA
lags of ARCH	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(2)	ARCH(2)	ARCH(1)	ARCH(1)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X ² in variance equation	(0...-3)	(0...-4)	(0...-4)	(0...-0)	(0...-1)	(0...-0)	(-1...-5)	No Caus. in variance	No Caus. in variance	(0...-4)
---	---	---	---	---	---	---	---	---	---	---
α_0 (Constant)	0.031882	0.032607	0.022018	0.071198 *	0.021290	0.076460 *	-0.034573	0.038698 **	7.39E-05	0.040294 **
θ_1 (Oil price returns)	-0.006602	0.030290 *	0.003275	0.028947 *	0.012746 *	0.006863	0.009319	-0.000356	7.04E-05	0.002605
λ_0	0.199890 **	0.567831 **	0.182663 **	0.592638 **	0.132120 **	0.782516 **		0.054022 **		0.010415
λ_1	0.052993 **	0.087796 **	0.051911 **		0.052194 **		0.460600 **	-0.021853 *	7.90E-05	-0.012627
λ_2		0.023579			-0.000667		0.080185 **		0.000292	0.005761
λ_3		0.033907			0.003949				9.14E-05	-0.016047 *
λ_4		0.065256 *			-0.009274				0.000148	-0.009824
λ_5					-0.014289 *					
AR(1)			-0.056090 **		-0.038479 *				-0.002378	
AR(2)									-6.84E-05	
AR(3)										
MA(1)		0.048044 **		0.048597 **		0.040164 *				
MA(2)										
MA(3)										
---	---	---	---	---	---	---	---	---	---	---
ω_0 (Constant)	-0.116058 **	-0.054850 **	-0.087603 **	-0.059196 **	-0.106874 **	-0.059236 **	-0.119977 **	-0.082141 **	-0.130028 **	-0.081131 **
ARCH(1)	0.148944 **	0.074100	0.110260 **	0.103838 *	0.110571 **	0.058861	0.091043	0.097544 **	0.232432 **	0.092202 **
ARCH(2)		0.142955 **		0.091484		0.173909 **	0.068106			
γ (Assymmentric effect)	-0.063465 **	-0.155515 **	-0.040145 **	-0.130198 **	-0.078935 **	-0.148035 **	-0.051005 **	-0.116974 **	-0.029261	-0.116411 **
GARCH(1)	0.984396 **	0.886379 **	0.985786 **	0.909798 **	0.970495 **	0.891115 **	0.974502 **	0.977171 **	0.965440 **	0.978803 **
GARCH(2)										
μ_0	0.004302 *	0.021787 **	0.005747 **	0.019498 **	0.010094 **	0.031419 **				0.008401 **
μ_1	0.002214	-0.004412	-0.000550		-0.008842 **		0.022030 *			-0.007869
μ_2	-0.000696	0.005678	-0.001456				0.003519			0.000562
μ_3	-0.005299 *	-0.009465	-0.004844 *				-0.005399			-0.005558
μ_4		0.006859	0.001707				-0.017960			0.005794
μ_5							0.009827			
---	---	---	---	---	---	---	---	---	---	---
No X mean Causality ($H_0: \lambda_{ix,y} = \dots = \lambda_g = 0$)	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%		
No X variance Causality ($H_0: \mu_{ix,y} = \dots = \mu_w = 0$)	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%			Rej. 1%
---	---	---	---	---	---	---	---	---	---	---
LB Q-stat(10)	30.622 **	15.529	29.056 **	12.033	29.818 **	8.5129	21.278 *	15.249	18.237	16.268
LB Q2-stat(10)	7.6729	7.8896	17.316	8.1730	16.366	9.5182	5.8065	3.0497	4.4335	3.1809
LM-test(10)										
LogLikelihood	-4868.331	-6547.040	-4637.353	-6588.480	-3882.552	-6576.723	-5329.844	-3928.144	-5341.416	-3933.638

Table A.5-2 (Page 7 out of 8)

Pair direction	US-->IN	IN-->US	US-->RU	RU-->US	US-->GE	GE-->US	US-->FR	FR-->US	US-->UK	UK-->US
Sample	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
Relation	Next day	Same day	Next day	Same day	Same day	Same day	Same day	Same day	Same day	Same day
Equation state	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
lags of X in mean equation	(-1...-4)	(0...-2)	(-1...-3)	(0...-0)	(0...-1)	(0...-0)	(0...-1)	(0...-1)	(0...-1)	(0...-5)
lags of AR	AR(1)	No AR	No AR	No AR	No AR	No AR	AR(1)	No AR	AR(1)	No AR
lags of MA	MA(2)	No MA	MA(1)	No MA	No MA	No MA	No MA	No MA	No MA	No MA
lags of ARCH	ARCH(1)	ARCH(1)	ARCH(2)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)	GARCH(1)
lags of X ² in variance equation	(-1...-5)	(0...-1)	(-1...-1)	(0...-0)	(0...-2)	(0...-4)	(0...-2)	(0...-4)	(0...-0)	(0...-4)
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α_0 (Constant)	0.098494 **	0.033883 *	0.131591 **	0.031974 *	0.017458	0.003734	0.012729	0.008474	0.006070	0.010049
θ_1 (Oil price returns)	-0.002921	0.001737	0.077965 **	-0.003199	-0.002336	0.001513	0.013002	-0.003466	0.017553 **	-0.009929
λ_0		0.036698 **		0.038761 **	0.657685 **	0.333780 **	0.652190 **	0.348117 **	0.461229 **	0.411053 **
λ_1	0.194842 **	-0.012933	0.345238 **		0.323915 **		0.310258 **	0.024411 *	0.264988 **	0.005361
λ_2	0.066018 **	0.014619	0.019016							-0.013937
λ_3	0.078630 **		0.042939							0.017207
λ_4	0.073498 **									0.008372
λ_5										-0.024347
AR(1)	0.458998						-0.198938 **		-0.153086 **	
AR(2)										
AR(3)										
MA(1)	-0.363151		0.030473							
MA(2)	-0.012526									
MA(3)										
---	---	---	---	---	---	---	---	---	---	---
ω_0 (Constant)	-0.149669 **	-0.077428 **	-0.139226 **	-0.083203 **	-0.110254 **	-0.112856 **	-0.104614 **	-0.111454 **	-0.169993 **	-0.114215 **
ARCH(1)	0.267297 **	0.089450 **	0.314357 **	0.094154 **	0.130211 **	0.115613 **	0.119867 **	0.099390 **	0.130716 **	0.100618 **
ARCH(2)			-0.076295							
γ (Assymmentric effect)	-0.095392 **	-0.114163 **	-0.010097	-0.117647 **	-0.036809 **	-0.114010 **	-0.018826	-0.119656 **	-0.065091 **	-0.128483 **
GARCH(1)	0.928026 **	0.978635 **	0.977003 **	0.975062 **	0.979286 **	0.973359 **	0.980180 **	0.964524 **	0.925795 **	0.959896 **
GARCH(2)										
μ_0		0.010234 *		0.000375	0.047958 **	0.046820 **	0.039639 *	0.050135 **	0.031155 **	0.079159 **
μ_1	0.039211 *	-0.009450 *	0.001757		-0.006487	-0.030902 **	0.000776	-0.032303 *		-0.045424 *
μ_2	-0.023376				-0.029847 *	-0.004662	-0.030727 *	-0.005418		-0.042637 **
μ_3	-0.003885					-0.006668		-0.011337		0.028073
μ_4	-0.004840					-0.001249		0.007428		-0.004069
μ_5	-0.005225									
---	---	---	---	---	---	---	---	---	---	---
No X mean Causality ($H_0: \lambda_{ix,y} = \dots = \lambda_g = 0$)	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%
No X variance Causality ($H_0: \mu_{ix,y} = \dots = \mu_w = 0$)					Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%	Rej. 1%
---	---	---	---	---	---	---	---	---	---	---
LB Q-stat(10)	21.205 *	16.657	37.557 **	15.558	107.64 **	61.860 **	36.501 **	75.987 **	32.471 **	53.764 **
LB Q2-stat(10)	5.8755	5.1119	7.6396	3.5851	11.062	4.7477	9.5308	5.2523	13.022	4.5208
LM-test(10)										
LogLikelihood	-5529.818	-3934.570	-6712.469	-3923.674	-4625.179	-3510.396	-4302.518	-3554.218	-3596.290	-3600.886

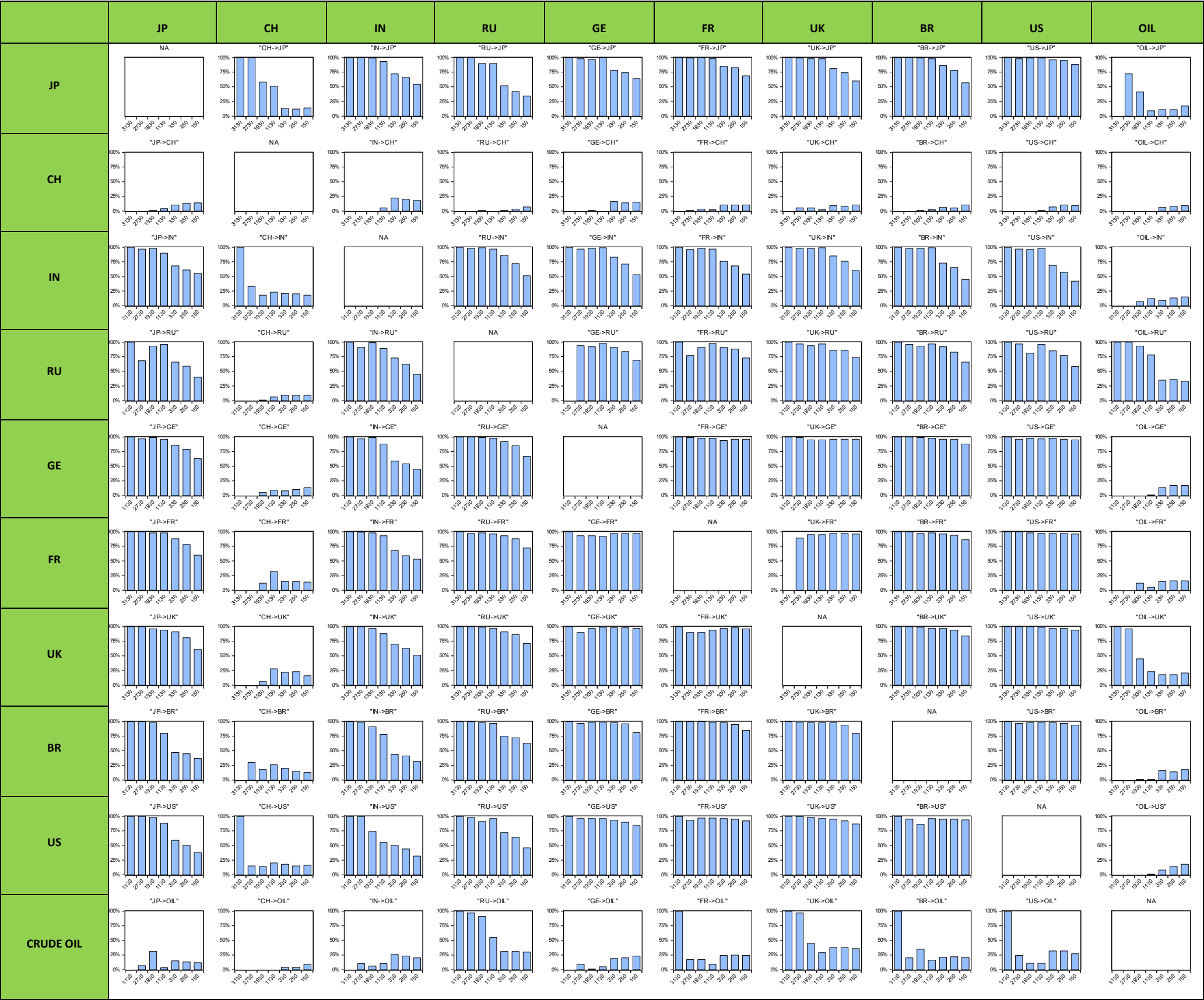
Table A.5-2 (Page 8 out of 8)

Pair direction	US-->BR	BR-->US
Sample	FS	FS
Relation	Same day	Same day
Equation state	OK	OK
lags of X in mean equation	(0...-3)	(0...0)
lags of AR	No AR	No AR
lags of MA	MA(1)	No MA
lags of ARCH	ARCH(2)	ARCH(1)
lags of GARCH	GARCH(1)	GARCH(1)
lags of X ² in variance equation	(0...-2)	(0...-4)
---	---	---
α_0 (Constant)	0.046143	0.016695
θ_1 (Oil price returns)	0.035100 **	-0.013461 **
λ_0	1.210661 **	0.195417 **
λ_1	0.215601 **	
λ_2	-0.061897	
λ_3	0.074919 *	
λ_4		
λ_5		
AR(1)		
AR(2)		
AR(3)		
MA(1)	0.055053 **	
MA(2)		
MA(3)		
---	---	---
ω_0 (Constant)	-0.098760 **	-0.097306 **
ARCH(1)	0.167541 **	0.101097 **
ARCH(2)	0.029888	
γ (Assymmentric effect)	-0.090108 **	-0.086021 **
GARCH(1)	0.927019 **	0.981330 **
GARCH(2)		
μ_0	0.050270 **	0.009903 **
μ_1	-0.033046	-0.005445
μ_2	0.016490	-0.000995
μ_3		-0.003048
μ_4		0.000730
μ_5		
---	---	---
No X mean Causality ($H_0: \lambda_{1X,Y} = \dots = \lambda_g = 0$)	Rej. 1%	Rej. 1%
No X variance Causality ($H_0: \mu_{1X,Y} = \dots = \mu_w = 0$)	Rej. 1%	Rej. 1%
---	---	---
LB Q-stat(10)	9.4949	17.173
LB Q2-stat(10)	11.538	12.336
LM-test(10)		
LogLikelihood	-6307.351	-3478.784

A.6. Non-causality hypothesis rejection frequency with respect to the descending window sizes.

Table A.6-1

Mean non-causality hypothesis rejection frequency with respect to the descending window size.



Notes: The table represents the *non-causality HRF vs. rolling window size* diagrams. Each diagram is located in the intersection of the column and row, where the country in the column attempts to cause the country in the row.

Each bar of HRF inside the diagram demonstrates the percentage number of rolling sub-samples out of total number of rolling sub-samples at a certain window size where the $H_0: \lambda_{1,X,Y} = \dots = \lambda_g = 0$, of no mean causality (spillover) from X to Y , in oil unadjusted model (21) is rejected at 5% level of significance (see Section 5.2.2.1).

The absence of the HRF bars at certain lags inside the diagrams is due to:

- 1) the absence of case where the non-causality hypothesis is rejected;
- 2) the existence of the cases where the CCF is not detected in s-statistics significant causality, thus no causality testing is performed in ARMA(m,n)-EGARCH(p,q) framework;
- 3) the existence of the cases where convergence in ARMA(m,n)-EGARCH(p,q) model is not achieved.

Interpretation of the *HRF vs. rolling window size* diagrams is performed using patterns of non-causality HRF behaviour suggested in Table 5.3-2, and the synthesis of the current table is given in Panel A, of Table A.6-5.

Table A.6-2
Mean non-causality hypothesis rejection frequency with respect to the descending window size oil price adjusted.



Notes: The table represents the *non-causality HRF vs. rolling window size* diagrams. Each diagram is located in the intersection of the column and row, where the country in the column attempts to cause the country in the row.

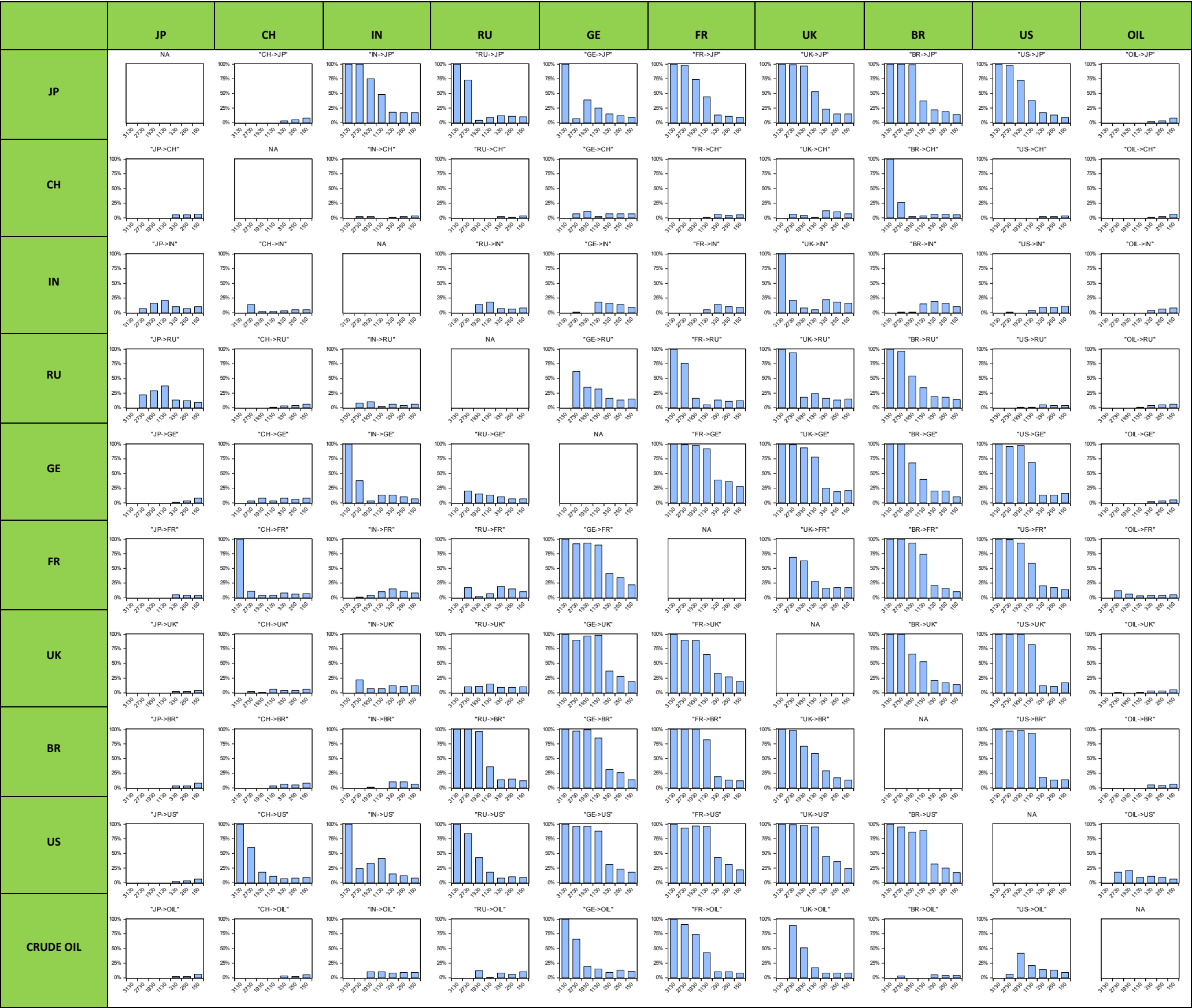
Each bar of HRF inside the diagram demonstrates the percentage number of rolling sub-samples out of total number of rolling sub-samples at a certain window size where the $H_0: \lambda_{1,X,Y} = \dots = \lambda_g = 0$, of no mean causality (spillover) from X to Y , in oil adjusted model (22) is rejected at 5% level of significance (see Section 5.2.2.1).

The absence of the HRF bars at certain lags inside the diagrams is due to:

- 1) the absence of case where the non-causality hypothesis is rejected;
- 2) the existence of the cases where the CCF is not detected in s-statistics significant causality, thus no causality testing is performed in ARMA(m,n)-EGARCH(p,q) framework;
- 3) the existence of the cases where convergence in ARMA(m,n)-EGARCH(p,q) model is not achieved.

Interpretation of the *HRF vs. rolling window size* diagrams is performed using patterns of non-causality HRF behaviour suggested in Table 5.3-2, and the synthesis of the current table is given in Panel B, of Table A.6-5.

Table A.6-3
Variance non-causality hypothesis rejection frequency with respect to the descending window size.



Notes: The table represents the *non-causality HRF vs. rolling window size* diagrams. Each diagram is located in the intersection of the column and row, where the country in the column attempts to cause the country in the row.

Each bar of HRF inside the diagram demonstrates the percentage number of rolling sub-samples out of total number of rolling sub-samples at a certain window size where the $H_0: \mu_{I_{X,Y}} = \dots = \mu_W = 0$, of no variance causality (spillover) from X to Y , in oil adjusted model (21) is rejected at 5% level of significance (see Section 5.2.2.1).

The absence of the HRF bars at certain lags inside the diagrams is due to:

- 1) the absence of case where the non-causality hypothesis is rejected;
- 2) the existence of the cases where the CCF is not detected in s-statistics significant causality, thus no causality testing is performed in $ARMA(m,n)$ -EGARCH(p,q) framework;
- 3) the existence of the cases where convergence in $ARMA(m,n)$ -EGARCH(p,q) model is not achieved.

Interpretation of the *HRF vs. rolling window size* diagrams is performed using patterns of non-causality HRF behaviour suggested in Table 5.3-2, and the synthesis of the current table is given in Panel C of Table A.6-5.

Table A.6-4
Variance non-causality hypothesis rejection frequency with respect to the descending window size oil price adjusted.



Notes: The table represents the *non-causality HRF vs. rolling window size* diagrams. Each diagram is located in the intersection of the column and row, where the country in the column attempts to cause the country in the row.

Each bar of HRF inside the diagram demonstrates the percentage number of rolling sub-samples out of total number of rolling sub-samples at a certain window size where the $H_0: \mu_{I_{X,Y}} = \dots = \mu_w = 0$, of no variance causality (spillover) from X to Y , in oil adjusted model (22) is rejected at 5% level of significance (see Section 5.2.2.1).

The absence of the HRF bars at certain lags inside the diagrams is due to:

- 1) the absence of case where the non-causality hypothesis is rejected;
- 2) the existence of the cases where the CCF is not detected in s-statistics significant causality, thus no causality testing is performed in ARMA(m,n)-EGARCH(p,q) framework;
- 3) the existence of the cases where convergence in ARMA(m,n)-EGARCH(p,q) model is not achieved.

Interpretation of the *HRF vs. rolling window size* diagrams is performed using patterns of non-causality HRF behaviour suggested in Table 5.3-2, and the synthesis of the current table is given in Panel D of Table A.6-5.

Table A.6-5

Synthesis of *non-causality HRF vs. rolling window sizes* diagrams with respect to the interpretational cases displayed in Table 5.3-2.

Panel A. Mean causality between indices, (no adjustment for oil). Synthesis of Table A.6-1.

	JP ^(DI)	CH ^(EI)	IN ^(EI)	RU ^(EE)	GE ^(DI)	FR ^(DI)	UK ^(DS)	BR ^(ES)	US ^(DI)	OIL
JP ^(DI)		C1-C2	C1	C1-C2	C1	C1	C1	C1	C1	C4-C3
CH ^(EI)	C2		C2	C2	C2	C2	C2	C2	C2	C2
IN ^(EI)	C1	C3		C1	C1	C1	C1	C1-C2	C1-C2	C2
RU ^(EE)	C1-C2	C2	C1-C2		C4	C1	C1	C1	C1	C1-C2
GE ^(DI)	C1	C2	C1	C1		C1	C1	C1	C1	C2
FR ^(DI)	C1	C2	C1	C1	C1		C4	C1	C1	C2
UK ^(DS)	C1	C2	C1	C1	C1	C1		C1	C1	C1-C2
BR ^(ES)	C1-C2	C2	C1-C2	C1	C1	C1	C1		C1	C2
US ^(DI)	C1-C2	C3	C1-C2	C1-C2	C1	C1	C1	C1		C2
OIL	C2	C2	C2	C1-C2	C2	C3	C1-C2	C3	C3	

Panel B. Mean causality between indices, (with adjustment for oil). Synthesis of Table A.6-2.

	JP ^(DI)	CH ^(EI)	IN ^(EI)	RU ^(EE)	GE ^(DI)	FR ^(DI)	UK ^(DS)	BR ^(ES)	US ^(DI)	OIL
JP ^(DI)		C1-C2	C1	C1-C2	C1	C1	C1	C1	C1	-
CH ^(EI)	C2		C2	C2	C2	C2	C2	C2	C2	-
IN ^(EI)	C1	C3		C1	C1	C1	C1	C1-C2	C1-C2	-
RU ^(EE)	C1-C2	C2	C1-C2		C1	C4	C1	C1	C1	-
GE ^(DI)	C1	C2	C1-C2	C1		C1	C1	C1	C1	-
FR ^(DI)	C1	C2	C1	C1	C1		C1	C1	C1	-
UK ^(DS)	C1	C2	C1	C1	C1	C1		C1	C1	-
BR ^(ES)	C1-C2	C2	C1-C2	C1	C1	C1	C1		C1	-
US ^(DI)	C1-C2	C2	C1-C2	C1-C2	C1	C1	C1	C1		-
OIL	-	-	-	-	-	-	-	-	-	

Panel C. Variance causality between indices, (no adjustment for oil) . Synthesis of Table A.6-3.

	JP ^(DI)	CH ^(EI)	IN ^(EI)	RU ^(EE)	GE ^(DI)	FR ^(DI)	UK ^(DS)	BR ^(ES)	US ^(DI)	OIL
JP ^(DI)		C2	C1-C2	C1-C2	C3	C1-C2	C1-C2	C1-C2	C1-C2	C2
CH ^(EI)	C2		C2	C2	C2	C2	C2	C3	C2	C2
IN ^(EI)	C2	C2		C2	C2	C2	C3	C2	C2	C2
RU ^(EE)	C2	C2	C2		C4-C3	C1-C2	C1-C2	C1-C2	C2	C2
GE ^(DI)	C2	C2	C3	C2		C1-C2	C1-C2	C1-C2	C1-C2	C2
FR ^(DI)	C2	C3	C2	C2	C1-C2		C4-C2	C1-C2	C1-C2	C2
UK ^(DS)	C2	C2	C2	C2	C1-C2	C1-C2		C1-C2	C1-C2	C2
BR ^(ES)	C2	C2	C2	C1-C2	C1-C2	C1-C2	C1-C2		C1-C2	C2
US ^(DI)	C2	C1-C2	C3	C1-C2	C1-C2	C1-C2	C1-C2	C1-C2		C2
OIL	C2	C2	C2	C2	C1-C2	C1-C2	C4-C2	C2	C2	

Table A.6-5 continue on the next page

Table A.6-5 continue

Panel D. Variance causality between indices, (with adjustment for oil). Synthesis of Table A.6-4.

	JP ^(DI)	CH ^(EI)	IN ^(EI)	RU ^(EE)	GE ^(DI)	FR ^(DI)	UK ^(DS)	BR ^(ES)	US ^(DI)	OIL
JP ^(DI)		C2	C1-C2	C1-C2	C3	C1-C2	C1-C2	C1-C2	C1-C2	-
CH ^(EI)	C2		C2	C2	C2	C2	C2	C3	C2	-
IN ^(EI)	C2	C2		C3	C2	C2	C3	C2	C2	-
RU ^(EE)	C2	C2	C2		C1-C2	C4-C3	C1-C2	C1-C2	C2	-
GE ^(DI)	C2	C2	C2	C2		C1-C2	C1-C2	C1-C2	C1-C2	-
FR ^(DI)	C2	C3	C2	C2	C1-C2		C1-C2	C1-C2	C1-C2	-
UK ^(DS)	C2	C2	C3	C2	C1-C2	C1-C2		C1-C2	C1-C2	-
BR ^(ES)	C2	C2	C2	C1-C2	C1-C2	C1-C2	C1-C2		C1-C2	-
US ^(DI)	C2	C1-C2	C2	C4-C2	C1-C2	C1-C2	C1-C2	C1-C2		-
OIL	-	-	-	-	-	-	-	-	-	

Notes: The table is a compound of Table A.6-1 (allocated to Panel A), Table A.6-2 (allocated to Panel B), Table A.6-3 (allocated to Panel C), Table A.6-4 (allocated to Panel D), where each cell is organised manually by a collation of the non-causality HRF diagrams of the mentioned tables with the interpretational cases from Table 5.3-2. Interpretational case is represented by markers for the purpose of space conservation. Note that besides the standard markers (C1,C2,C3,C4), the combined markers (C1-C2, C4-C2, C4-C3) are used for the transitional cases, when the standard cases were not suitable for interpretation of non-causality HRF diagrams.

The result of this table is integrated into Table 7.4-1 in order to provide greater evidence of stability/instability of the rejection of non-causality hypothesis inside the sample.