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School of Business and Management

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The Dynamic Relationship between Finnish Stock Market and Commodities

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Abstract

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Since different stock markets have become more integrated during 2000s, investors need new asset classes in order to gain diversification benefits. Commodities have become popular to invest in and thus it is important to examine whether the investors should use commodities as a part for portfolio diversification. This master's thesis examines the dynamic relationship between Finnish stock market and commodities.

The methodology is based on Vector Autoregressive models (VAR). The long-run relationship between Finnish stock market and commodities is examined with Johansen cointegration while short-run relationship is examined with VAR models and Granger causality test. In addition, impulse response test and forecast error variance decomposition are employed to strengthen the results of short-run relationship. The dynamic relationships might change under different market condi-

tions. Thus, the sample period is divided into two sub-samples in order to reveal whether the dynamic relationship varies under different market conditions.

The results show that Finnish stock market has stable long-run relationship with industrial metals, indicating that there would not be diversification benefits among the industrial metals. The long-run relationship between Finnish stock market and energy commodities is not as stable as the long-run relationship between Finnish stock market and industrial metals. Long-run relationship was found in the full sample period and first sub-sample which indicate less room for diversification. However, the long-run relationship disappeared in the second sub-sample which indicates diversification benefits. Long-run relationship between Finnish stock market and agricultural commodities was not found in the full sample period which indicates diversification benefits between the variables. However, long-run relationship was found from both sub-samples. The best diversification benefits would be achieved if investor invested in precious metals. No long-run relationship was found from either sample.

In the full sample period OMX Helsinki had short-run relationship with most of the energy commodities and industrial metals and the causality was mostly running from equities to commodities. During the first sub period the number of short-run relationships and causality shrunk but during the crisis period the number of short-run relationships and causality increased. The most notable result found was uni-directional causality from gold to OMX Helsinki during the crisis period.

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2000-luvun aikana eri osakemarkkinat ovat entistä integroituneimpia mikä rajoittaa hajauttamisesta saatavaa hyötyä. Raaka-aineisiin sijoittamisesta on tullut yhä suositumpaa, joten sijoittajien tulisi harkita raaka-aineita sisällytettäväksi portfolioihinsa. Tässä pro gradu-tutkielmassa tutkitaan Suomen osakemarkkinoiden ja raaka-aineiden dynaamista suhdetta.

Tutkielman metodologia perustuu vektoriautoregressiomalleihin (VAR). Pitkän aikavälin suhde tutkitaan Johansenin cointegraatiotestillä, kun taas lyhyen aikavälin suhde tutkitaan VAR-mallilla sekä Grangerin kausaliteettitestillä. Lisäksi impulse response-testiä sekä variance decomposition-analyysiä käytetään vahvistamaan lyhyen aikavälin suhteen tuloksia. Suomen osakemarkkinoiden ja raaka-aineiden suhde saattaa muuttua erilaisten markkinaolosuhteiden aikana. Siksi ajanjakso on

jaettu kahdeksi alaperiodiksi, jotta pystytään tutkimaan onko Suomen osakemarkkinoiden ja raaka-aineiden suhde muuttunut eri markkinaolosuhteiden aikana.

Tulokset osoittavat, että Suomen osakemarkkinoilla ja teollisuusmetalleilla on vakaa pitkän ajan suhde, sillä muuttujien havaittiin olevan cointegroituneita joka näytteessä. Tämä osoittaa sen, että hajauttaminen teollisuusmetalleihin ei ole tehokasta. Energiasektorin raaka-aineisiin hajauttaminen on myös varsin tehotonta. Pitkän aikavälin suhde löytyi täydestä ajanjaksosta sekä ensimmäisestä alaperiodista. Mutta, toisesta alaperiodista, joka vastaa kriisiperiodia, ei löytynyt cointegraatiota. Suomen osakemarkkinoiden ja maatalous raaka-aineiden välillä pitkän aikavälin suhdetta ei löytynyt täydestä ajanjaksosta, mutta alaperiodeista löytyi mikä jättää maatalous raaka-aineisiin hajauttamisen tehokkuuden kyseenalaiseksi. Parhaat hajautushyödyt löytyvät jalometalleista, sillä cointegraatiota Suomen osakemarkkinoiden ja jalometallien välillä ei löytynyt yhdestäkään näytteestä.

Lyhyen aikavälin suhdetta ja kausaalisuutta tutkittaessa havaittiin, että OMX Helsinki selittää useiden energia raaka-aineiden sekä teollisuusmetallien hinnan muutoksia. Kausaalisuuden havaittiin olevan osakkeista raaka-aineisiin. Ensimmäisessä alaperiodissa lyhyen aikavälin ja kausaalisten suhteiden määrä kutistui, mutta kriisiperiodilla lyhyen aikavälin ja kausaalisten suhteiden määrä kasvoi. Huomattavin löydös oli kausaalinen suhde kullasta OMX Helsinkiin.

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In Helsinki, January 23, 2016

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Table of contents

1. Introduction 10

1.1. Background and motivation 10

1.2. Objectives and research questions 11

1.3. Methodology 12

1.4. Limitations of the study 13

1.5. Structure 14

2. Literature review 15

2.1. The relationship between stock markets and oil 15

2.1. The relationship between stock markets and gold and other commodities 22

2.3. Cointegration between stock markets and cointegration between stock markets and exchange rates 28

3. Data and methodology 32

3.1. Data 32

3.2. Methodology 34

3.2.1. Stationarity 35

3.2.2. Vector autoregressive models 36

3.2.3. Cointegration and error correction 37

3.2.4. Granger causality 40

3.2.5. Impulse response and forecast error variance decomposition 40

4. Empirical results 43

4.1. Full sample period 43

4.1.1. Correlation, unit root and stationarity tests 43

4.1.2. Johansen cointegration 46

4.1.3. VECM and VAR 48

4.1.4. Granger causality, impulse response and variance decomposition 52

4.2. Sub period 1/2000-12/2007 59

4.2.1. Correlation 59

4.2.2. Johansen cointegration 61

4.2.3. VECM and VAR 62

4.2.4. Granger causality, impulse response and variance decomposition 67

4.3. Sub period 1/2008-12/2014 73

4.3.1 Correlation ... 73
4.3.2. Johansen cointegration ... 75
4.3.3. VECM and VAR ... 76
4.3.4. Granger causality, impulse response and variance decomposition ... 81
5. Conclusions ... 88
References ... 94
Appendices ... 103

List of figures

Figure 1 Development of OMX Helsinki ... 33

List of Tables

Table 1 Descriptive statistics for the full sample period ... 34
Table 2 Correlation coefficients for the return series ... 44
Table 3 Stationarity and unit root test for the full sample period. ... 45
Table 4 Johansen cointegration test. Period 1/2000-12/2014. ... 47
Table 5 VECM for OMX Helsinki and energy commodities. Period 1/2000-12/2014. ... 49
Table 6 VECM for OMX Helsinki and industrial metals. Period 1/2000-12/2014. ... 50
Table 7 VAR for OMX Helsinki and agricultural commodities. Period 1/2000-12/2014. ... 51
Table 8 VAR for OMX Helsinki and precious metals. Period 1/2000-12/2014. ... 52
Table 9 Granger causality for the period 1/2000-12/2014. ... 54
Table 10 Impulse response of OMX Helsinki. Period 1/2000-12/2014. ... 55
Table 11 Variance decomposition of OMX Helsinki. Period 1/2000-12/2014. ... 57
Table 12 Correlation coefficients for the sub period 1/2000-12/2007 ... 60
Table 13 Johansen cointegration test. Period 1/2000-12/2007. ... 62
Table 14 VECM for OMX Helsinki and energy commodities. Period 1/2000-12/2007. ... 63
Table 15 VECM for OMX Helsinki and industrial metals. Period 1/2000-12/2007. ... 65
Table 16 VECM for OMX Helsinki and agricultural commodities. Period 1/2000-12/2007. ... 66
Table 17 VAR for OMX Helsinki and precious metals. Period 1/2000-12/2007 ... 67
Table 18 Granger causality for the period 1/2000-12/2007. ... 68
Table 19 Impulse response of OMX Helsinki. Period 1/2000-12/2007. ... 69
Table 20 Variance decomposition of OMX Helsinki. Period 1/2000-12/2007. ... 71
Table 21 Correlation coefficients for the second sub period 1/2008-12/2014. ... 74

Table 22 Johansen cointegration. Period 1/2008-12/2014. 76
Table 23 VECM for OMX Helsinki and industrial metals. Period 1/2008-12/2014. 78
Table 24 VECM for OMX Helsinki and agricultural commodities. Period 1/2008-12/2014............. 79
Table 25 VAR for OMX Helsinki and energy commodities. Period 1/2008-12/2014. 80
Table 26 VAR for OMX Helsinki and precious metals. Period 1/2008-12/2014.............................. 81
Table 27 Granger causality for the period 1/2008-12/2014. 82
Table 28 Impulse response of OMX Helsinki. Period 1/2008-12/2014... 84
Table 29 Variance decomposition of OMX Helsinki. Period 1/2008-12/2014. 87

List of abbreviations

Abreviation	Explanation	Abreviation	Explanation
ADF	Augmented Dickey-Fuller test	KPSS test	Test for stationarity
Ag	Silver	Ni	Nickel
Al	Aluminum	OMX	OMX Helsinki total return index
Au	Gold	Pb	Lead
Brent	Crude oil Brent	Pt	Platinum
Coc	Cocoa	SB	Soybeans
Cof	Coffee	SBO	Soybeanoil
CointEq1	Speed of adjustment coefficient of VECM	Sn	Tin
Cor	U.S yellow corn	VAR	Vector autoregressive model
Cu	Copper	VECM	Vector error correction model
“D” prefix	Denotes that series are first differenced	Whe	HRW wheat Kentucky city
DF	Dickey-Fuller test	WTI	West Texas Intermediate crude oil
Gas	Gasoline	Zn	Zinc

1. Introduction

1.1. Background and motivation

Traditionally asset portfolios consist for example of stocks and bonds. However, the globalization and recent financial crises have shown that different stock markets are becoming interdependent and thus diversification between different stock markets might not be effective. Hence there is growing need for assets where investors can diversify their portfolios. An asset class which should be considered as a part of portfolio is commodities.

Commodities have become more popular asset class to invest in the 2000s. According to Masters (2008) and U.S. Commodity Futures Trading Commission (CFTC, 2008) the value of commodity index investment has increased from $15 billion in 2003 to at least $200 billion in June 2008. There has been criticism and concerns for investing in commodities. For instance, Masters (2008) and U.S. Senate Permanent Subcommittee on Investigations (2009) argue that speculation in commodity markets has led commodity prices to spike in late 2000s. However, there is only little evidence for that commodity prices are under speculation (see Irwin & Sanders (2011) and Will et al. (2012)). Furthermore, many studies establish that speculation do not cause change in commodity prices (e.g. Lehecka (2015), Manera et al. (2013) and Östensson (2012)).

Despite the shadow of speculation and subsequent moral issues, the relationship between stock markets and commodities must be studied since it is important for different groups. For instance, investors need information whether the assets have long-run relationship or not. If the assets have long-run relationship the diversification is not effective due to comovements of two assets. For the corporate managers it is important to know how are the stock price of the company and commodities used in manufacturing process bounded to each other. In addition, the relationship between stock markets and commodities is important to know for policy-makers since when they are for instance imposing tariffs or other restrictions for example importing or exporting commodities which might have consequences for the respective firms.

The focus in this master's thesis is on investor point of view since different stock markets have become more integrated and diversification between them might not be effective. This master's thesis makes a contribution to the existing literature by examining the dynamic relationship between Finnish stock market and commodities and tries to find out whether the commodities could be used as a part of portfolio diversification. The existing literature provides limited and conflicting evidence about the relationship between stock markets and commodities. Most of the studies are focused on one particular commodity or they are using commodity indices where it cannot be observed how one particular commodity affects to stock markets. In addition, the methodology used in the studies might be different. One study focuses on long-run relationship whereas one accounts only the short-run relationship. However, this master's thesis accounts both short and long-run relationship and includes several commodities from different sectors in order to bring extensive evidence for the dynamic relationship between small stock market and commodities.

1.2. Objectives and research questions

The objective of this master's thesis is to study dynamic relationship between Finnish stock market and different commodity groups between 1/2000-12/2014. The Finnish stock market is selected as a proxy for equities since there are companies which are dependent on global commodity prices and it is important to examine whether the global commodity prices have an impact on the equities of the small and developed stock market. The main objective is to examine whether there are diversification benefits between the variables or not. If there was long-run relationship i.e. cointegration between variables then diversification benefits between the variables would be limited. Furthermore, the short-run relationship, direction of causality and the impact of shocks are examined.

The analyses are first made to full sample period and after that the dataset is divided into two subsamples in order to find out whether the dynamics have changed or not under the different market conditions. The first subsample is 1/2000-12/2007 which refers to pre-crisis period and the second subsample is 1/2008-12/2014 which refers to crisis period.

The research questions are as follows:

1: Is there long-run relationship between Finnish stock market and commodities?

2: Is there short-run relationship between Finnish stock market and commodities?

3: What is the direction of causality between Finnish stock market and commodities? Is it unidirectional or bi-directional?

4: Are the dynamic relationships between Finnish stock market and commodities time-varying?

1.3. Methodology

This thesis utilizes widely used methodology in the field of examining dynamic relationships between different variables. The foundation of the analyses is Vector Autoregressive (VAR) models. VAR models have several advantages over structural models. For instance, it avoids identification problem since all variables are treated as endogenous variables in the VAR models.

The analysis begins with testing the series for unit roots and stationarity. This is done with augmented Dickey-Fuller (ADF) test and KPSS test. The former tests series for the presence of unit root whereas the latter tests series for stationarity. If the series are non-stationary at their levels it can be tested whether the combination of non-stationary variables is stationary i.e. variables are cointegrated. Long-run relationship is studied by utilizing Johansen cointegration test (1991).

Depending on the results of Johansen cointegration, the testing proceeds with VAR or Vector Error Correction Model (VECM). Short-run linkages are examined with VAR while VECM examines the amount of last period's equilibrium error is corrected for current period. In addition short-run dynamics are included in VECM as well. Furthermore the causality between Finnish stock market and commodities is examined with Granger causality test. However, Granger causality cannot say anything about the sign of the causality, thus impulse response function and forecast error variance decomposition are used to find out the sign of the causality and strengthen the results of short-run dynamics.

1.4. Limitations of the study

Despite the fact that this master's thesis extensively brings its contribution to the existing literature considering the relationship between equities and commodities, it also has limitations. For instance, it excludes possible common trends out of the data. This means that the variables are following some common trend more than cointegrating relation that binds the variables together in the long run. Due to its small size, the Finnish stock market makes challenging to conclude the economic significance of the causality tests where equities lead the commodity prices. In addition, the explaining power of the impulse response test could be greater if the shock was divided into demand and supply shocks.

1.5. Structure

The structure of this thesis is following. The literature review for existing literature about the relationship between stock markets and different variables is presented in section 2. Section 3 describes the data and methodology used in this thesis. The empirical results are presented in section 4. Finally, the conclusions are made in section 5.

2. Literature review

2.1. The relationship between stock markets and oil

Oil is the most important commodity and every country is dependent on it, both oil exporting and importing countries. Thus, it is important to study whether the country's stock markets have comovements with oil prices. Seminal studies examine the relationship between oil and economic activity (e.g. Hamilton (1983)) whereas the field of study has moved towards examining the relationship between oil price and stock markets in the 1990s (e.g. Jones & Kaul (1996), Huang et al. (1996) and Sadorsky (1999)). There are conflicting results in the literature considering for cointegration between oil price and stock prices (e.g. Hammoudeh et al. (2004) and Ciner (2013)), linear or nonlinear relationship (e.g. Balcilar & Ozdemi (2013) and Wang et al. (2013)), and the response of stock prices to oil price shocks (e.g. Creti et al. (2014) and Cunado & Perez de Garcia (2014)) . Next, some earlier and more recent studies are presented.

Huang et al. (1996) employed VAR model to study the effects of energy shocks (heating oil and crude oil) to U.S. stock markets. They used daily data from October 1979 to March 1990 for heating oil and stock markets. Time period from April 1983 to March 1990 was used for crude oil since crude oil futures did not exist before 1983. They concluded that oil futures return do not lead the stock returns, except oil futures returns cause the returns of the oil industry companies. Different results were provided by Jones and Kaul (1996) who examined whether the oil price shocks effect on the real cash flows and/or changes in expected returns for international stock markets (USA, Canada U.K. and Japan). They applied standard cash-flow/dividend valuation model on quarterly data from 1947-1991, 1960-1991, 1970-1991 and 1962-1991 for USA, Canada, Japan and U.K., respectively. Their results indicated that increasing oil price have negative impact on stock returns in every country.

Sadorsky (1999) applied VAR model for monthly U.S. stock market data from January 1950 to April 1996. He conducted Johansen cointegration test in order to test whether the industrial production, interest rates and real oil prices have long-run relationship or not. The variables were not cointegrated. However, the results might have been different if stock prices were included into cointegration model. The estimated coefficients of VAR were not significant, however, for further analysis, Sadorsky (1999) employed impulse response function and variance decomposition in order to see the shock effects. The variance decomposition revealed for the full sample period that oil price movements explain approximately 5% of stock return forecast error variance while 1986-1996 the figure was 16%. The impulse response function showed that an oil price shock has negative impact on stock returns.

Balcilar and Ozdemi (2013) used a Markov switching vector autoregressive model (MS-VAR) to analyse causality between oil futures price changes and S&P 500 index which had been divided into sub-groups. They concluded that there is unidirectional predictive power from oil futures prices to all stock price index subgroups. In addition, they concluded that the relationship between the variables is nonlinear. Ciner (2013) also examined the relationship between oil price change and stock returns with US stock market data. He used monthly data from January 1986 to December 2010. After conclusion that oil price and stock market are not cointegrated he employed frequency domain methods to examine linkages between oil price and stock prices. Ciner (2013) found that if oil price change had less than 12-month persistency, the stock markets would have negative response while from 12 to 36-month persistency will increase stock returns.

Hammoudeh et al. (2004) studied the spillover effects, day effects and relationship between five S&P oil sector stock indices and oil prices. They found out that oil prices (spot and futures prices) are cointegrated while oil sector stock indices are not. However, when Hammoudeh et al. (2004) included oil price into the model where the stock indices were, they became cointegrated. The results of the VECM model revealed that none of the oil sector indices can explain the future movements of the 3-month futures prices However, the 3-month futures prices had predictive power on the stock prices of companies engaged in exploration, refining and marketing. Hammoudeh et al. (2004) suggest that investors should not use these stocks in predicting future oil prices. Instead of using stock prices, the futures prices should be used in predicting future stock prices.

Similar to study of Hammoudeh et al. (2004), El-Sharif et al. (2005) conducted a study where UK oil and gas sector firms were under examination. Their first priority was to analyse the relationship between oil price and stock prices of oil and gas sector. For comparison they also included other sectors (mining transport, banking and software and computer services) in the analysis. El-Sharif et al. (2005) concluded that oil prices have a positive impact on stock prices in oil and gas sector while the impact on the other sectors is weak.

Creti et al. (2014) studied the degree of interdependence between oil price and stock markets for oil-importing (France, Germany, Italy, Netherlands and USA) and oil-exporting countries (Kuwait, Saudi Arabia, United Arab Emirates and Venezuela). They applied evolutionary co-spectral analysis developed by Priestley and Tong (1973) for monthly data from September 2000 to December 2010 to discover short-run and medium-run relationships. The long-run relationship was tested with Engle and Granger (1987) cointegration method. The results of the study suggest that all countries react weakly to oil price fluctuations in the short-run while they react strongly in the medium-run. The long-run relationship was found with all oil-importing countries whereas from oil-exporting countries only Kuwait and Venezuela were cointegrated with the oil price. The result of Kuwait is consistent with the results of Maghyereh and Al-Kandari (2007), who applied nonlinear cointegration analysis on GCC countries. Creti et al. (2014) suggest that oil price shocks are more persistent in oil-importing countries which are due to the high consumption of oil.

Cunado and Perez de Garcia (2014) examined the impact of different oil price shocks to stock returns for 12 oil importing European countries (including Finland). They divided the oil price shocks into demand and supply shocks. They found out that all countries' stock markets, except Germany, have long-run relationship with the oil price and thus employ VECM model for those countries. Their results suggest that real oil price change has negative impact on stock returns for example in Finland and U.K. When dividing oil price change into demand and supply shocks, Cunado and Perez de Garcia (2014) found that demand shocks have negative effect on stock returns in Italy, Luxembourg, Portugal and U.K. The demand shock into oil price had positive effect on stock returns in Denmark and France. The supply shocks had negative impact on most countries' (including Finland) stock returns. Their results are consistent in that sense that countries included in the study are oil importers.

Wang et al. (2013) conducted broader analysis compared to Creti et al. (2014) and Cunado & Perez de Garcia (2014). They studied the relationship between oil price and stock markets in oil-importing and oil-exporting countries. They also divided oil price shock into demand and supply shocks as Cunado and Perez de Garcia (2014) did. They found that positive supply shock had positive effect on stock prices in USA, U.K. and Italy, while the effect on other oil-importing countries and all oil-exporting countries were insignificant. The demand shock had significant effect on stock prices in most countries but effects were different depending on the country. The impact of demand shock was stronger and more persistent in oil-exporting countries than oil-importing countries.

Park and Ratti (2008) had mostly similar results when they examined the effect of oil price shocks on stock returns in the USA and 13 European countries. They used monthly data from January 1986 to December 2005. The time period Park and Ratti used is shorter than Cunado and Perez de Garcia (2014) had (2/1973-12/2011). The Johansen test of cointegration revealed that only the stock markets of Finland, France, Greece, Italy and UK are cointegrated with the oil price. Although the cointegration was detected Park and Ratti (2008) employed VAR model for all variables in order to test short-run relationship. They justified the use of VAR model based on previous studies written by Engle & Yoo (1987), Clements & Hendry (1995), Hoffman & Rasche (1996) and Naka & Tufte (1997). The impulse response of stock returns to oil price shocks revealed that for the eleven of thirteen European countries (Finland has 10% significance) and for the USA, the oil price shock has a negative impact on stock returns in the same month and or/within one month whereas stock market of Norway had positive response to oil price shock.

After examining short-run relationship between oil price and stock returns, Ratti conducted with Miller (Miller & Ratti 2009) a study where they examined the long-run relationship between oil price and stock markets. Their sample consisted of monthly data of six OECD countries from January 1971 to March 2008. They conducted the analysis by including structural breaks into model. After identification of break points Miller and Ratti (2009) first estimated the long-run relationship with no breaks for the full sample period and find no cointegration between oil price and stock markets. When including breaks into analysis Miller and Ratti found long-run relationship from January 1971 to May 1980 and from February 1988 to September 1999. They concluded that stock prices increase as the oil price decreases and vice versa.

The long-run relationship and causality during the financial crisis between the oil price and stock markets were examined by Constantin et al. (2010). They used daily data for All Country World Index (ACKWI) and MSCI Frontier Markets Index (FMIND) from January 3 2008 to March 30 2010. Both significant benchmarks of oil spot price (Brent and WTI) were used in the analysis. They tested the cointegration in pairs and used different lag lengths suggested by the information criteria. Cointegration was found between WTI and ACKWI when 20 lags were used. Next step was to conduct Granger causality test in order to test the causality between the variables. Constantin et al. (2010) found unidirectional causality from

ACKWI to Brent oil whereas bi-directional causality was detected between FMIND and WTI.

Raul and Arouri (2009) examined the relationship between oil prices and stock markets in Gulf Corporation Council countries (GCC). They used both weekly and monthly time series data from June 2005 to October 2008 and from January 1996 to December 2007, respectively. They found bi-directional causality for Saudi-Arabia and unidirectional causality for other GCC countries from oil price changes to stock price changes. Maghyereh and Al-Kandari (2007) applied nonlinear cointegration analysis on GCC countries. They used daily data from January 1996 to December 2003. First Maghyereh and Al-Kandari (2007) tested linear cointegration by using Johansen test of cointegration and concluded that there is no long-run relationship between oil price and stock markets. However, they conducted nonlinear cointegration test and found evidence for nonlinear cointegration for the variables.

When considering new long-term investments, it might be ideal to invest in emerging market hoping to gain better profits and diversification than from developed markets. However, the emerging markets are more volatile and therefore it is essential to examine whether there is long-run relationship between important commodities and stock markets or not. Oil can be seen as a growth engine for economy. As emerging countries evolve it is expected that their demand for oil increases substantially (Basher & Sadorsky (2006)). The relationship between oil price risk and emerging stock markets was studied by Basher and Sadorsky (2006). They included 21 emerging markets into their study with time period from December 1992 to December 2005. They concluded that relationship depends on the data frequency used. For instance, for daily and monthly data, the emerging markets have positive response for oil price increase whereas the impact of oil price turns opposite when weekly and monthly data is used.

Gil-Alana and Yaya (2014) examined the relationship between Nigerian stock market and oil prices. They used monthly data from January 2000 to December 2011 and used fractional integration and cointegration to conclude whether there is long-run relationship or not. Gil-Alana and Yaya (2014) did not find long-run relationship. However, they found positive short-run relationship between oil price and stock market. Conflicting results considering Nigerian stock markets were found by Nwosa (2014). He applied Johansen test of cointegration and VECM for quarterly data from March 1985 to December 2010. Nwosa (2014) found out that oil prices (international and domestic prices) and Nigerian stock market have long-run relationship but not short-run. The coefficient of speed of adjustment was significant in the case where international oil price was dependent variable. His results implied that international oil price and stock market have unidirectional long run causality running from stock market to oil price whereas unidirectional causality was detected from domestic oil price to stock market. He also pointed out that oil price and stock market adjust slowly to their long-run equilibrium in both cases.

Papapetrou (2001) used multivariate VAR model when she examined the relationship among oil prices, stock prices, interest rates, real economic activity and employment in Greece. She used monthly data from January 1989 to June 1999. The cointegration test did not reveal long-run relationship among the variables and thus VAR is correct model to proceed. However, the results of cointegration test might be incorrect because Papapetrou (2001) used stock returns, which are stationary [I(0)] while other variables were non-stationary [I(1)], in the cointegration test. The variables used in cointegration test should be at their levels. She concluded that oil price affect to the economic activity and employment of Greece. She also concluded that stock returns are depressed by positive oil price shock.

Similar methodology was used by Cong et al. (2008). They examined the relationship between oil price and Chinese stock market. They used monthly data from January 1996 to December 2007. After confirming that interest rates, oil price and industrial production are not cointegrated, Cong et al. (2008) employed VAR model to examine short-run relationship of the variables. They found out that most of the stock market indices do not have short-run relationship with the oil price. However, shocks to oil price increased the returns of manufacturing index and some oil companies.

2.1. The relationship between stock markets and gold and other commodities

Gold has been important store of value for centuries and also has been considered as a safe haven during the recessions. Gold is popular asset to invest and the field of study is more focused on whether gold is a hedge against stock market decline or not. Supporting evidence that gold acts as safe haven for developed stock market have found by Baur & McDermott (2010) and Baur (2011) while Ciner et al. (2013) found that gold is not safe haven for the U.S. and U.K. equities.

Gold has also proposed as a hedge against rising inflation and depreciating exchange rate. Baur (2011) examined the relationship between gold and financial variables. He concluded that effectiveness of gold hedge is time varying. For the time period 1979-1994 Baur (2011) found that gold is not safe haven for equities and inflation whereas the role of gold changed for the period 1995-2011 and it was found that gold acts as a safe haven for inflation and equities. It was also found by Baur (2011) that gold is a hedge for depreciating U.S. dollar. Worthington and Pahlavani (2007) also divided their sample into two subsamples and concluded that gold price and U.S. inflation rate are cointegrated and gold is a hedge against rising inflation for both subsamples.

Ciner et al. (2013) also concluded that gold serves as a safe haven for both British Pound and U.S. Dollar while bonds serve as a hedge for equities. Similarly, Hammoudeh et al. (2009) found that gold can be used as a hedge against depreciating dollar when they examined the relationship between the commodities and the U.S.

financial variables. The effectiveness of hedge might also be dependent on the amount of depreciation. Wang and Lee (2010) examined whether gold is a hedge against currency depreciation in Japan. They concluded that gold serves as effective hedge when the depreciation is greater than 2,62%. Patel (2013b) examined the cointegration between gold price and Indian financial variables. He found that gold price is cointegrated with inflation and exchange rate. After further analysis Patel (2013b) concluded that gold is a hedge against the rising inflation. However, the results of cointegration test might be violated since inflation and gold were not integrated for same order.

The existing literature provide limited amount of information whether the stock markets have long-run relationship with the gold or other commodities. However, the existing literature about whether the gold is a safe haven or not indirectly refers to that gold is not cointegrated with equities and other financial variables. More evidence is needed in this area and this master’s thesis makes the contribution in order to reveal the dynamic linkages between Finnish stock markets and commodities.

Causal relationship between gold prices and Indian stock market has been studied by Patel (2013a). He used monthly data from January 1991 to December 2011. The Johansen test of cointegration revealed that each stock market index is cointegrated with the gold price. The results of Granger causality test showed that there is unidirectional causality from gold price to S&P BNC Nifty. In addition, Srinivasan and Prakasam (2014) examined the relationship between Indian stock market, gold and exchange rate with monthly data for the time period June 1990 to April 2014. Instead of using Johansen cointegration test Srinivasan and Prakasam (2014) applied Autoregressive Distributed Lag (ADRL) model and Granger causality to detect long-run and short-run relationships. The ADRL test showed opposite results to the study of Patel (2013a). However, cointegration was found when the exchange rate was used as a dependent variable. Srinivasan and Prakasam (2014) finally concluded that there is no stable long-run relationship between gold and Indian stock market. In addition, the Granger causality test did not reveal any short-run relationship between the variables and the same conclusion was achieved with variance decomposition.

Do and Sriboonchitta (2009) examined cointegration and causality among gold and the Association of South East Asian Nations (ASEAN) emerging stock markets (Indonesia, Malaysia, Philippines, Thailand and Vietnam). They used daily data from July 2000 to March 2009. The cointegration between all variables was first tested and no cointegration was found. However, when Do and Sriboonchitta (2009) tested cointegration in pairs, they found that there is cointegration between almost half of the stock market index pairs but no cointegration was found between gold price and stock market indices. The Granger causality between gold and stock market indices existed only in the case of gold SET-index of Thailand where there was unidirectional causality from gold to stock market. Bi-directional causality was detected between gold and VN-index of Vietnam.

Samanta and Zadeh (2011) examined co-movements between gold price, oil price U.S. dollar and Dow Jones index from January 1989 to September 2009. They used vector autoregressive moving average (VARMA) and Johansen cointegration to forecast spillovers and long-run relationship, respectively. The cointegration existed among the variables and Granger causality test showed unidirectional causality from gold price and stock price to oil price and exchange rate.

Contrary to the study of Samanta and Zadeh (2011), Smith (2001) did not find long-run relationship between gold and the U.S. stock market. He used four gold prices and six stock market indices from January 1991 to October 2001. Smith tested cointegration between gold prices and stock market indices in pairs and employed Engle-Granger cointegration test. Smith (2001) also tested short-run dynamics with Granger causality test. When the gold price was set in the morning fixing, unidirectional causality from stock market indices to the gold price was found. However, the causality appeared to be bi-directional when the gold price was set in the afternoon fixing.

The relationship between commodities (WTI oil, gold and aggregate index of metals and minerals) and relevant individual stocks during bull and bear market was studied by Ntantamis and Zhou (2015). They first concluded that commodities have longer duration for bear market than bull market while bull phase tends to have longer duration for individual stocks. Regardless of the market phase of stocks, Ntantamis and Zhou (2015) concluded that it does not have impact on market phase of commodities. In addition, they found that commodity prices provide information for their respective stock market sectors. Gwilym et al. (2011) examined whether the gold prices can explain the future returns of gold equity index. They concluded that the sensitivity of gold price equities to gold price has declined in recent years when the gold price has increased. The relationship between gold price and gold equities was reported negative and the conclusion was that gold price was not a good predictor of future returns of gold equities. However, when the real interest rates were included in the model, Gwilym et al. (2011) found that the explanatory power of the model increased substantially.

Gilmore et al. (2009) studied the long-run and short-run relationship between gold price, stock price indices of gold mining companies and stock market indices. They used weekly data from June 1996 to January 2007. They found that CBOE Gold Index (GOX) is cointegrated with gold price and stock market indices. They found negative short-run relationship running from S&P 500 to GOX and positive short-run relationship running from GOX to gold price.

There is also evidence for cointegration between gold and other commodities. Baur and Tran (2014) examined the long-run relationship between gold and silver prices and the influence of bubble or financial crisis period to the cointegration. They used monthly data from January 1970 to July 2011. Baur and Tran (2014) found cointegration between gold and silver prices, however, bubble periods and financial crises affect to the long-run relationship between the variables. The Granger causality showed that there is unidirectional causality from gold price to silver price. Opposite results are provided by Ciner (2001). He used daily data for gold and silver futures prices from 1992 to 1998. Ciner (2001) found that the long-run relationship between gold and silver prices had disappeared.

The long-run relationship between oil price and gold price was examined by Zhang and Wei (2010). They used daily data from January 2000 to March 2008. Johansen cointegration and VECM model was applied to test long-run and short-run dynamics. Cointegration between oil and gold price was found and thus VECM model was employed. The coefficient of speed of adjustment was negative and significant. However, the speed towards the equilibrium was very low. The VECM model also showed that oil price have impact on gold price on the same day and one day lag whereas gold has only contemporaneous effect on oil price. Also the Granger causality test revealed that change in the oil price causes a change in the gold price.

The cointegration literature considering the long-run relationship between different commodities and stock markets is fairly limited. The literature of commodities is more focused on the relationship between commodities and macroeconomic variables since increased commodity prices are seen as a signal of rising inflation and interest rates. For instance, Browne & Cronin (2010), Mahadevan & Suardi (2013) and Hristu-Varsakelis & Kyrtsou (2008) have examined the relationship between commodity prices and inflation with the U.S. data. Conflicting results for the cointegration was found in the studies of Browne & Cronin (2010) and Mahadevan & Suardi (2013). The former study found cointegration between commodity prices and inflation while the latter did not. The differing results might be due to different data frequency. Both, Mahadevan & Suardi (2013) and Hristu-Varsakelis & Kyrtsou (2008) found that there is causality from commodity prices to inflation. It would have been an interesting addition into study of Hristu-Varsakelis and

Kyrtsou (2008) if they had added a causality test between metals and stock market while they focused the causality between metals and inflation and causality between stock market and inflation.

Black et al. (2014) examined the relationship between S&P 500 index and S&P GSCI Commodity total return index from 1973 to 2012. They tried to find out whether the commodity prices predict the future stock returns. The commodity index used in the study of Black et al. (2014) contains commodities from wide sector, for instance, metals, energy, agricultural and livestock products and precious metals. The results of Johansen test of cointegration indicated that stock market index and commodity index are cointegrated. The Granger causality indicates that stock prices drive commodity prices. However predicting power from commodity prices to stock prices was found when Black et al. (2014) divided their sample period into three subsamples.

Similar Granger causality test results were achieved by Rossi (2012). She examined whether the stock markets of commodity exporting countries (Australia, New Zealand, Canada, Chile and South Africa) have predictive ability on commodity prices. Rossi (2012) used both global commodity price index and country-specific indices, where appropriate weights for different commodities were used depending on which particular commodity for instance Australia exports most. Granger causality test between stock markets and global commodity index showed no causality between variables for one quarter ahead. However, the results changed when two quarters were used. It seems that stock markets of Australia, New Zealand and Canada have predictive power on global commodity index. The results were slightly different when county-specific commodity prices were used. Rossi (2012) found some predictive power already on one quarter ahead while results of two quarters ahead were similar to global commodity index.

The long-run relationship and causality between food commodities and stock prices were examined by Lehecka (2014). He divided the sample into four subsamples and the cointegration between FAO Food Price Index and MSCI World Stock Market Index was found for the time periods 2004-2012 and 2004-2008. However, Lehecka (2014) found no cointegration for the time period 2008-2012. The causality between the variables was mostly bi-directional, except for the time period 1990-2003, where no causality was detected.

2.3. Cointegration between stock markets and cointegration between stock markets and exchange rates

When considering investing or establishing a new factory in foreign country, the investor must take into account the exchange rate between domestic and foreign currency. He or she prefers to invest in countries where the currency is expected to appreciate and through currency appreciation better gains in domestic currency are achieved. It is highly important that investor knows whether the domestic stock markets are cointegrated with the exchange rate or not in order to being able to utilize exchange rate movements.

Especially during the financial crises the existence of cointegration is important factor because otherwise enormous losses might occur. The long-run relationship between stock markets and exchange rate during the recent financial crisis is examined by Tsagkanos and Siriopoulos (2013). They tried to find out whether Eurotop 300 or Dow Jones Index is cointegrated with euro-dollar exchange rates or not by applying non-linear cointegration model. They reported positive long-run relationship from Eurotop 300 to euro-dollar exchange rate while there was no long-run relationship between Dow Jones and euro-dollar exchange rate. At 10% level Tsagkanos and Siriopoulus (2013) concluded that in the pre-crisis period, the causality runs from the exchange rate to stock markets whereas during the crisis the causality runs from stock markets to exchange rates.

Similar to Tsagkanos and Siriopoulos (2013), Kollias et al. (2012) investigated the long-run relationship and causality between European stock markets and the euro-dollar exchange rate. They applied rolling cointegration method for daily data from January 2002 to December 2008. They did not find any cointegration among the variables. However, they concluded that causality between variables is time variant which is consistent with the study of Tsagkanos and Siriopoulos (2013). Long-run relationship between stock markets and exchange rate was neither found by Zhao (2010) who examined the linkages between Renminbi exchange rate and Chinese stock market. However, Rutledge et al. (2014) found cointegration between Renminbi exchange rate and Chinese industry specific stock indices. They also divided their sample period into subsamples and concluded that stock markets and exchange rate were not cointegrated during the crisis period. Rutledge et al. (2014) reported that causality between stock markets and exchange rate is mainly bi-directional. However, no causality was detected during the financial crisis which is different to findings of Tsagkanos and Siriopoulos (2013).

Kim (2003) examined the cointegration among the U.S. stock markets and macroeconomic variables (e.g. exchange rate) for time period 1974-1998. He found that U.S. stock markets have long-run relationship with the macroeconomic variables. Variance decomposition analysis revealed that variation in the stock prices are also influenced by the interest rate variation whereas stock price variations cause variations in inflation, exchange rate and industrial production.

As globalization and the removing of the restrictions on capital inflows have occurred, one might expect the stock markets around the world to become more integrated. The convergence between developed European and emerging European stock markets due to acceptance for EU member and adoption of Euro was examined by Dunis et al. (2013). The Johansen cointegration test showed that acceptance for EU member induces long-run relationship between developed European countries and Cyprus, Slovakia and Slovenia. After the adoption of Euro only Malta and Slovenia exhibited long-run relationship with the rest of the euro area.

For the further analysis Dunis et al. (2013) performed beta- and sigma-convergence test and the conclusion was same as in the Johansen cointegration test.

Syriopoulos (2007) also examined the relationship between emerging Central European countries and developed stock markets (USA and Germany). He divided the sample into pre-EMU and post-EMU periods and concluded that emerging markets are cointegrated with their developed counterparts. The Granger causality showed that both U.S. and German stock markets tend to lead emerging markets in both periods. Syllignakis and Kouretas (2010) conducted similar study to Syriopoulos (2007) but they added more emerging European countries into the analysis. Syllignakis and Kouretas (2010) also found that emerging European stock markets are cointegrated with their developed counterparts. In addition they performed common trend analysis which revealed that there were more common trends than cointegrating vectors which means that markets can only be partially integrated. Sylligkanis and Kouretas (2010) also found that EU accession process was an important factor for the convergence between emerging and developed markets.

Similar studies (Phengpis & Swanson (2006) and Aggarwal & Kyaw (2005)) were conducted considering the impact of the North American Free Trade Agreement (NAFTA) on the relationships between its members' stock markets. Phengis and Swamnson (2006) found no cointegration between variables and concluded that cointegration might be time-varying since cointegration was found in the rolling window analysis during the crisis period. They also found that short-run interdependencies had increased after the adoption of the NAFTA. Slightly different results were presented by Aggarwal and Kyaw (2005) who found cointegration in the post-NAFTA period. However, Aggarwal and Kyaw (2005) used daily, weekly and monthly data whereas Phengpis and Swanson (2006) used only weekly data. Aggarwal and Kyaw (2005) also tested cointegration pairwise which showed different results. Finally, based on this evidence NAFTA has brought some convergence among the U.S, Canadian and Mexican stock markets.

3. Data and methodology

3.1. Data

The data set consists of 180 monthly observations for OMX Helsinki and 19 commodities from January 31 2000 to December 31 2014. The index type chosen for OMX Helsinki is total return index in which the dividends are added and it thus gives more realistic view for performance of OMX Helsinki. For the commodities, their spot prices are used. All data is gathered from DataStream. In order to examine the dynamics between OMX Helsinki and commodities, the commodities are grouped into four sectors which are energy, industrial metals and precious metals and agricultural commodities, which include both agricultural commodities and softs.

The analysis is first performed for full sample period and then the dataset is divided into two sub-samples in order to examine whether the dynamics between stock price index and commodities have changed or not. The sub-sample periods used in this thesis are 1/2000-12/2007 and 1/2008-12/2014. The previous can be referred to pre-crisis period and the latter can be referred to crisis period since the both include the main impacts of the subprime mortgage crisis and also the European debt crisis. Despite the fact that some observable events occurred during 2007, the main events of the financial crisis occurred during 2008 and thus the crisis period is set to begin 1/2008. Figure 1 shows the development of OMX Helsinki for the selected time period. The development of the commodity prices can be seen from the Appendix 2. In this thesis both logarithmic prices and logarithmic returns are used. The previous is used to test long-run dynamics while the latter is used to test short-run dynamics.

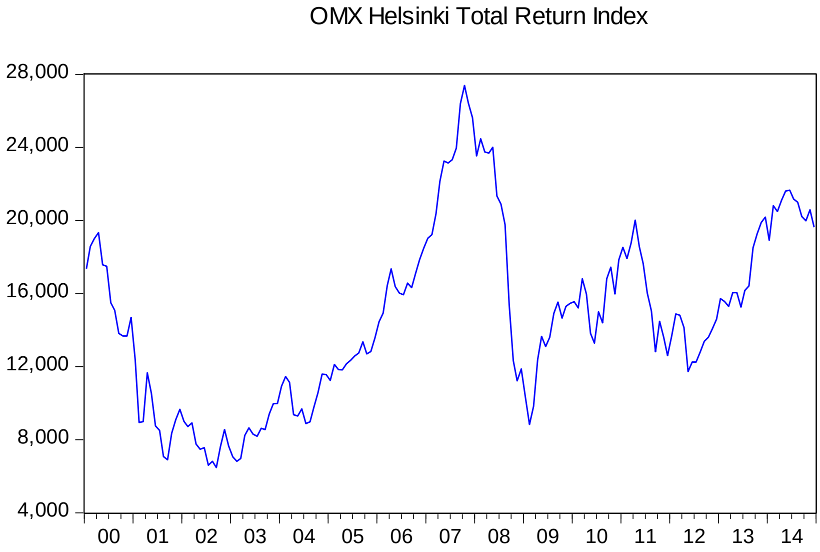

Figure 1. Development of OMX Helsinki

The descriptive statistics for the dataset are presented in the Table 1. Mean is multiplied by 12 and standard deviation is multiplied by the square root of 12 in order to show returns and volatility on annual basis. Minimum and maximum indicate monthly variation. Annualized continuously compounded returns show that OMX Helsinki has yielded on average 0,82% annually between 2000-2014. The best returns would have been gained if investment was made into gold. The highest annual volatility is in the returns of gasoline while the gold has the least volatile returns. It can be seen that all the returns exhibit leptokurtosis and most of the returns are negatively skewed. Also the null hypothesis of normality is clearly rejected among 15 variables. Only the returns of aluminum, corn, nickel, sugar and tin are normally distributed.

Table 1. Descriptive statistics for the full sample period.

	Mean (%)	Max (%)	Min (%)	Std. Dev. (%)	Skew-ness	Kurtosis	Jarque-Bera
Ag	7.45	25.15	-33.40	32.10	-0.56	4.44	24.76***
Al	0.36	15.64	-17.80	21.02	0.02	3.09	0.07
Au	9.61	11.86	-18.61	17.20	-0.40	3.81	9.78***
Brent	4.73	31.18	-43.93	36.81	-0.73	5.20	52.22***
Coc	7.92	29.69	-24.23	27.91	0.11	4.43	15.53***
Cof	3.81	29.19	-21.83	26.29	0.30	3.92	8.94**
Cor	4.23	28.27	-24.75	32.36	-0.10	3.65	3.47
Cu	8.36	27.09	-44.32	27.58	-0.98	8.76	276.09***
Gas	4.95	42.16	-53.46	43.50	-0.31	5.37	44.69***
Ni	3.65	30.05	-29.65	37.05	-0.13	3.13	0.62
OMX	0.82	25.94	-32.41	29.01	-0.50	4.61	26.71***
Pb	9.28	23.99	-32.01	32.14	-0.45	4.20	16.79***
Pt	6.12	21.68	-38.74	23.67	-1.41	9.37	362.21***
Sb	4.89	18.85	-40.26	31.86	-1.21	5.98	110.03***
Sbo	4.91	26.05	-25.21	26.94	-0.26	4.05	10.32***
Sn	8.11	23.82	-23.61	25.68	0.06	3.74	4.25
Sug	7.36	28.77	-30.23	33.12	0.12	3.63	3.41
Whe	6.73	29.42	-19.63	28.69	0.26	3.92	8.30**
WTI	4.42	27.53	-39.12	32.36	-0.63	4.28	24.03***
Zn	4.43	24.50	-41.17	29.01	-0.64	5.84	72.62***

****, **, * denotes significance at 1%, 5% and 10% level, respectively*

3.2. Methodology

This thesis utilizes methodology which is used in several studies in order to determine the long-run and short-run dynamics between different variables. First, the stationarity of the series must be tested in order to ensure which tests can be used. Second, the Johansen test of cointegration is used to test the long-run relationship between OMX Helsinki and the commodities. Depending on the results of the Johansen cointegration test, this study proceeds with vector error correction model (VECM) or unrestricted vector autoregressive model (VAR). In addition, Granger causality test, impulse response and variance decomposition tests are employed in order to deepen the results of short-relationships. All computations are made with EViews.

3.2.1. Stationarity

The concept of stationarity is highly important in time series analysis. The non-stationarity of the variables leads to that the coefficient estimates of ordinary least regression (OLS) are not BLUE (best linear unbiased estimator). A stationary series has a constant mean, constant variance and constant autocovariances for each given lag. Performing the time series analysis without confirming whether the series are stationary or not, can be problematic due to the behavior and properties of the series. For instance, unexpected shocks into stationary series gradually die away while in non-stationary series the shock's persistence is infinite. Using the non-stationary data can lead to spurious regressions where one might get significant result albeit the variables do not have anything to do with each other. (Brooks 2008, 318-319)

A random walk model with drift is a popular model to illustrate the non-stationarity and how to overcome it.

$$y_t = \mu + y_{t-1} + u_t \tag{1}$$

Where μ is constant drift term, y_{t-1} is a previous value of y and u_t is a white noise disturbance term. In order to overcome the stochastic non-stationarity, subtracting y_{t-1} from both sides of the equation, we get:

$$y_t - y_{t-1} = \mu + u_t \tag{2}$$

$$\Delta y_t = \mu + u_t$$

The process does not now depend on time t but only on the difference between two time periods. The new variable Δy_t is stationary [I(0)]. If the stationarity is achieved by "differencing once" the series are integrated of order one [I(1)]. (Brooks 2008, 332)

The series are tested for unit roots and stationarity with augmented Dickey-Fuller test (ADF) and KPSS test, respectively. The traditional Dickey-Fuller test (DF) (1979) tests the hypothesis that $\Phi = 1$. The alternative hypothesis is $\Phi < 1$. If the null hypothesis is not rejected it means that series contain a unit root [I(1)]. The DF test can be expressed as:

$$y_t = \Phi y_{t-1} + u_t \qquad (3)$$

The problem with the DF test is that it assumes u_t to be white noise i.e. not autocorrelated. The solution is to use the ADF test (Dickey & Fuller, 1981) which uses *p* number of lags for the dependent variable in order to soak up any dynamic structure present in the dependent variable to ensure that u_t is not autocorrelated (Brooks 2008, 329). The null hypothesis is same as in the DF test [I(1)]. The ADF test can be expressed as:

$$\Delta y_t = \psi y_{t-1} + \Sigma_{i=1}^{p} \alpha_i \Delta y_{t-1} + u_t \qquad (4)$$

In order to strengthen the results of the ADF test, a KPSS test (Kwaitkowski et al., 1992) is employed. The setting of the null hypothesis is contrary to the ADF test. The null hypothesis is that series is stationary [I(0)]. In the KPSS test, the series of observations can be expressed as a sum of deterministic trend, a random walk and a stationary error term:

$$\mathrm{y_t} = \xi \mathrm{t} + \mathrm{r_t} + \varepsilon_\mathrm{t} \qquad (5)$$

$$\mathrm{r_t} = \mathrm{r_{t-1}} + \mathrm{u_t}$$

ADF test and KPSS test are run for each variable at their levels and first differences to examine the order of integration [I(d)].

3.2.2. Vector autoregressive models

The bases of the analysis in this thesis are vector autoregressive models (VAR) and vector error correction models (VECM) which is a restricted form of VAR. VAR models are made known by Sims (1980). He argued that other macroeconomic models are over identified and the identification is often done inappropriately that it does not follow economic theory. VAR models have many advantages over simultaneous equations structural models. For instance, by using VAR model, researcher avoids the identification problem since all variables are treated as endogenous. VAR model also allow the value of variable to depend on its past and contemporaneous value as well as the past and contemporaneous values of other variables.

A VAR model can be expressed as:

$$\underset{g \times 1}{y_t} = \underset{g \times 1}{\beta_0} + \underset{g \times g}{\beta_1} \underset{g \times 1}{y_{t-1}} + \underset{g \times g}{\beta_2} \underset{g \times 1}{y_{t-2}} + \cdots + \underset{g \times g}{\beta_k} \underset{g \times 1}{y_{t-k}} + \underset{g \times 1}{u_t} \qquad (6)$$

Where *g* is the number of variables, *k* is the number of lags, β_0 is an intercept and u_t is a white noise disturbance term.

3.2.3. Cointegration and error correction

After testing the series for unit roots and stationarity, it can be tested whether the variables have long-run equilibrium i.e. are cointegrated. Engle & Granger (1987) defines cointegration as that a linear combination between two variables that are I(1) becomes I(0) if they are cointegrated. The term cointegration can also be referred to long-run relationship or long-run equilibrium. However, variables may have deviations from their long-run equilibrium in the short-run. When these short-run deviations occur, which may be due to political decisions or other shocks, vector error correction model (VECM) is a tool to capture the proportion of last period's disequilibrium which will be corrected.

Let the long-run equilibrium between two cointegrated variables be:

$$y_t = \beta x_t + u_t \qquad (7)$$

Assume that changes in y_t depend on the deviations from the equilibrium in period *t-1*:

$$\Delta y_t = \beta(y_{t-1} - \gamma x_{t-1}) + u_t \tag{8}$$

Model 7 is an error correction model where $y_{t-1} - \gamma x_{t-1}$ is an error correction term, γ is cointegrating coefficient and β describes the speed of adjustment back to equilibrium. In order to get back into the equilibrium, the speed of adjustment should be negative. It is also possible to add intercept and/or trend term into cointegrating term or in the model or both. (Brooks 2008, 338-339; Lütkepohl 2005, 246)

Furthermore, it is possible to add short-run dynamics into VECM. This thesis examines both, short-run and long-run dynamics between Finnish stock markets and commodities. In addition, the intercept is included into the cointegrating term and the model. Hence, the VECM can be expressed as:

$$\Delta y_t = \beta_0 + \beta_1 \Delta x_t + \beta_2 (y_{t-1} - \alpha - \gamma x_{t-1}) + u_t \tag{9}$$

Where the new coefficient β_1 describes the short-run relationship between changes in *x* and *y*. Terms β_0 and α are intercepts for the model and cointegrating term, respectively.

In this thesis cointegration is examined by using the Johansen cointegration test (Johansen, 1991). In order to utilize Johansen cointegration test, a general VAR needs to be transformed into a vector error correction form:

$$\Delta y_t = \Pi y_{t-k} + \Sigma_{i=1}^{k-1} \Gamma_i \Delta y_{t-i} + u_t \tag{10}$$

Where $\Pi = \left(\Sigma_{i=1}^{k} \beta_i\right) - I_g$ and $\Gamma_i = \left(\Sigma_{j=1}^{i} \beta_j\right) - I_g$. Γ refers to coefficient matrix for the lagged differences of the stochastic variables. The focus of the test is on Π matrix since it can be referred to long-run coefficient matrix. Π matrix can be presented as *Π=αβ'*, where *α* is a vector of adjustment parameter and *β'* represents cointegrating vector(s). Both are (g x r) matrices. *r* is the rank of Π matrix, i.e. the amount of cointegrating vectors. The rank cannot be full r=g since this would imply y_t being stationary. If r=0, then there is no cointegration. Cointegration exists if the rank of Π matrix is 0<r<g. (Brooks 2008, 350;352)

There are two tests that are used to calculate cointegration between *y*s. This occurs by looking at the rank of the Π matrix via its eigenvalues (λ_i). The rank of the Π matrix is equal to the number of its characteristic roots (eigenvalues) that are different from zero. The tests used to determine the rank of Π matrix, are trace test and maximum eigenvalue test. (Brooks 2008, 350-351)

$$\lambda_{trace}(r) = -T\, \Sigma_{i=r+1}^{g}\, ln(1 - \hat{}\lambda_i) \quad (11)$$

and

$$\lambda_{max}(r, r+1) = -Tln(1 - \hat{}\lambda_{r+1}) \quad (12)$$

Where *r* is the number of cointegrating vectors under the null hypothesis, *ˆλs* estimated eigenvalues of the Π matrix and *T* is the number of observations. These two tests have different hypothesis. The null of the trace test is that the number of cointegrating vectors is less than or equal to *r* against the alternative hypothesis that there are more than *r* cointegrating vectors. The null of the maximum eigenvalue test is that the number of cointegrating vectors is *r* against the alternative hypothesis *r+1*. (Brooks 2008, 351)

One might get conflicting results between these two tests. In the case of conflict, the trace test is preferred over maximum eigenvalue test due to its robustness against skewness and excess kurtosis compared to the maximum eigenvalue test (See Table 1 and Dunis et al., 2013).

3.2.4. Granger causality

Interpretation of a mere VAR model might be difficult when the number of variables and lags grow. Granger causality test (Granger, 1969) is used to examine short-run dynamics and causal relationship between the variables. The definition of the test is if previous values of *X* can be used to forecast the current value of *Y* it is said that "*X* Granger causes *Y* ". Hence the null hypothesis of the test is "*X* does not Granger cause *Y*". The term Granger causality might be slightly misleading since it does not exactly mean that past values of *X* cause changes in *Y*. It rather means that previous values of *X* have explaining power on the future value of *Y* (Brooks 2008, 298).

Since the Granger causality test is performed alongside the VAR models, the variables must be stationary. First differenced series then contains only information about short-run dynamics while long-run information is removed by first differencing the series.

3.2.5. Impulse response and forecast error variance decomposition

In order to strengthen the results of the Granger causality test, impulse response and forecast error variance decomposition tests are employed. Granger causality test tells the direction of the causality between the variables. However, it is not able to tell anything about the sign of the causality and the duration of the effects. (Brooks 2008, 299)

Impulse response examines the responsiveness of each variable in the VAR system to shocks to each of the variable. A unit shock or one standard deviation shock is applied to the error term of each variable in the system. If the system is stable the shock gradually dies away. This can be shown by presenting VAR as vector moving average (VMA). Next, the illustration of Brooks (2008, 299) is shown in order to see how the shock works its way out of the system. (Brooks 2008, 299)

Consider following VAR:

$$y_t = A_1 y_{t-1} + u_t \tag{13}$$

Where $A_1 = \begin{bmatrix} 0{,}5 & 0{,}3 \\ 0{,}0 & 0{,}2 \end{bmatrix}$

The VAR could be written in a matrix form:

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} 0{,}5 & 0{,}3 \\ 0{,}0 & 0{,}2 \end{bmatrix} \begin{bmatrix} y_{1t-1} \\ y_{2t-1} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \tag{14}$$

Consider unit shock applied to y_{1t} at *t = 0*

$$y_0 = \begin{bmatrix} u_{10} \\ u_{20} \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} \tag{15}$$

$$y_1 = A_1 y_0 = \begin{bmatrix} 0{,}5 & 0{,}3 \\ 0{,}0 & 0{,}2 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 0{,}5 \\ 0 \end{bmatrix} \tag{16}$$

$$y_2 = A_1 y_1 = \begin{bmatrix} 0{,}5 & 0{,}3 \\ 0{,}0 & 0{,}2 \end{bmatrix} \begin{bmatrix} 0{,}5 \\ 0 \end{bmatrix} = \begin{bmatrix} 0{,}25 \\ 0 \end{bmatrix} \tag{17}$$

It is now possible to plot the impulse responses of y_{1t} in a graph. We can see that the system is stable since the shock works its way out of the system. Lütkepohl (2005, 53) emphasizes that it is useful to use standard deviation shocks instead of unit shocks if the variables have different scales. Hence, in this thesis standard deviation shocks are used.

Another test used to confirm the results of Granger causality test is forecast error variance decomposition. While impulse response function tests the impact of unit shock applied to the error term, variance decomposition examines which proportion of movements in the dependent variables are due to their own shock versus shocks to the other variables (Brooks 2008, 300). Since VAR systems have dynamic nature, the shock to the *i* th variable affects directly that particular variable but also to the other variables in the system.

It is not realistic to expect that error terms of the variables in the VAR system are uncorrelated. When a shock is applied into one variable or error term it is likely that variables in the VAR system are correlated at some level. In order to account the correlation, an orthogonalisation is done for the impulse responses and variance decomposition. This means that variables are set in specific order before tests are done. The method applied is Cholesky decomposition and variables are ordered in a way that commodities are before OMX Helsinki since the focus is more on how shocks to commodities affect OMX Helsinki.

4. Empirical results

4.1. Full sample period

4.1.1. Correlation, unit root and stationarity tests

Table 2 presents the correlation coefficients of the return series. It can be seen that OMX Helsinki exhibits highest correlation with nickel (0,45) and generally the correlation coefficients are higher with OMX Helsinki and industrial metals compared to the other commodity groups. In addition, correlation between different commodity groups is relatively low. Furthermore, high correlations are found inside the commodity groups. For instance, energy commodities and precious metals are highly correlated when examining correlation within commodity groups.

Next, the series are tested for unit roots and stationarity. In order to being able to conduct Johansen test of cointegration it must be ensured that series are $I(1)$ at their levels, meaning that the series contain one unit root and they are non-stationary. In the case of VAR model the assumption is that the series are $I(0)$ and are stationary. Stationarity is achieved by first differencing the level series.

First, the ADF and KPSS tests are employed to test series for the unit root and stationarity for the levels, respectively. For the ADF test, the null hypothesis is that series contain a unit root. The objective is that the null hypothesis is not rejected at levels but it should be rejected when the first difference is taken. For the KPSS the null hypothesis is that series are stationary. When the series are at their levels, the objective is that the null hypothesis is rejected meaning that the series are non-stationary. When the first differences are taken the null hypothesis should not be rejected which indicates that stationarity is induced by first differencing the series.

Table 2. Correlation coefficients for the return series.

	OMX	Brent	Gas	WTI	Al	Cu	Ni	Pb	Sn	Zn	Ag	Au	Pt	Coc	Cof	Cor	SB	SBO	Sug	Whe
OMX	1.00																			
Brent	0.15	1.00																		
Gas	0.16	0.81	1.00																	
WTI	0.22	0.89	0.76	1.00																
Al	0.41	0.33	0.21	0.36	1.00															
Cu	0.42	0.42	0.39	0.47	0.67	1.00														
Ni	0.45	0.26	0.26	0.28	0.49	0.52	1.00													
Pb	0.36	0.21	0.13	0.25	0.51	0.55	0.40	1.00												
Sn	0.41	0.36	0.32	0.40	0.57	0.56	0.47	0.41	1.00											
Zn	0.39	0.26	0.22	0.31	0.61	0.74	0.48	0.57	0.47	1.00										
Ag	0.30	0.30	0.32	0.34	0.35	0.46	0.32	0.29	0.46	0.43	1.00									
Au	0.14	0.25	0.23	0.27	0.23	0.35	0.23	0.15	0.30	0.32	0.77	1.00								
Pt	0.38	0.40	0.36	0.42	0.44	0.57	0.44	0.30	0.45	0.45	0.64	0.56	1.00							
Coc	0.04	0.22	0.17	0.18	0.19	0.23	0.13	0.12	0.19	0.17	0.30	0.24	0.33	1.00						
Cof	0.26	0.20	0.21	0.17	0.29	0.30	0.26	0.31	0.29	0.35	0.36	0.28	0.34	0.30	1.00					
Cor	0.18	0.10	0.09	0.14	0.16	0.20	0.22	0.09	0.27	0.19	0.26	0.20	0.24	0.15	0.20	1.00				
SB	0.29	0.14	0.10	0.13	0.19	0.18	0.21	0.14	0.20	0.12	0.17	0.13	0.28	0.13	0.26	0.64	1.00			
SBO	0.27	0.16	0.05	0.15	0.32	0.40	0.16	0.33	0.28	0.34	0.28	0.24	0.33	0.20	0.23	0.44	0.55	1.00		
Sug	0.09	0.20	0.14	0.16	0.28	0.23	0.11	0.24	0.23	0.25	0.09	0.08	0.22	0.12	0.21	0.01	0.08	0.10	1.00	
Whe	0.24	0.14	0.14	0.14	0.18	0.24	0.18	0.15	0.14	0.21	0.25	0.27	0.33	0.17	0.30	0.48	0.39	0.37	0.11	1.00

From the Table 3 can be seen that the null hypothesis of the ADF test cannot be rejected which means that all variables are I(1) at their levels, in the other words, contain a unit root. When series contain a unit root, it means that the series follow random walk process, indicating that past information cannot be utilized in predicting future returns. This also means that the series fulfill the condition of the weak-form market efficiency. Table 3 also presents the results of KPSS test. The null hypothesis is rejected at 5% level for aluminum and OMX Helsinki and at 1% level for the rest of the variables, indicating that all variables are non-stationary at their levels. In order to induce stationarity, the series must be first differenced. The results of first differenced series show that the unit root and non-stationarity have been removed. The next step after the confirmation that series are I(1) at levels and I(0) when first differenced, is to conduct Johansen test of cointegration for the series levels in order to test whether the variables have long-run relationship or not.

Table 3. Stationarity and unit root test for the full sample period.

	KPSS		ADF	
	Levels	First differenced	Levels	First differenced
Ag	1.555***	0.168	-1.165	-14.096***
Al	0.631**	0.061	-2.651	-5.733***
Au	1.666***	0.277	-1.079	-15.109***
Brent	1.510***	0.156	-1.573	-12.446***
Coc	1.368***	0.085	-1.934	-14.630***
Cof	1.458***	0.131	-0.918	-15.185***
Cor	1.333***	0.087	-1.456	-11.867***
Cu	1.411***	0.115	-1.472	-10.648***
Gas	1.492***	0.121	-1.942	-12.133***
Ni	0.811***	0.103	-1.575	-12.159***
OMX	0.702**	0.131	-1.613	-10.169***
Pb	1.448***	0.138	-1.425	-12.591***
Pt	1.47***	0.152	-1.900	-10.657***
SB	1.503***	0.065	-1.663	-14.686***
SBO	1.403***	0.089	-1.395	-13.150***
Sn	1.565***	0.084	-0.849	-11.355***
Sug	1.401***	0.106	-2.045	-10.765***
Whe	1.432***	0.065	-1.880	-12.967***
WTI	1.470***	0.144	-1.666	-11.116***
Zn	0.892***	0.082	-1.227	-13.440***

****, **, * denotes significance at 1%, 5% and 10% level, respectively*

4.1.2. Johansen cointegration

After ensuring that series are non-stationary at their levels, then it can be tested whether they exhibit long-run relationship. The cointegration between OMX Helsinki and commodities is tested in a way that commodities are grouped in four sectors which are agricultural commodities, energy commodities, industrial metals and precious metals. The results of the Johansen cointegration test for each group can be seen from the Table 4. It can be clearly seen that OMX Helsinki does not exhibit long-run relationship with every commodity sector. The null hypothesis of no cointegrating equations cannot be rejected in the case of agricultural commodities and precious metals which imply possible diversification benefits among the variables. For instance, Baur and McDermott (2010) found that gold acts as a safe haven for developed stock markets which means that stock markets and gold cannot be cointegrated.

Interestingly, trace test and maximum eigenvalue test provide conflicting results for the long-run relationship between OMX Helsinki and industrial metals. The trace test indicates two cointegrating equations whereas the null hypothesis of no cointegrating equations cannot be rejected according to maximum eigenvalue test. According to Dunis et al. (2013) trace test should be preferred over maximum eigenvalue test since it is more robust to skewness and excess kurtosis (see Table 1) than maximum eigenvalue test. Thus, it can be said that OMX Helsinki exhibits long-run relationship with industrial metals which implies that there is less room for diversification among the variables.

The long-run relationship is also found between OMX Helsinki and energy commodities. Both trace test and maximum eigenvalue clearly reject the null hypothesis of no cointegrating equations which means that there is one cointegrating equation. The results of Johansen cointegration test showed that OMX Helsinki has long-run equilibrium with industrial metals and energy commodities whereas no long-run relationship was found with the agricultural commodities and precious metals. The results of cointegration test for energy sector is consistent with the study of Cunado and Perez de Garcia (2014) who found that Finnish stock markets are cointegrated with oil. Next VECM model is employed to test the speed of adjustment towards equilibrium and short-run relationship for the cointegrated series while unrestricted VAR is used to test short-run relationship for the series without cointegration.

Table 4. Johansen cointegration test. Period 1/2000-12/2014.

If the Trace Statistics or Max-Eigen Statistic exceeds the 5% Critical Value, it shows that H0 can be rejected and there is at least one cointegrating vector. The process continues until H0 cannot be rejected. Column "Prob." presents the p-value.

Trace test					
Group	No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	Prob.
Agriculturals	None	0.242946	146.7608	159.5297	0.4457
Energy	None	0.187907	65.56381	47.85613	0.0005*
	At most 1	0.088894	28.51481	29.79707	0.0697
Industrial metals	None	0.224495	142.333	125.6154	0.0032*
	At most 1	0.187582	97.07818	95.75366	0.0404*
	At most 2	0.144808	60.10031	69.81889	0.2323
Precious metals	None	0.112311	35.04358	47.85613	0.4457

Maximum Eigenvalue test					
Group	No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5% Critical value	Prob.
Agriculturals	None	0.242946	49.54097	52.36261	0.0947
Energy	None	0.187907	37.049	27.58434	0.0023*
	At most 1	0.088894	16.57116	21.13162	0.1932
Industrial metals	None	0.224495	45.25484	46.23142	0.0634
	At most 1	36.97787	36.97787	40.07757	0.1073
	At most 2	27.84437	27.84437	33.87687	0.2208
Precious metals	None	0.112311	21.20587	27.58434	0.264

** indicates cointegrating equation(s) at the 5% level*

4.1.3. VECM and VAR

The results of VECM can be seen from Tables 5 and 6. In the VECM model the sign of speed of adjustment is preferred to be negative and significant when examining how the dependent variable adjusts back to its equilibrium value.

When examining the results between OMX Helsinki and energy commodities the coefficient of speed of adjustment is only statistically significant when the dependent variable is gasoline. However, the sign of the coefficient is not correct. When the OMX Helsinki is dependent variable the sign is correct but it is not significant. These results indicate that the series can wander apart from each other for a long time and it cannot be said how long it will take to get back into equilibrium. From the Table 5 can be seen that the lagged value of OMX Helsinki has significant coefficient for itself and every energy commodity which indicates positive short-run relationship from the OMX Helsinki to energy commodities while none of the coefficients of energy commodities are significant when the OMX Helsinki is dependent variable. There is neither short-run feedback between the energy commodities which is slightly surprising.

The results of VECM for OMX Helsinki and industrial metals are presented in the Table 6. The coefficient of speed of adjustment has correct sign and is significant at 1% level in every case. However, the speed of adjustment is very low. For instance, when OMX Helsinki is dependent variable the coefficient value is only -0,067426 which implies that approximately only 6,74% of the last period's equilibrium error is corrected during one month. When examining the short-run dynamics it can be seen that lagged value of OMX Helsinki can explain the movements of industrial metals. The only industrial metal that lagged value of OMX Helsinki cannot explain is lead. In addition, it can explain the movements of zinc only at 10% level. When examining the short-run relationships when OMX Helsinki is dependent variable only the lagged value of nickel is significant at 5% level. The relationship is negative which implies that increasing nickel returns depress the returns of OMX Helsinki.

Table 5. VECM for OMX Helsinki and energy commodities. Period 1/2000-12/2014.

The first row refers to the contemporaneous and differenced dependent variables while the first column refers to speed of adjustment coefficient and independent variables. The term CointEq1 shows the speed of adjustment back to equilibrium for the dependent variable. Columns 2-5 show the impact of lagged independent variables which denote the short-run relationship. "D" refers to differenced series.

VECM	D(OMX)	D(Brent)	D(Gas)	D(WTI)
CointEq1	-0.001652 (0.00404) [-0.40855]	0.001547 (0.00502) [0.30808]	0.020999 (0.00582) [3.60893]***	0.002439 (0.00449) [0.54372]
D(OMX(-1))	0.197362 (0.07667) [2.57409]**	0.335422 (0.09524) [3.52170]***	0.252133 (0.11034) [2.28513]**	0.180971 (0.08507) [2.12720]**
D(Brent(-1))	-0.15538 (0.14728) [-1.05502]	-0.232537 (0.18295) [-1.27104]	-0.087852 (0.21194) [-0.41452]	0.12763 (0.16342) [0.78101]
D(Gas(-1))	0.047301 (0.09488) [0.49854]	0.112851 (0.11786) [0.95748]	0.106137 (0.13654) [0.77734]	0.057721 (0.10528) [0.54827]
D(WTI(-1))	0.073986 (0.14943) [0.49513]	0.17451 (0.18562) [0.94014]	0.170622 (0.21503) [0.79347]	-0.053688 (0.1658) [-0.32381]

****, **, * denotes significance at 1%, 5% and 10% level, respectively. Standard errors in ( ) & t-statistics in [ ]*

For the agricultural commodities and precious metals an unrestricted VAR is employed to examine short-run linkages between the variables. The results of VAR for the relationship between OMX Helsinki and agricultural commodities can be seen from the Table 7. It is bit surprising that OMX Helsinki has negative short-run relationship with the cocoa since there are only few companies listed which might be affected by the change in the price of cocoa. Furthermore, it is also interesting that there are only two short-run relationships detected between different agricultural commodities indicating that agricultural commodities are mostly independent from each other.

Table 6. VECM for OMX Helsinki and industrial metals. Period 1/2000-12/2014.

VECM	D(OMX)	D(Al)	D(Cu)	D(Pb)	D(Ni)	D(Sn)	D(Zn)
CointEq1	-0.067426	-0.042938	-0.05006	-0.082968	-0.057181	-0.050763	-0.045311
	(0.01383)	(0.01000)	(0.01294)	(0.01527)	(0.01844)	(0.01210)	(0.01425)
	[-4.87697]***	[-4.29475]***	[-3.86757]***	[-5.43264]***	[-3.10042]***	[-4.19570]***	[-3.17909]***
D(OMX(-1))	0.186368	0.136087	0.201775	0.111304	0.268021	0.187823	0.16396
	(0.08217)	(0.05942)	(0.07693)	(0.09077)	(0.10961)	(0.07191)	(0.08471)
	[2.26809]**	[2.29025]**	[2.62291]***	[1.22625]	[2.44515]**	[2.61200]***	[1.93554]*
D(Al(-1))	0.114678	0.151205	0.245705	0.382774	0.247196	0.186444	0.316372
	(0.15008)	(0.10853)	(0.14051)	(0.16578)	(0.20021)	(0.13134)	(0.15472)
	[0.76411]	[1.39321]	[1.74871]*	[2.30886]**	[1.23471]	[1.41958]	[2.04479]**
D(Cu(-1))	0.108385	0.241635	0.405579	0.205694	-0.021702	0.225548	0.296899
	(0.12423)	(0.08983)	(0.11630)	(0.13722)	(0.16572)	(0.10871)	(0.12807)
	[0.87248]	[2.68983]***	[3.48731]***	[1.49896]	[-0.13096]	[2.07473]**	[2.31831]**
D(Pb(-1))	-0.128984	-0.077653	-0.124899	-0.137852	-0.193438	0.028694	-0.149113
	(0.08242)	(0.05960)	(0.07716)	(0.09104)	(0.10995)	(0.07213)	(0.08497)
	[-1.56496]	[-1.30287]	[-1.61865]	[-1.51411]	[-1.75936]*	[0.39783]	[-1.75492]*
D(Ni(-1))	-0.175577	-0.133681	-0.079943	-0.098724	-0.073425	-0.132994	-0.110237
	(0.07105)	(0.05138)	(0.06652)	(0.07848)	(0.09478)	(0.06218)	(0.07325)
	[-2.47121]**	[-2.60188]**	[-1.20184]	[-1.25789]	[-0.77470]	[-2.13899]**	[-1.50502]
D(Sn(-1))	0.096012	-0.055613	-0.129879	-0.081623	-0.039323	0.037534	-0.175101
	(0.10291)	(0.07442)	(0.09635)	(0.11368)	(0.13728)	(0.09006)	(0.10609)
	[0.93295]	[-0.74729]	[-1.34803]	[-0.71800]	[-0.28644]	[0.41677]	[-1.65043]
D(Zn(-1))	-0.014291	-0.159342	-0.321532	-0.212691	0.044846	-0.311462	-0.238251
	(0.00590)	(0.00426)	(0.00552)	(0.00651)	(0.00787)	(0.00516)	(0.00608)
	[-0.12914]	[-1.99104]**	[-3.10329]***	[-1.73980]*	[0.30377]	[-3.21597]***	[-2.08825]**

****, **, * denotes significance at 1%, 5% and 10% level, respectively Standard errors in ( ) & t-statistics in [ ]*

Table 7. VAR for OMX Helsinki and agricultural commodities. Period 1/2000-12/2014.

VAR	D(OMX)	D(Coc)	D(Cof)	D(Cor)	D(SB)	D(SBO)	D(Sug)	D(Whe)
D(OMX(-1))	0.198821	0.072445	0.025808	0.054407	0.134051	0.067158	0.034147	-0.020362
	(0.07991)	(0.07694)	(0.07303)	(0.09050)	(0.08877)	(0.07599)	(0.09119)	(0.08152)
	[2.48811]**	[0.94156]	[0.35338]	[0.60119]	[1.51005]	[0.88378]	[0.37446]	[-0.24979]
D(Coc(-1))	-0.167363	-0.023847	0.014070	-0.139340	-0.091369	0.024199	0.177672	-0.016907
	(0.08195)	(0.07891)	(0.07489)	(0.09281)	(0.09104)	(0.07793)	(0.09352)	(0.08360)
	[-2.04231]**	[-0.30222]	[0.18787]	[-1.50135]	[-1.00363]	[0.31053]	[1.89986]*	[-0.20224]
D(Cof(-1))	0.061847	-0.293907	-0.125094	0.166346	0.119407	-0.017173	-0.116143	0.039034
	(0.09285)	(0.08940)	(0.08486)	(0.10516)	(0.10315)	(0.08830)	(0.10596)	(0.09472)
	[0.66610]	[-3.28748]***	[-1.47418]	[1.58191]	[1.15762]	[-0.19449]	[-1.09611]	[0.41211]
D(Cor(-1))	-0.042499	0.031763	0.093594	0.130558	0.149375	0.027796	0.003519	-0.102029
	(0.09295)	(0.08950)	(0.08495)	(0.10526)	(0.10326)	(0.08839)	(0.10607)	(0.09482)
	[-0.45725]	[0.35491]	[1.10181]	[1.24028]	[1.44664]	[0.31448]	[0.03318]	[-1.07607]
D(SB(-1))	-0.097605	0.038968	0.019503	-0.090458	-0.251952	-0.008962	0.116314	0.016491
	(0.09691)	(0.09332)	(0.08857)	(0.10976)	(0.10766)	(0.09216)	(0.11060)	(0.09886)
	[-1.00713]	[0.41759]	[0.22020]	[-0.82415]	[-2.34016]**	[-0.09725]	[1.05169]	[0.16680]
D(SBO(-1))	0.085261	-0.050111	0.040892	0.137093	0.023893	-0.037180	-0.123432	0.143254
	(0.09917)	(0.09549)	(0.09064)	(0.11232)	(0.11018)	(0.09431)	(0.11318)	(0.10117)
	[0.85971]	[-0.52477]	[0.45116]	[1.22058]	[0.21686]	[-0.39424]	[-1.09062]	[1.41597]
D(Sug)(-1)	-0.008712	0.017847	-0.029512	-0.071060	-0.077965	0.031416	0.195375	-0.024588
	(0.06674)	(0.06426)	(0.06099)	(0.07558)	(0.07414)	(0.06346)	(0.07616)	(0.06808)
	[-0.13054]	[0.27772]	[-0.48386]	[-0.94016]	[-1.05157]	[0.49501]	[2.56528]**	[-0.36116]
D(Whe(-1))	0.058481	0.035042	-0.153308	-0.078969	-0.003779	0.057524	0.085525	0.021828
	(0.08977)	(0.08644)	(0.08205)	(0.10167)	(0.09973)	(0.08537)	(0.10245)	(0.09158)
	[0.65143]	[0.40539]	[-1.86855]*	[-0.77670]	[-0.03790]	[0.67382]	[0.83481]	[0.23835]

****, **, * denotes significance at 1%, 5% and 10% level, respectively. Standard errors in ( ) & t-statistics in [ ]*

For the precious metals it was expected that they are not cointegrated which supports the diversification benefits between stock and precious metals. The results of VAR model are presented in Table 8. When the dependent variable is OMX Helsinki the coefficients of precious metals are as would have been expected i.e. small positive values or negative values. OMX Helsinki does not have short-run relationship with any precious metal and neither do the precious metals have with each other. The lagged values of gold and platinum have impact on their own current value but the signs are different ones.

Table 8. VAR for OMX Helsinki and precious metals. Period 1/2000-12/2014.

The VAR model examines only the short-run relationship and thus there is no speed of adjustment coefficient. Differenced and contemporaneous dependent variables are on the first row while lagged independent variables are on the first column. "D" refers to differenced series.

VAR	D(OMX)	D(Au)	D(Pt)	D(Ag)
D(OMX(-1))	0.178032	-0.002103	0.06036	0.088461
	(0.08161)	(0.04892)	(0.06632)	(0.09131)
	[2.18162]**	[-0.04298]	[0.91012]	[0.96880]
D(Au(-1))	-0.277459	-0.277806	-0.185569	-0.212455
	(0.201)	(0.1205)	(0.16336)	(0.22491)
	[-1.38037]	[-2.30545]**	[-1.13598]	[-0.94464]
D(Pt(-1))	0.094843	0.07092	0.256692	0.222056
	(0.12443)	(0.0746)	(0.10113)	(0.13923)
	[0.76220]	[0.95072]	[2.53830]**	[1.59487]
D(Ag(-1))	0.049157	0.066141	0.007628	-0.101268
	(0.11615)	(0.06963)	(0.09439)	(0.12996)
	[0.42323]	[0.94990]	[0.08081]	[-0.77922]

****, **, * denotes significance at 1%, 5% and 10% level, respectively. Standard errors in ( ) & t-statistics in [ ]*

4.1.4. Granger causality, impulse response and variance decomposition

In order to deepen the understanding the results of VECM and VAR, it is useful to employ Granger causality, impulse response and variance decomposition test to get a better understanding how the variation of the variables occur. The term "Granger causality" does not actually mean that movements of one variable can cause the changes in other variable. It is better to say that the movements of one variable can lead the movements of another variable. The null hypothesis of Granger causality test is that “X does not Granger cause Y”. The impulse response function describes how the dependent variable responses when a one standard deviation shock is applied to the error term. Variance decomposition describes the proportion of movements of dependent variable which is due to its own shocks or shocks into other variables.

The results of Granger causality for each group can be seen from the Table 9. For the cointegrated series it can be clearly seen that there is unidirectional causality from OMX Helsinki to every energy commodities. Furthermore, the returns of OMX Helsinki can lead the returns of energy commodity prices. This also confirms the results of short-run relationship in the VECM presented above. It can be also seen from the results that there is no causality between the energy commodities. For the industrial metals bi-directional causality is found between OMX Helsinki and nickel. There is also unidirectional causality from OMX Helsinki to the most of the industrial metals.

When examining the Granger causality between OMX Helsinki and agricultural commodities, unidirectional causality from cocoa to OMX Helsinki was found. OMX Helsinki did not “Granger cause” any changes in the agricultural commodities. In addition, only few causal relationships were detected among the agricultural commodities. The results of Granger causality between OMX Helsinki and precious metals did not show any causal relationships among the variables indicating that variables are independent also in the short-run.

Table 9. Granger causality for the period 1/2000-12/2014.

*Rows show causality to columns. → refers to unidirectional causality from rows to columns while ↔ refers to bi-directional causality between rows and columns. ***, **, * denotes significance at 1%, 5% and 10% level, respectively. Only the causal relationships found, are reported in the table.*

Independent variables	Dependent variables						
Energy	OMX	Brent	Gas	WTI			
OMX		***→	**→	**→			
Industrial metals	OMX	Al	Cu	Ni	Pb	Sn	Zn
OMX		**→	***→	**↔		***→	*→
Al			*↔		**→		**↔
Cu		***↔				**→	**↔
Ni	**↔	***→				**→	
Pb				*→			*↔
Sn							*↔
Zn		**↔	***↔		*↔	***↔	
Agriculturals	OMX	Coc	Cof	Sug			
Coc	**→			*→			
Cof		***→					
Whe			*→				

The results of impulse response test can be seen from the Table 10. First, the results of cointegrated series are presented. When examining the impact of innovations between OMX Helsinki and energy commodities, OMX Helsinki has a positive response to the innovations to energy commodities. From the energy commodities, innovations to WTI oil have the strongest impact (2,31%) on OMX Helsinki. Common to all shocks is that they die away after two periods. Standard deviation shock to Brent oil has different impact on OMX Helsinki than WTI oil and gasoline. The response of OMX Helsinki is positive in the first period while it turns negative during the second period.

The responsiveness of OMX Helsinki to the innovations to industrial metals is presented next. OMX Helsinki has a positive response to the standard deviation shocks in industrial metals. Innovations to the aluminum have the strongest impact (3,25%) on OMX Helsinki in the first period. It is a bit surprising that OMX Helsinki has positive response to innovations to nickel in the first period. During the second period the response turns to negative as the results of VECM represent. In most cases the impact of innovations to industrial metals disappears after three periods.

Table 10. Impulse response of OMX Helsinki. Period 1/2000-12/2014.

The first column refers to variables where standard deviation shock is set. Columns 2-6 refer to shock duration (months) and how OMX Helsinki responses to those shocks (size and sign). The reporting of responses ends when the absolute value of shock is < 0,1%.

Response of OMX Helsinki	Periods				
Energy	1	2	3	4	5
Brent	0.73	-0.33	0.07		
Gas	0.86	0.65	-0.05		
WTI	2.32	0.75	0.00		
Industrial metals					
Al	3.25	0.55	0.17	0.06	
Cu	1.66	0.99	0.34	0.12	0.04
Ni	1.63	-0.36	-0.13	-0.01	
Pb	0.96	-0.19	0.01		
Sn	0.98	0.92	0.17	0.06	
Zn	0.40	0.16	-0.32	-0.09	
Agriculturals					
Coc	0.39	-1.11	-0.02		
Cof	2.47	0.89	0.33	-0.03	
Cor	0.85	-0.26	-0.16	-0.01	
SB	1.36	-0.14	0.12	0.01	
SBO	1.24	0.84	0.19	0.00	
Sug	0.32	0.00			
Whe	0.69	0.54	0.05		
Precious metals					
Ag	1.46	0.52	-0.01		
Au	0.93	-0.49	0.06		
Pt	2.91	1.15	0.27	0.08	

The response of OMX Helsinki to the innovations to agricultural commodities is positive in the first period. The standard deviation shock to coffee has the strongest impact (2,47%) on OMX Helsinki during the first period while shock to cocoa has only 0,39% impact on OMX Helsinki. The impact of innovations to cocoa magnifies (-1,11%) and the sign turns to negative as the results of VAR indicate. Standard deviation shocks to agricultural commodities die away after two or three periods.

Similarly, OMX Helsinki responses positively to the innovations to precious metals of which innovations to platinum have the strongest impact (2,91%) to OMX Helsinki. The standard deviation shock to the gold has the lowest impact on OMX Helsinki and the impact of shock turns to negative after the first period. The impact of gold and silver shocks disappears after two periods while the impact of platinum disappears after three periods.

Finally, the results of variance decomposition tests are presented in the Table 11. When examining the variation of OMX Helsinki and energy commodities it can be seen that the movements of OMX Helsinki is mostly due to its own shocks. The variation of OMX Helsinki can be explained by the fact that approximately 90% of the variation is due to its own shocks. From the energy commodities the only variable which variation can significantly explain the variation of OMX Helsinki is WTI oil. It can explain approximately 8% of the variation of OMX Helsinki during the whole ten month forecasting horizon.

When comparing the results of industrial metals and energy commodities it can be clearly seen that industrial metals can explain a larger proportion of movements of OMX Helsinki. In this group 71,77-73,68% of the movements of OMX Helsinki are due to its own shocks. Similar to impulse response test, innovations to aluminum has again strongest impact on movements of OMX Helsinki. The movements of aluminum can explain 15,41% of the movements of OMX Helsinki and it remains stable for whole ten month forecast horizon. Other innovations to industrial metals that explain the movements of OMX Helsinki are innovations to copper and nickel. The explanation power of copper rises by over 1% after first month and same occurs to tin.

Table 11. Variance decomposition of OMX Helsinki. Period 1/2000-12/2014.

Table shows how large proportion of the movements (%) of OMX Helsinki is due to its own movements versus movements of other variables. Columns 2-5 refer to forecasting horizon which is expressed in months.

Variance decomposition of OMX Helsinki				
Energy	1	2	5	10
OMX	90.27	89.23	89.22	89.22
Brent	0.78	0.90	0.91	0.91
Gas	1.09	1.62	1.63	1.63
WTI	7.85	8.25	8.25	8.25
Industrial metals				
OMX	73.68	72.04	71.77	71.77
Al	15.41	14.92	14.87	14.87
Cu	4.05	5.15	5.30	5.30
Ni	3.89	3.84	3.84	3.84
Pb	1.35	1.32	1.31	1.31
Sn	1.39	2.47	2.50	2.50
Zn	0.24	0.26	0.41	0.41
Agriculturals				
OMX	83.88	80.60	80.60	80.59
Coc	0.22	1.89	1.88	1.88
Cof	8.98	9.41	9.53	9.53
Cor	1.07	1.08	1.11	1.11
SB	2.72	2.55	2.56	2.56
SBO	2.28	3.08	3.12	3.12
Sug	0.15	0.14	0.14	0.14
Whe	0.70	1.05	1.05	1.05
Precious metals				
OMX	83.16	81.43	81.36	81.36
Ag	3.11	3.33	3.33	3.33
Au	1.27	1.55	1.55	1.55
Pt	12.46	13.68	13.76	13.76

The results of variance decomposition for OMX Helsinki and agricultural commodities showed that 83,88% of the variation of OMX Helsinki is due to its own shocks. However, the proportion declines to 80,59% in the tenth month. Surprisingly the innovations to coffee have the largest proportion (9,5%) when explaining the movements of OMX Helsinki. Albeit it was reported above that cocoa has short-run relationship with OMX Helsinki, the innovations to cocoa can explain only approximately 2% of the movements of OMX Helsinki. Even the innovations to soybeans and soybean oil can explain slightly larger proportion of movements of OMX Helsinki than cocoa.

Finally the results of variance decomposition of OMX Helsinki and precious metals are presented. The own shocks account over 80% of the movements of OMX Helsinki for the whole ten month forecasting horizon. The innovations to gold can explain only approximately 1,5% of the variation of OMX Helsinki which also gives some support for that the gold could act as a safe haven. Similar to impulse response test, innovations to platinum have the highest impact on the movements of OMX Helsinki. It can account over 13% of the variation of OMX Helsinki. Also innovations to silver can explain a small proportion of the movements of OMX Helsinki.

Overall, the results for full sample period seems to be realistic since OMX Helsinki exhibits long-run relationship with energy commodities and industrial metals from which most of the listed companies would have been expected to be dependent on. Long-run relationship was not found between OMX Helsinki and agricultural commodities and between OMX Helsinki and precious metals. The result that OMX Helsinki and precious metals are not cointegrated gives support for diversification benefits and a possibility that precious metals could act as a safe haven. The results also give support for that the agricultural commodities should be considered to include into portfolios.

The Granger causality, impulse response and variance decomposition revealed direction and sign of the causality between OMX Helsinki and commodities which is important for investors and policy makers who manage the portfolios or make political decisions. Next, the same tests are performed for two sub periods which are 1/2000-12/2007 and 1/2008-12/2014 in order to see do the dynamics between OMX Helsinki and commodities change under the different market conditions.

4.2. Sub period 1/2000-12/2007

4.2.1. Correlation

The correlation coefficients for the first sub period are presented in the Table 12. It can be clearly seen that the correlation coefficients are smaller than in the full sample period. Some of the correlation coefficients have been turned to negative. For instance, correlation between OMX Helsinki and both oil price benchmarks have turned negative. OMX Helsinki has highest correlation again with nickel. The correlation coefficients between OMX Helsinki different commodity groups are approximately on the same level when comparing to the full sample period. The energy commodities are the only exception in this sub period.

Table 12. Correlation coefficients for the sub period 1/2000-12/2007.

	OMX	Brent	Gas	WTI	Al	Cu	Ni	Pb	Sn	Zn	Ag	Au	Pt	Coc	Cof	Cor	SB	SBO	Sug	Whe
OMX	1.00																			
Brent	-0.08	1.00																		
Gas	0.00	0.71	1.00																	
WTI	-0.05	0.91	0.75	1.00																
Al	0.25	0.13	-0.04	0.09	1.00															
Cu	0.25	0.18	0.16	0.20	0.56	1.00														
Ni	0.33	0.13	0.14	0.13	0.38	0.42	1.00													
Pb	0.22	0.00	-0.15	0.03	0.41	0.39	0.26	1.00												
Sn	0.21	0.18	0.15	0.20	0.45	0.32	0.31	0.30	1.00											
Zn	0.20	0.09	0.07	0.10	0.55	0.67	0.40	0.44	0.34	1.00										
Ag	0.23	0.09	0.13	0.18	0.19	0.36	0.27	0.16	0.29	0.37	1.00									
Au	0.15	0.18	0.15	0.26	0.20	0.29	0.28	0.02	0.26	0.18	0.64	1.00								
Pt	0.21	0.26	0.21	0.32	0.16	0.43	0.37	0.10	0.20	0.27	0.50	0.48	1.00							
Coc	-0.21	0.12	0.07	0.07	0.06	0.05	-0.13	0.00	0.04	-0.06	0.15	0.10	0.08	1.00						
Cof	0.24	-0.01	-0.02	-0.06	0.27	0.20	0.20	0.34	0.23	0.29	0.19	0.07	0.17	0.13	1.00					
Cor	0.13	-0.13	-0.06	-0.12	0.00	-0.06	0.06	-0.05	0.21	0.11	0.11	0.06	-0.01	-0.02	0.08	1.00				
SB	0.20	-0.11	-0.13	-0.16	0.02	-0.08	0.03	-0.07	0.14	-0.11	-0.03	0.06	0.00	-0.04	0.09	0.63	1.00			
SBO	0.06	-0.17	-0.32	-0.22	0.05	0.05	-0.08	0.15	0.01	0.09	-0.06	-0.01	-0.14	0.02	-0.06	0.28	0.42	1.00		
Sug	-0.01	0.27	0.20	0.22	0.33	0.13	0.01	0.10	0.18	0.24	-0.05	0.00	0.20	0.00	0.13	-0.15	-0.15	-0.12	1.00	
Whe	0.21	0.00	0.03	0.04	0.00	0.09	-0.04	-0.01	-0.04	0.07	0.07	0.15	0.10	-0.05	0.07	0.22	0.10	0.05	-0.01	1.00

4.2.2. Johansen cointegration

The results of cointegration test can be seen from the Table 13. It can be clearly seen that the integration between OMX Helsinki and different commodity groups is greater than during the full sample period. The null hypothesis of no cointegrating equations cannot be rejected only in the case of precious metals which indicate diversification benefits between the OMX Helsinki and precious metals.

When examining the results of energy sector, the trace shows two cointegrating equations for this sub period which implies higher integration for the time period 1/2000-12/2007 than for the full sample period. The results for maximum eigenvalue test are similar to full sample period. Long-run relationship was also found between OMX Helsinki and industrial metals. However, there are few changes in the results of cointegration test compared to full sample period. The trace test indicates now only one cointegrating equation whereas the trace test indicated two cointegrating equations for the full sample period. Also the results of maximum eigenvalue test changed for this sub sample period indicating now one cointegrating equation for the time period 1/2000-12/2007. Overall the long-run relationship between OMX Helsinki and industrial metals seems to be pretty stable and thus there is little room for diversification opportunities among the variables.

The biggest change in the results of cointegration test compared to the full sample period is that the null hypothesis of no cointegrating equations was clearly rejected among OMX Helsinki and agricultural commodities. Both trace test and maximum eigenvalue test indicate one cointegrating equation. According to trace test, the null hypothesis of at most 1 cointegrating equation is also close to 95% confidence level. The change in the dynamics between OMX Helsinki and agricultural commodities might be due to financialization of commodities in early 2000s (see Tang & Xiong (2012)). Next, VECM is employed for agricultural commodities, energy commodities and industrial metals while unrestricted VAR is employed for precious metals.

Table 13. Johansen cointegration test. Period 1/2000-12/2007.

Trace test					
Group	No. of CE(s)	Eigenvalue	Trace Statis-tic	5% Critical Value	Prob.
Agriculturals	None	0.453932	181.5509	159.5297	0.0018*
	At most 1	0.338440	124.6797	125.6154	0.0569
Energy	None	0.296027	63.75756	47.85613	0.0008*
	At most 1	0.189139	30.76207	29.79707	0.0386*
	At most 2	0.108471	11.05412	15.49471	0.2082
Industrial metals	None	0.427312	140.3034	125.6154	0.0047*
	At most 1	0.271558	87.90657	95.75366	0.1534
Precious metals	None	0.161130	41.02889	47.85613	0.1878

Maximum Eigenvalue test					
Group	No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5% Critical value	Prob.
Agriculturals	None	0.453932	56.87117	52.36261	0.0162*
	At most 1	0.338440	38.83656	46.23142	0.2481
Energy	None	0.296027	32.99550	27.58434	0.0091*
	At most 1	0.189139	19.70794	21.13162	0.0781
	At most 2	0.108471	10.79281	14.26460	0.1649
Industrial metals	None	0.427312	52.39688	46.23142	0.0098*
	At most 1	0.271558	29.78370	40.07757	0.4381
Precious metals	None	0.161130	16.51574	27.58434	0.6217

** indicates cointegrating equation(s) at the 5% level*

4.2.3. VECM and VAR

First, the result of VECM for OMX Helsinki and energy commodities are presented in the Table 14. When OMX Helsinki is the dependent variable the coefficient of speed of adjustment has correct sign and it is statistically significant at 10% level. However, the speed back to the equilibrium is very slow. Also the coefficient of the speed of adjustment is highly significant when gasoline is dependent variable. However, the coefficient has wrong sign. The results of the first sub period differ to the full sample period in that sense that there is no short-run relationship running from OMX Helsinki to energy commodities. There is also lack of short-run relationship running from energy commodities to OMX Helsinki. The coefficient of Brent oil is very close to significance at 10% level.

Table 14. VECM for OMX Helsinki and energy commodities. Period 1/2000-12/2007.

VECM	D(OMX)	D(Brent)	D(Gas)	D(WTI)
CointEq1	-0.023659 (0.01366) [-1.73197]*	0.019536 (0.01790) [1.09158]	0.068104 (0.02028) [3.35814]***	0.003704 (0.01502) [0.24655]
D(OMX(-1))	0.194878 (0.10136) [1.92259]*	0.131161 (0.13280) [0.98767]	-0.075853 (0.15048) [-0.50406]	0.046109 (0.11148) [0.41362]
D(Brent(-1))	-0.341388 (0.20656) [-1.65272]	-0.308850 (0.27062) [-1.14125]	0.377472 (0.30667) [1.23089]	0.040384 (0.22717) [0.17777]
D(Gas(-1))	0.046988 (0.10481) [0.44833]	0.141594 (0.13731) [1.03119]	0.116257 (0.15560) [0.74716]	0.027013 (0.11526) [0.23435]
D(WTI(-1))	0.126180 (0.26436) [0.47731]	0.008886 (0.34634) [0.02566]	-0.451708 (0.39247) [-1.15094]	-0.157739 (0.29073) [-0.54256]

****, **, * denotes significance at 1%, 5% and 10% level, respectively. Standard errors in ( ) & t-statistics in [ ]*

In the case of industrial metals it can be seen that the coefficient of speed of adjustment is not significant when the dependent variable is OMX Helsinki. The results of VECM are presented in the Table 15. The results indicate that series can wander long time apart from their equilibrium value. The speed of adjustment is again significant among four industrial metals but sign is not correct as it was during the full sample period. Furthermore, the short-run relationships running from OMX Helsinki to industrial metals have declined from five to three. Also the negative short-run relationship from nickel to OMX Helsinki has disappeared. Similarly the number of short-run relationship is smaller during the first sub sample than full sample period among the industrial metals indicating that the financialization of commodities start to affect during the second sub period and/or financial crisis cause the interdependence between industrial metals.

The biggest change to the results of the first sub period compared to full sample period was that cointegration between OMX Helsinki and agricultural commodities were found. The results are presented in the Table 16. The speed of adjustment coefficient is highly significant when coffee, corn or soybeans are dependent variable. However, the sign is not correct. Similarly, the sign is not correct when OMX Helsinki is dependent variable. In addition, the results show that the negative short-run relationship running from cocoa to OMX Helsinki has disappeared. The results also show that there are more short-run relationships among the agricultural commodities during the first sub sample compared to the full sample period. This might be due to financialization of commodities which have occurred faster than among the industrial metals.

Finally, the results of VAR model for precious metals for the first sub sample are presented in the Table 17. There are few changes in the results compared to the full sample period. First, positive short-run relationship running from OMX Helsinki to platinum was found. Also the short-run relationship from OMX Helsinki to silver is very close to significance at 10% level. In addition, it was found that there is negative short-run relationship running from platinum to gold at 10% level.

Table 15. VECM for OMX Helsinki and industrial metals. Period 1/2000-12/2007.

	D(OMX)	D(Al)	D(Cu)	D(Pb)	D(Ni)	D(Sn)	D(Zn)
CointEq1	-0.027917	0.005375	0.070686	0.058654	0.010517	0.042772	0.128292
	(0.02967)	(0.01662)	(0.02284)	(0.02861)	(0.03916)	(0.02150)	(0.02316)
	[-0.94098]	[0.32330]	[3.09524]***	[2.04977]**	[0.26858]	[1.98963]**	[5.54050]***
D(OMX(-1))	0.258789	0.198330	0.211291	0.101435	0.238008	0.135859	0.130257
	(0.10989)	(0.06158)	(0.08459)	(0.10599)	(0.14504)	(0.07963)	(0.08577)
	[2.35499]**	[3.22080]***	[2.49786]**	[0.95702]	[1.64097]	[1.70619]*	[1.51871]
D(Al(-1))	-0.419800	-0.100852	-0.292005	-0.083468	0.066987	-0.229412	-0.186090
	(0.25534)	(0.14308)	(0.19655)	(0.24628)	(0.33702)	(0.18503)	(0.19929)
	[-1.64406]	[-0.70484]	[-1.48562]	[-0.33891]	[0.19876]	[-1.23990]	[-0.93374]
D(Cu(-1))	0.067512	0.001638	0.208691	-0.213266	-0.070557	0.003876	0.069634
	(0.18232)	(0.10216)	(0.14034)	(0.17585)	(0.24064)	(0.13211)	(0.14230)
	[0.37030]	[0.01603]	[1.48703]	[-1.21278]	[-0.29321]	[0.02934]	[0.48936]
D(Pb(-1))	-0.035336	-0.009773	-0.031027	0.213458	-0.239519	0.162075	-0.031415
	(0.12689)	(0.07111)	(0.09768)	(0.12239)	(0.16749)	(0.09195)	(0.09904)
	[-0.27847]	[-0.13744]	[-0.31765]	[1.74405]*	[-1.43008]	[1.76266]*	[-0.31719]
D(Ni(-1))	-0.069832	-0.103742	-0.119055	-0.108544	0.024798	-0.137792	-0.213523
	(0.09519)	(0.05334)	(0.07327)	(0.09181)	(0.12564)	(0.06897)	(0.07429)
	[-0.73363]	[-1.94496]*	[-1.62485]	[-1.18227]	[0.19738]	[-1.99776]**	[-2.87408]***
D(Sn(-1))	0.117736	-0.095867	0.032336	0.027939	0.154494	0.240206	0.076220
	(0.16881)	(0.09459)	(0.12994)	(0.16282)	(0.22281)	(0.12232)	(0.13175)
	[0.69746]	[-1.01347]	[0.24885]	[0.17159]	[0.69340]	[1.96376]*	[0.57851]
D(Zn(-1))	0.147435	0.055526	-0.172209	-0.167894	0.012584	-0.137808	-0.033164
	(0.16532)	(0.09264)	(0.12725)	(0.15945)	(0.21820)	(0.11979)	(0.12903)
	[0.89184]	[0.59940]	[-1.35328]	[-1.05296]	[0.05767]	[-1.15042]	[-0.25703]

****, **, * denotes significance at 1%, 5% and 10% level, respectively. Standard errors in ( ) & t-statistics in [ ]*

Table 16. VECM for OMX Helsinki and agricultural commodities. Period 1/2000-12/2007.

VECM	D(OMX)	D(Coc)	D(Cof)	D(Cor)	D(SB)	D(SBO)	D(Sug)	D(Whe)
CointEq1	0.009163	-0.016778	0.120353	0.092888	0.119291	0.048513	0.046547	0.017981
	(0.03199)	(0.03163)	(0.02286)	(0.02945)	(0.02916)	(0.02945)	(0.03465)	(0.02502)
	[0.28643]	[-0.53050]	[5.26522]***	[3.15420]***	[4.09077]***	[1.64717]	[1.34352]	[0.71865]
D(OMX(-1))	0.155523	0.079726	-0.011166	-0.144344	-0.039043	-0.071806	0.088401	-0.070675
	(0.11537)	(0.11406)	(0.08244)	(0.10620)	(0.10517)	(0.10622)	(0.12494)	(0.09023)
	[1.34800]	[0.69898]	[-0.13545]	[-1.35911]	[-0.37125]	[-0.67603]	[0.70752]	[-0.78324]
D(Coc(-1))	-0.178807	0.002422	0.069380	-0.095579	-0.147625	-0.003825	0.263110	0.015810
	(0.10981)	(0.10856)	(0.07846)	(0.10108)	(0.10009)	(0.10109)	(0.11892)	(0.08588)
	[-1.62839]	[0.02231]	[0.88430]	[-0.94558]	[-1.47491]	[-0.03784]	[2.21258]**	[0.18410]
D(Cof(-1))	0.149125	-0.273228	-0.192209	0.125632	0.052442	0.067828	-0.154038	-0.075580
	(0.13872)	(0.13714)	(0.09912)	(0.12770)	(0.12645)	(0.12771)	(0.15023)	(0.10850)
	[1.07500]	[-1.99228]**	[-1.93919]*	[0.98383]	[0.41473]	[0.53110]	[-1.02535]	[-0.69662]
D(Cor(-1))	0.050617	0.093326	0.239109	0.393453	0.384181	0.056551	-0.010950	0.000975
	(0.15176)	(0.15003)	(0.10843)	(0.13970)	(0.13833)	(0.13972)	(0.16435)	(0.11869)
	[0.33353]	[0.62203]	[2.20509]**	[2.81640]***	[2.77719]***	[0.40476]	[-0.06662]	[0.00821]
D(SB(-1))	-0.205542	-0.123218	-0.052120	-0.156023	-0.288692	0.043109	0.229476	-0.021655
	(0.14437)	(0.14273)	(0.10316)	(0.13290)	(0.13160)	(0.13292)	(0.15635)	(0.11292)
	[-1.42367]	[-0.86328]	[-0.50524]	[-1.17397]	[-2.19368]**	[0.32433]	[1.46769]	[-0.19177]
D(SBO(-1))	0.035590	-0.021408	-0.060963	0.071884	-0.116162	-0.118934	-0.222515	0.079129
	(0.12635)	(0.12491)	(0.09028)	(0.11631)	(0.11517)	(0.11632)	(0.13683)	(0.09882)
	[0.28168]	[-0.17139]	[-0.67529]	[0.61805]	[-1.00862]	[-1.02247]	[-1.62622]	[0.80076]
D(Sug(-1))	-0.064976	-0.036369	0.011035	-0.067169	-0.031310	-0.004420	0.190864	-0.044380
	(0.09758)	(0.09647)	(0.06972)	(0.08983)	(0.08895)	(0.08984)	(0.10568)	(0.07632)
	[-0.66586]	[-0.37699]	[0.15827]	[-0.74776]	[-0.35199]	[-0.04920]	[1.80610]*	[-0.58150]
D(Whe(-1))	0.009552	0.175483	-0.360585	-0.202282	-0.083994	0.115301	0.110234	0.071382
	(0.15690)	(0.15512)	(0.11211)	(0.14444)	(0.14302)	(0.14445)	(0.16992)	(0.12272)
	[0.06088]	[1.13127]	[-3.21634]***	[-1.40050]	[-0.58727]	[0.79819]	[0.64873]	[0.58168]

****, **, * denotes significance at 1%, 5% and 10% level, respectively. Standard errors in ( ) & t-statistics in [ ]*

Table 17. VAR for OMX Helsinki and precious metals. Period 1/2000-12/2007.

VAR	D(OMX)	D(Au)	D(Pt)	D(Ag)
D(OMX(-1))	0.233380	0.041821	0.151972	0.141486
	(0.10638)	(0.05074)	(0.06043)	(0.08616)
	[2.19378]**	[0.82422]	[2.51468]**	[1.64206]
D(Au(-1))	0.000108	-0.132761	0.069510	0.124549
	(0.29178)	(0.13917)	(0.16576)	(0.23633)
	[0.00037]	[-0.95396]	[0.41935]	[0.52702]
D(Pt(-1))	-0.202907	-0.193341	0.030779	-0.230184
	(0.21505)	(0.10257)	(0.12217)	(0.17418)
	[-0.94352]	[-1.88492]*	[0.25194]	[-1.32151]
D(Ag(-1))	-0.046572	0.091326	-0.107582	-0.219650
	(0.17236)	(0.08221)	(0.09791)	(0.13960)
	[-0.27021]	[1.11094]	[-1.09876]	[-1.57345]

****, **, * denotes significance at 1%, 5% and 10% level, respectively. Standard errors in ( ) & t-statistics in [ ]*

4.2.4. Granger causality, impulse response and variance decomposition

The results of Granger causality test can be seen from the Table 18. The Granger causality test confirms the results of VECM and VAR for different commodity groups. In the case of OMX Helsinki and energy commodities it can be clearly seen that there is no unidirectional causality running from OMX Helsinki to energy commodities. However, unidirectional causality running from Brent oil to OMX Helsinki was detected at 10% level indicating that oil price could lead equity prices.

In the full sample period OMX Helsinki had causality with most of the industrial metals. However, during the first sub period the number of causal relationships has shrunk. For instance, bi-directional causality between OMX Helsinki and nickel was disappeared. Furthermore, the causal relationships among the industrial metals had also been declined.

The results for OMX Helsinki and agricultural commodities were quite similar compared to the full sample period. The biggest change was the lack of unidirectional causality running from cocoa to OMX Helsinki. Among OMX Helsinki and precious metals two causal relationships were found. First, unidirectional causality running from OMX Helsinki to platinum and unidirectional causality running from platinum to gold was found.

Table 18. Granger causality for the period 1/2000-12/2007.

Independent variables	Dependent variables			
Energy	OMX			
Brent	*→			
Industrial metals	Al	Cu	Sn	Zn
OMX	***→	**→	*→	
Ni	*→		**→	***→
Pb			*→	
Agriculturals	Coc	Cof	SB	Sug
Coc				**→
Cof	**→			
Cor		**→	***→	
Whe		***→		
Precious metals	Au	Pt		
OMX		**→		
Pt	*→			

****, **, * denotes significance at 1%, 5% and 10% level, respectively.*

Next, the results of impulse response test are presented in the Table 19. When examining the response of OMX Helsinki to the innovations to energy commodities, the most prominent change is that the response of OMX Helsinki to the shock to the Brent oil is negative and significant. The impact of shock even magnifies during the second period until it dies. It can be also seen that shocks to the gasoline seems to have larger impact on OMX Helsinki compared to the full sample period. In addition, shocks to WTI oil have rather big impact on OMX Helsinki but the shocks work out their way out of the system more quickly than shocks to Brent oil or gasoline.

There are also some changes occurred when examining the response of OMX Helsinki to the innovations to industrial metals. The most notable change compared to the full sample period was the response of OMX Helsinki to the shocks to aluminum. The impact is now 1,78% while it was 3,25% in the full sample period. Interestingly, the impact of shock turns to negative in the second period before it works out its way from the system. Other interesting findings were that innovations to tin and zinc magnify during the second period while they were mainly declining after the first period in the full sample period.

Table 19. Impulse response of OMX Helsinki. Period 1/2000-12/2007.

Response of OMX Helsinki	Periods				
Energy	1	2	3	4	5
Brent	-1.48	-1.77	0.16	-0.08	
Gas	1.44	0.97	-0.06		
WTI	1.51	0.13	-0.08		
Industrial metals					
Al	1.78	-1.21	0.00		
Cu	1.16	0.81	0.34	0.00	
Ni	1.73	-0.18	-0.06		
Pb	1.12	0.37	0.18	0.09	
Sn	0.32	1.09	0.45	0.06	
Zn	-0.01	0.71	-0.10	-0.15	-0.03
Agriculturals					
Coc	-1.92	-1.55	-0.01		
Cof	2.75	1.21	0.27	0.06	
Cor	0.85	-0.44	-0.18	-0.04	
SB	0.15	-1.10	0.26	-0.02	
SBO	0.59	0.46	0.30	-0.07	
Sug	0.11	-0.60	-0.13	0.00	
Whe	1.64	0.44	-0.46	-0.02	
Precious metals					
Ag	1.13	0.03			
Au	1.02	-0.46	-0.07		
Pt	1.03	-0.65	-0.13	-0.03	

The results of impulse response test show significant changes when examining the response of OMX Helsinki to the innovations to agricultural commodities. The responsiveness of OMX Helsinki to the shocks to agricultural commodities during the first sub period is mainly higher compared to the full sample period. For instance, the response to shocks to cocoa has turned highly negative and the impact lasts for two periods. Also the impact of shocks to soybeans and wheat has increased significantly.

The response of OMX Helsinki to the innovations to precious metals is rather similar when compared to the results of the full sample period. The most notable change is that the responsiveness of OMX Helsinki to the shock to platinum has declined. It also turned out that the impact of shocks to platinum turns negative during the second period. It is also notable that the shocks to silver work their way out of the system after the first period.

Next, the results of variance decomposition tests are presented in the Table 20. The variation of OMX Helsinki is mainly due to its own shocks when the variance decomposition is examined among the energy commodities. The proportion of own movements is a bit smaller compared to the full sample period. There have also occurred changes how the variation of energy commodities can explain the movements of OMX Helsinki. For instance innovations to Brent oil can account over 7% of variation of OMX Helsinki whereas corresponding figure was below 1% in the full sample period. Also the innovations to gasoline can explain larger proportion of the movements of OMX Helsinki compared to the full sample period.

Different to the results of energy sector, when examining the variance decomposition of OMX Helsinki with the industrial metals it can be seen that OMX Helsinki can account larger proportion of its movements compared to the full sample period. The corresponding proportion is now over 82% while it was below 72% in the full sample period. There is dramatic decline in the explaining power of innovations to aluminum which has declined to 10%. In addition, the proportion of copper has declined compared to the full sample period. From the other industrial metals lead and nickel account slightly larger proportion of the movements of OMX Helsinki than compared to the full sample period.

Table 20. Variance decomposition of OMX Helsinki. Period 1/2000-12/2007.

Variance decomposition of OMX Helsinki				
Energy	1	2	5	10
OMX	90.50	85.81	85.75	85.75
Brent	3.17	7.11	7.15	7.15
Gas	3.02	4.03	4.04	4.04
WTI	3.30	3.06	3.06	3.06
Industrial metals				
OMX	87.16	83.31	82.87	82.87
Al	4.56	6.00	5.97	5.97
Cu	1.96	2.62	2.75	2.75
Ni	4.35	3.95	3.93	3.93
Pb	1.82	1.81	1.86	1.86
Sn	0.15	1.67	1.93	1.93
Zn	0.00	0.65	0.70	0.70
Agriculturals				
OMX	78.72	73.04	72.57	72.57
Coc	5.21	7.78	7.73	7.73
Cof	10.72	11.56	11.58	11.58
Cor	1.02	1.16	1.20	1.20
SB	0.03	1.57	1.65	1.65
SBO	0.49	0.71	0.83	0.83
Sug	0.02	0.48	0.50	0.50
Whe	3.80	3.69	3.94	3.94
Precious metals				
OMX	95.21	94.63	94.58	94.58
Ag	1.80	1.70	1.72	1.72
Au	1.48	1.68	1.69	1.69
Pt	1.51	1.98	2.01	2.01

Similar to energy sector, when examining variance decomposition of OMX Helsinki with the agricultural commodities, the variation of OMX Helsinki which is due to its own shocks has declined in the first sub period. OMX Helsinki can account 72,5%

of its movements while corresponding figure was over 80% in the full sample period. Innovations to coffee can again account the largest proportion of the variation of OMX Helsinki. The most notable change in the results was that innovations to cocoa can now account quite large proportion of variation of OMX Helsinki. In addition, the movements of wheat can account larger proportion of the variation of OMX Helsinki compared to the full sample period while the explaining power of soybeans and soybean oil has declined.

OMX Helsinki accounts almost 95% of its variation when variance decomposition test is implemented with precious metals. The result is reasonable since it would be expected that precious metals could account larger proportions of the variation of OMX Helsinki during the crisis period which is included in the full sample period and will be covered above. Furthermore, the notable change in the results is that explanation power of platinum has declined by over 10% compared to the full sample period.

The analysis of the first sub period showed that OMX Helsinki and agricultural commodities induced long-run relationship. However that might not be stable since long-run relationship is not found in the full sample. It might be also true that agricultural commodities become more rapidly interdependent than industrial metals since more short-run relationships were captured among the agricultural commodities than among the industrial metals. Despite the fact that unidirectional causality from Brent oil to OMX Helsinki was significant only at 10% level it can be said that there is evidence for that increasing oil prices depress the stock returns in Finland during the pre-crisis period. This is also supported by the results of impulse response test and variance decomposition where the impact of Brent oil price to OMX Helsinki is significantly higher when comparing to the full sample period. Next, the same tests are performed for the second sub sample which covers the time period from 1/2008 to 12/2014.

4.3. Sub period 1/2008-12/2014

This sub period can be referred as crisis period since it includes both subprime mortgage crisis and European debt crisis. It is important to examine whether the financial crisis do have impact on the dynamics between equity and commodity markets since incorrect decisions might be fatal.

4.3.1 Correlation

The correlation coefficients for the second sub period are presented in the Table 21. It can be clearly seen that the correlation between OMX Helsinki and different commodities is significantly greater when comparing to the full sample period or to the first sub period. In this sub period the correlation between OMX Helsinki and energy commodities has turned from the first sub period’s negative correlation to positive for the crisis period. The highest correlations are with OMX Helsinki and industrial metals where five industrial metals have correlation coefficient which is greater than 0.5.

The smallest correlation coefficient is found with OMX Helsinki and gold. This low coefficient is necessary when considering gold as a safe haven. Furthermore, the correlation between different commodities is greater than in the full sample period or in the first sub period, especially within energy commodities and industrial metals.

Table 21. Correlation coefficients for the second sub period 1/2008-12/2014.

	OMX	Brent	Gas	WTI	Al	Cu	Ni	Pb	Sn	Zn	Ag	Au	Pt	Coc	Cof	Cor	SB	SBO	Sug	Whe
OMX	1.00																			
Brent	0.42	1.00																		
Gas	0.34	0.92	1.00																	
WTI	0.49	0.87	0.76	1.00																
Al	0.55	0.50	0.40	0.55	1.00															
Cu	0.57	0.65	0.59	0.67	0.73	1.00														
Ni	0.58	0.40	0.40	0.43	0.60	0.62	1.00													
Pb	0.48	0.41	0.36	0.41	0.58	0.65	0.53	1.00												
Sn	0.59	0.53	0.48	0.54	0.63	0.70	0.61	0.47	1.00											
Zn	0.57	0.42	0.35	0.48	0.66	0.78	0.56	0.67	0.56	1.00										
Ag	0.35	0.48	0.46	0.45	0.43	0.52	0.38	0.36	0.54	0.48	1.00									
Au	0.12	0.31	0.30	0.26	0.24	0.38	0.18	0.22	0.32	0.41	0.83	1.00								
Pt	0.51	0.52	0.48	0.48	0.56	0.64	0.52	0.38	0.57	0.56	0.70	0.60	1.00							
Coc	0.34	0.34	0.29	0.30	0.30	0.40	0.44	0.24	0.32	0.39	0.43	0.36	0.54	1.00						
Cof	0.28	0.42	0.42	0.37	0.31	0.37	0.31	0.30	0.33	0.40	0.46	0.42	0.45	0.48	1.00					
Cor	0.21	0.31	0.23	0.34	0.24	0.37	0.36	0.17	0.30	0.24	0.34	0.28	0.36	0.31	0.28	1.00				
SB	0.38	0.38	0.32	0.35	0.29	0.37	0.38	0.29	0.23	0.29	0.28	0.17	0.44	0.30	0.38	0.65	1.00			
SBO	0.51	0.55	0.47	0.52	0.55	0.71	0.43	0.48	0.50	0.58	0.53	0.44	0.64	0.42	0.50	0.59	0.68	1.00		
Sug	0.20	0.12	0.07	0.09	0.25	0.31	0.22	0.35	0.28	0.26	0.19	0.15	0.25	0.26	0.29	0.14	0.29	0.34	1.00	
Whe	0.26	0.25	0.22	0.19	0.26	0.32	0.34	0.22	0.22	0.30	0.33	0.32	0.42	0.34	0.44	0.63	0.57	0.62	0.19	1.00

4.3.2. Johansen cointegration

The results of the Johansen cointegration test are presented in the Table 22. Again, changes in the relationships between OMX Helsinki and different commodities have occurred. For instance, the results of the maximum eigenvalue test show no cointegration between OMX Helsinki and commodity groups. However, when the results are in conflict, the results of the trace test are preferred over maximum eigenvalue tests as mentioned earlier.

The biggest change in results of cointegration test was that OMX Helsinki and energy sector do not exhibit long-run relationship anymore. This indicates that series wander apart from each other which create opportunities in diversification. The result is surprising since it would have been expected that the series would remain cointegrated due to the high dependence on energy, especially on oil. The second reason why the result is surprising is that since these two crises were global it would be reasonable that these series would converge and thus exhibit long-run relationship.

The results of cointegration test for OMX Helsinki and industrial metals indicate one cointegrating equation among the variables. Industrial metals are the only commodity group which exhibit long-run relationship with OMX Helsinki in every sample period. This indicates that long-run relationship is stable and it provides little room for diversification between the variables.

Similar to first sub period, the agricultural commodities exhibit long-run relationship with OMX Helsinki. This implies that the long-run relationship is not stable since the full sample period does not indicate cointegration between the variables. This could refer to that OMX Helsinki and agricultural commodities share more common trends than cointegrating equations and thus the series do not exhibit long-run relationship in the full sample period.

Table 22. Johansen cointegration. Period 1/2008-12/2014.

Trace test					
Group		Eigenvalue	Trace Statistic	5% Critical Value	Prob.
Agriculturals	None	0.446766	164.8630	159.5297	0.0247*
	At most 1	0.311689	115.1371	125.6154	0.1820
Energy	None	0.212503	40.62602	47.85613	0.2009
Industrial metals	None	0.404558	138.1941	125.6154	0.0068*
	At most 1	0.363286	94.64415	95.75366	0.0595
Precious metals	None	0.173356	31.34439	47.85613	0.6480

Maximum Eigenvalue test					
Group		Eigenvalue	Max-Eigen Statistic	5% Critical value	Prob.
Agriculturals	None	0.446766	49.72581	52.36261	0.0909
Energy	None	0.212503	20.06720	27.58434	0.3365
Industrial metals	None	0.404558	43.54992	46.23142	0.0944
Precious metals	None	0.173356	15.99200	27.58434	0.6665

** indicates cointegrating equation(s) at the 5% level*

Finally, the results of cointegration test for OMX Helsinki and precious metals have remained similar regardless of the time period. Again, the null hypothesis of no cointegrating equations could not be rejected. Due to the absence of long-run relationship between OMX Helsinki and precious metals, it gives strong support for the diversification benefits among the variables. The possible use of precious metals as a safe haven will be discussed below. Next, VECM is employed for industrial metals and agricultural commodities while unrestricted VAR is employed for energy commodities and precious metals.

4.3.3. VECM and VAR

First, the results of VECM for OMX Helsinki and industrial metals are presented in the Table 23. The only case when speed of adjustment coefficient is significant is when aluminum is dependent variable. However, the sign of the coefficient is not correct. When the dependent variable is OMX Helsinki the coefficient has correct sign but the null hypothesis could not be rejected even at 10% level. It can be clearly seen that short-run relationships running from OMX Helsinki to industrial metals have shrunk to two which indicates that equities and industrial metals are not dependent on each other in the short run. However, the number of short-run relationships among the industrial metals is greater than during the first sub period indicating that financialization of commodities affect later and/or financial crises increase short-run dependencies. Especially, copper exhibits short-run relationship with most of the industrial metals.

Next, the results of VECM for OMX Helsinki and agricultural commodities are presented in the Table 24. Significant speed of adjustment coefficients were found among agricultural commodities but sign was not correct. In the case of OMX Helsinki the sign was correct but it was not significant. One short-run relationship was found running from OMX Helsinki to corn at 10% level. Furthermore, the number of short-run relationships between agricultural commodities was less than during the first sub period indicating that during the financial crisis period agricultural commodities are moving more independently in the short run.

The most surprising result in the cointegration test was that OMX Helsinki and energy commodities are not cointegrated in this second sub period. Thus, unrestricted VAR is employed and the results are presented in the Table 25. The results show positive short-run relationships running from OMX Helsinki to Brent oil and gasoline. In addition, short-run relationships running from Brent oil to gasoline and WTI oil were discovered. These findings indicate that during the crisis period the equity indices lead the energy prices which is rational for instance during the financial turmoil the equity prices drop and it lead to that the amount of investments decline and thus the demand for energy declines which depresses the energy prices.

Table 23. VECM for OMX Helsinki and industrial metals. Period 1/2008-12/2014.

VECM	D(OMX)	D(Al)	D(Cu)	D(Pb)	D(Ni)	D(Sn)	D(Zn)
CointEq1	-0.044812	0.085757	0.025957	-0.035375	0.002605	0.041892	-0.024197
	(0.03268)	(0.02588)	(0.03406)	(0.03802)	(0.04246)	(0.03186)	(0.03621)
	[-1.37122]	[3.31395]***	[0.76206]	[-0.93034]	[0.06134]	[1.31508]	[-0.66823]
D(OMX(-1))	0.094673	0.053164	0.194861	0.104118	0.358333	0.330538	0.255524
	(0.14826)	(0.11740)	(0.15453)	(0.17250)	(0.19263)	(0.14452)	(0.16428)
	[0.63856]	[0.45285]	[1.26101]	[0.60359]	[1.86018]*	[2.28720]**	[1.55546]
D(Al(-1))	0.240478	-0.027793	0.134902	0.053545	0.045245	0.013608	0.123497
	(0.20475)	(0.16213)	(0.21341)	(0.23823)	(0.26603)	(0.19958)	(0.22687)
	[1.17449]	[-0.17142]	[0.63214]	[0.22477]	[0.17007]	[0.06818]	[0.54436]
D(Cu(-1))	0.335925	0.341031	0.526388	0.817397	0.108498	0.454341	0.501840
	(0.21285)	(0.16854)	(0.22184)	(0.24764)	(0.27655)	(0.20747)	(0.23584)
	[1.57825]	[2.02345]**	[2.37279]**	[3.30068]***	[0.39233]	[2.18990]**	[2.12790]**
D(Pb(-1))	-0.100208	-0.054014	-0.089315	-0.378714	-0.065090	0.015073	-0.072279
	(0.12250)	(0.09700)	(0.12767)	(0.14252)	(0.15916)	(0.11940)	(0.13573)
	[-0.81805]	[-0.55686]	[-0.69956]	[-2.65721]***	[-0.40896]	[0.12623]	[-0.53253]
D(Ni(-1))	-0.063346	-0.131330	0.038941	0.220567	-0.074861	-0.043285	0.054721
	(0.12674)	(0.10035)	(0.13209)	(0.14746)	(0.16467)	(0.12354)	(0.14043)
	[-0.49983]	[-1.30867]	[0.29480]	[1.49582]	[-0.45462]	[-0.35039]	[0.38968]
D(Sn(-1))	0.052910	-0.029062	-0.178885	-0.256916	-0.183984	-0.151333	-0.193975
	(0.16134)	(0.12775)	(0.16816)	(0.18771)	(0.20962)	(0.15726)	(0.17876)
	[0.32795]	[-0.22749]	[-1.06381]	[-1.36866]	[-0.87769]	[-0.96230]	[-1.08509]
D(Zn(-1))	-0.148102	-0.133315	-0.374901	-0.198329	0.092884	-0.396322	-0.520111
	(0.18327)	(0.14512)	(0.19101)	(0.21323)	(0.23812)	(0.17864)	(0.20306)
	[-0.80813]	[-0.91868]	[-1.96270]*	[-0.93013]	[0.39008]	[-2.21858]**	[-2.56134]**

****, **, * denotes significance at 1%, 5% and 10% level, respectively. Standard errors in ( ) & t-statistics in [ ]*

Table 24. VECM for OMX Helsinki and agricultural commodities. Period 1/2008-12/2014.

VECM	D(OMX)	D(Coc)	D(Cof)	D(Cor)	D(SB)	D(SBO)	D(Sug)	D(Whe)
CointEq1	-0.039197 (0.02867) [-1.36733]	0.006172 (0.02669) [0.23124]	-0.031488 (0.02892) [-1.08869]	0.002080 (0.03676) [0.05659]	0.075229 (0.03454) [2.17775]**	0.023084 (0.02729) [0.84580]	0.078165 (0.03299) [2.36965]**	0.087017 (0.03415) [2.54825]**
D(OMX(-1))	0.170994 (0.13255) [1.29005]	0.060649 (0.12341) [0.49145]	-0.034785 (0.13373) [-0.26011]	0.293539 (0.16997) [1.72696]*	0.213223 (0.15972) [1.33494]	0.138488 (0.12619) [1.09741]	-0.068100 (0.15252) [-0.44650]	0.086755 (0.15789) [0.54946]
D(Coc(-1))	-0.209481 (0.14289) [-1.46606]	-0.068092 (0.13303) [-0.51184]	-0.137818 (0.14416) [-0.95598]	-0.345824 (0.18323) [-1.88736]*	-0.020666 (0.17218) [-0.12002]	0.031538 (0.13604) [0.23183]	0.144139 (0.16442) [0.87668]	-0.071996 (0.17020) [-0.42300]
D(Cof(-1))	-0.039038 (0.14077) [-0.27732]	-0.275092 (0.13106) [-2.09895]**	-0.135812 (0.14203) [-0.95623]	0.223365 (0.18052) [1.23737]	0.057988 (0.16963) [0.34185]	-0.125019 (0.13402) [-0.93282]	-0.174434 (0.16198) [-1.07689]	0.136291 (0.16768) [0.81279]
D(Cor(-1))	-0.106485 (0.13059) [-0.81540]	-0.011540 (0.12159) [-0.09491]	0.166619 (0.13176) [1.26457]	0.099932 (0.16747) [0.59673]	0.111878 (0.15737) [0.71094]	0.071996 (0.12433) [0.57907]	0.036944 (0.15027) [0.24585]	-0.153792 (0.15556) [-0.98863]
D(SB(-1))	0.022533 (0.14446) [0.15598]	0.190302 (0.13449) [1.41494]	0.094397 (0.14575) [0.64767]	-0.099040 (0.18524) [-0.53465]	-0.365596 (0.17407) [-2.10024]**	-0.110600 (0.13753) [-0.80418]	-0.119959 (0.16622) [-0.72168]	-0.092769 (0.17207) [-0.53912]
D(SBO(-1))	0.161342 (0.20662) [0.78085]	-0.021932 (0.19237) [-0.11400]	0.085719 (0.20847) [0.41118]	-0.000968 (0.26496) [-0.00365]	0.270757 (0.24899) [1.08744]	0.115016 (0.19672) [0.58467]	0.263833 (0.23775) [1.10969]	0.304234 (0.24613) [1.23609]
D(Sug(-1))	-0.009241 (0.10453) [-0.08840]	0.044641 (0.09732) [0.45868]	-0.042472 (0.10547) [-0.40270]	0.017957 (0.13405) [0.13396]	-0.010456 (0.12597) [-0.08301]	0.114355 (0.09952) [1.14904]	0.313195 (0.12028) [2.60382]**	0.083329 (0.12452) [0.66921]
D(Whe(-1))	0.021759 (0.13456) [0.16170]	-0.083492 (0.12528) [-0.66642]	-0.252342 (0.13577) [-1.85865]*	-0.053784 (0.17256) [-0.31169]	-0.066238 (0.16215) [-0.40849]	-0.031526 (0.12811) [-0.24608]	0.057507 (0.15484) [0.37140]	0.008995 (0.16029) [0.05612]

****, **, * denotes significance at 1%, 5% and 10% level, respectively. Standard errors in ( ) & t-statistics in [ ]*

Table 25. VAR for OMX Helsinki and energy commodities. Period 1/2008-12/2014.

VAR	D(OMX)	D(Brent)	D(Gas)	D(WTI)
D(OMX(-1))	0.135680 (0.12599) [1.07694]	0.393139 (0.13239) [2.96954]***	0.435222 (0.16673) [2.61033]**	0.177799 (0.13350) [1.33184]
D(Brent(-1))	0.139408 (0.31884) [0.43723]	0.707230 (0.33505) [2.11083]**	1.113821 (0.42195) [2.63968]***	0.756564 (0.33785) [2.23933]**
D(Gas(-1))	-0.091908 (0.19746) [-0.46545]	-0.282301 (0.20750) [-1.36051]	-0.675872 (0.26132) [-2.58640]**	-0.176459 (0.20923) [-0.84336]
D(WTI(-1))	0.068652 (0.20299) [0.33821]	-0.093364 (0.21331) [-0.43769]	-0.127509 (0.26864) [-0.47465]	-0.189437 (0.21509) [-0.88072]

****, **, * denotes significance at 1%, 5% and 10% level, respectively. Standard errors in ( ) & t-statistics in [ ]*

Finally the results of VAR model for OMX Helsinki and precious metals are presented in the Table 26. It can be clearly seen that the number of short-run relationship among the variables has increased tremendously. The most important finding from the results is that there is a significant negative short-run relationship running from gold to OMX Helsinki. This gives support for the belief that gold could serve as safe haven during the financial crisis. The negative coefficient shows that when gold price rises, it depresses stock returns. This evidence is in line with the studies of Baur & McDermott (2010) and Baur (2011). The results also show lagged gold return has a negative impact on current gold and platinum returns. In addition platinum has a positive short-run relationship with every variable which gives no support for that platinum could be used as hedge for equities during the crisis period.

Table 26. VAR for OMX Helsinki and precious metals. Period 1/2008-12/2014.

VAR	D(OMX)	D(Au)	D(Pt)	D(Ag)
D(OMX(-1))	0.023720 (0.13320) [0.17808]	-0.120505 (0.09446) [-1.27575]	-0.148987 (0.13561) [-1.09861]	-0.078080 (0.18534) [-0.42129]
D(Au(-1))	-0.626759 (0.29112) [-2.15293]**	-0.457456 (0.20644) [-2.21592]**	-0.581957 (0.29639) [-1.96348]*	-0.608008 (0.40506) [-1.50102]
D(Pt(-1))	0.279511 (0.16054) [1.74109]*	0.247415 (0.11384) [2.17331]**	0.422830 (0.16345) [2.58699]**	0.471366 (0.22337) [2.11022]**
D(Ag(-1))	0.172624 (0.16232) [1.06350]	0.077520 (0.11510) [0.67348]	0.169552 (0.16526) [1.02600]	0.032559 (0.22585) [0.14416]

****, **, * denotes significance at 1%, 5% and 10% level, respectively. Standard errors in ( ) & t-statistics in [ ]*

4.3.4. Granger causality, impulse response and variance decomposition

The results of the Granger causality can be seen from the Table 27. The Granger causality test shows no causality running from industrial metals to OMX Helsinki. Unidirectional causality running from OMX Helsinki to tin and nickel was detected at 5% and 10% level, respectively. In addition, unidirectional causality running from copper to most of the industrial metals and bi-directional causality between copper and zinc was detected.

For the OMX Helsinki and agricultural commodities only few causal relationships were found. For instance, OMX Helsinki can Granger cause the change of corn price at 10%. The only causal relationship which has been found in every sample period is unidirectional causality running from coffee to cocoa and the relationship is negative for the whole sample period.

The results of the Granger causality test for OMX Helsinki and energy commodities are presented next. The results show unidirectional causality running from

OMX Helsinki to Brent oil and gasoline. This result is in the line with the study of Constantin et al. (2010) which showed that changes in equity prices Granger cause changes in oil prices during the financial crisis. Furthermore, unidirectional causality running from Brent oil to WTI oil and gasoline was found.

Table 27. Granger causality for the period 1/2008-12/2014.

Independent variables	Dependent variables					
Energy	Brent	Gas	WTI			
OMX	***→	***→				
Brent		***→	**→			
Industrial metals	Al	Cu	Ni	Pb	Sn	Zn
OMX			*→		**→	
Cu	**→			***→	**→	**↔
Zn		**↔			**→	
Agriculturals	Coc	Cof	Cor			
OMX			*→			
Coc			*→			
Cof	**→					
Cor						
Whe		*→				
Precious metals	OMX	Ag	Au	Pt		
Au	**→			**↔		
Pt	*→	**→	**↔			

****, **, * denotes significance at 1%, 5% and 10% level, respectively*

Financial crisis increase the causality between the OMX Helsinki and precious metals. During the first sub period and full sample period none of the precious metals did Granger cause the changes in OMX Helsinki. During the financial crisis the situation is another. It can be seen that there is unidirectional causality running from gold and platinum to OMX Helsinki at 5% and 10% level, respectively. This result also strengthens the results of VAR model indicating that gold could serve as a safe haven during the financial crisis. In addition, bi-directional causality at 5% level between gold and platinum was found.

The results of impulse response test for OMX Helsinki are presented in the Table 28. The responsiveness of OMX Helsinki to innovations to every industrial metal seems to be increased compared to the first sub period. OMX Helsinki reacts strongly to shocks to aluminum and effects last for five periods. Furthermore, the impact of the shock is positive until it has worked out its way from the system whereas the impact of shock turned to negative after first period in the first sub sample. In addition, innovations to copper have doubled its impact on OMX Helsinki compared to the first sub period. The innovations to zinc are interesting since shocks to zinc have a large positive impact on OMX Helsinki in the first period. The impact dies in the second period while the impact turns significantly negative in the third period. Overall it seems that during the crisis period OMX Helsinki reacts more easily to the shocks to industrial metals.

Similar to shocks to industrial metals, shocks to agricultural commodities have greater impact on OMX Helsinki during the crisis period than in the first sub sample. The most prominent changes were that innovations to cocoa, soybeans and soybean oil have greater impact on OMX Helsinki than compared to the first sub sample or full sample.

The characteristics of innovations to energy commodities have also changed during the financial crisis. Especially the response of OMX Helsinki to the innovations to Brent oil has changed tremendously. The response is now significantly positive while it was negative in the first sub period. This might indicate that increase in the oil price during the pre-crisis period would depress stock prices while during the financial crises the increased oil price would indicate recovered demand which would increase the stock prices. The response of Brent oil is positive to shocks to OMX Helsinki which denotes positive unidirectional causality from OMX Helsinki to Brent oil (see Appendix 1). Also, the response of OMX Helsinki to the innovations to gasoline has changed in the second sub period. This might be due to that companies are influenced more directly by changes in gasoline prices than changes in oil prices. During the crisis period increasing fuel cost would lead to depression of stock prices.

Table 28. Impulse response of OMX Helsinki. Period 1/2008-12/2014.

Response of OMX Helsinki						
Energy	1	2	3	4	5	6
Brent	3.05	1.23	0.67	0.29	0.14	0.06
Gas	-1.27	-0.65	-0.06			
WTI	2.26	0.61	0.08			
Industrial metals						
Al	4.21	1.93	0.55	0.36	0.11	0.06
Cu	2.16	0.99	0.49	0.30	0.09	
Ni	1.89	-0.49	-0.10			
Pb	0.95	-0.93	-0.35	-0.14	-0.05	
Sn	1.61	0.51	0.07			
Zn	1.62	-0.15	-0.83	-0.13	-0.11	-0.01
Agriculturals						
Coc	2.98	-0.54	0.41	0.07		
Cof	1.34	0.41	0.21	-0.10		
Cor	0.23	-0.24	-0.14	0.04		
SB	2.29	0.86	-0.01			
SBO	2.74	1.76	0.45	0.05		
Sug	-0.04	0.19	0.22	0.15	0.04	
Whe	-0.72	0.27	0.23	0.00		
Precious metals						
Ag	1.93	1.02	0.09			
Au	0.36	-0.67	0.35	-0.02		
Pt	4.28	2.48	0.46	0.22	0.04	

The impact of innovations to precious metals on OMX Helsinki has been rather similar in every sample. The biggest changes in the crisis period were that innovations to platinum and silver have greater positive impact on OMX Helsinki than compared to first sub period. The response of OMX Helsinki to innovations to gold has remained quite small. However, the effect during the financial crisis is more persistent since it lasts now for three periods.

When examining the movements of OMX Helsinki due to its own shocks or shocks to different commodities, it can be clearly seen that the dependence on the shocks to the other variables has dramatically increased during the financial crisis. The results of variance decomposition are presented in the Table 29.

Table 29. Variance decomposition of OMX Helsinki. Period 1/2008-12/2014.

Variance decomposition of OMX Helsinki				
Energy	1	2	5	10
OMX	76.71	74.58	74.04	74.04
Brent	13.54	15.01	15.60	15.61
Gas	2.35	2.83	2.83	2.83
WTI	7.40	7.59	7.53	7.52
Industrial metals				
OMX	52.54	48.43	47.38	47.38
Al	26.26	29.01	28.95	28.95
Cu	6.92	7.64	7.92	7.92
Ni	5.28	5.15	5.05	5.05
Pb	1.33	2.38	2.52	2.52
Sn	3.82	3.84	3.77	3.77
Zn	3.86	3.56	4.42	4.42
Agriculturals				
OMX	65.54	62.46	61.96	61.96
Coc	12.73	12.09	12.22	12.22
Cof	2.59	2.59	2.64	2.64
Cor	0.08	0.14	0.17	0.17
SB	7.54	7.90	7.87	7.87
SBO	10.78	13.98	14.14	14.14
Sug	0.00	0.05	0.14	0.15
Whe	0.75	0.78	0.85	0.85
Precious metals				
OMX	65.78	58.83	58.52	58.52
Ag	5.74	6.57	6.55	6.55
Au	0.20	0.81	0.97	0.97
Pt	28.28	33.80	33.96	33.96

During the financial crisis the movements of industrial metals can explain a larger proportion of the movements of OMX Helsinki than OMX Helsinki can explain itself. In the first period 52,5% of the variation of OMX Helsinki is due to its own shocks. When moving forward in the forecasting horizon, the proportion declines to only 47,38%. The explaining power of aluminum has increased tremendously compared to the first sub period or full sample period. During the financial crisis it can account almost 30% of the variation of OMX Helsinki. Also the movements of copper can account much larger proportion of the movement compared to first sub period.

Interesting changes in the results of variance decomposition for OMX Helsinki and agricultural commodities have occurred during financial crisis. The variation of OMX Helsinki which is due to its own shocks has declined to 62% while the proportion was 72,5% and 80,6% in the first sub period and full sample period, respectively. In addition, there have been occurred changes how the movements of agricultural commodities explain the movements of OMX Helsinki. Surprisingly, the movements of soybean oil can account over 14% of the variation of OMX Helsinki which is the greatest proportion among the agricultural commodities. Another surprise was that the explanation power of coffee has shrunk from 9-11% to 2,6%. Other commodities which proportion is significant are cocoa (12,2%) and soybeans (7,8%).

When examining the variance decomposition of OMX Helsinki with energy commodities the decline of proportion of movements which are due to own shocks is rather similar to agricultural commodities. Brent oil can account over 15% of the variation of OMX Helsinki while corresponding figures for the first sub period and full sample period were 7,1% and 0,9%, respectively. This indicates that the movements of Brent oil can explain better the movements of OMX Helsinki in the shorter sample period while WTI oil can account larger proportion of the movements of OMX Helsinki in the longer sample period. This might due to that WTI oil is used as a crude oil benchmark in the USA and it might have a direct impact on the U.S. economy. This might then reflect into Finnish stock markets in the long-run. Furthermore, the explanation power of WTI oil increased approximately to the same value as it was in the full sample period.

The one of the major changes in the results of the variance decomposition for OMX Helsinki has occurred with precious metals. In the end of the forecasting horizon OMX Helsinki can account 58,5% of its own variation while corresponding figures for the first sub period and full sample period were 94,5% and 81,6%, respectively. The explaining power of the innovations to gold is still small and it even has shrunk little when compared to the other sample periods, which gives support for gold acting as safe haven. The variation of platinum can account almost 34% of the variation of OMX Helsinki. The difference between the figures of gold and platinum might be due to their different purpose of use.

5. Conclusions

This master's thesis analyses the long-run and short-run dynamics between Finnish stock market and various commodities. OMX Helsinki total return index is used as a proxy for Finnish stock market. Commodities are grouped into four sectors in order to see which types of commodities affect most to the Finnish stock market or vice versa. Time period used in this thesis is 1/2000-12/2014 which covers pre-crisis period of early 2000's where commodity prices boomed up and recent financial crises. Analyses were made for the full sample period as well as to two sub-samples which can be referred as pre-crisis period and financial crisis period. The division into two sub-samples was made since it is important to know whether the dynamics between Finnish stock markets and commodities change under different market conditions.

The methodology utilized in this thesis is widely used in existing literature. However, the existing literature rarely examines simultaneously both short-run and long-run dynamics. In addition impulse response and variance decomposition are absent in some studies. In this thesis long-run relationship is tested with Johansen cointegration test. If long-run relationship existed, VECM model was employed to examine speed of adjustment back to equilibrium and short-run dynamics. If cointegration was not detected, an unrestricted VAR was employed to examine short-run dynamics. In order to see the direction of causality in the short-run, Granger causality test was used. Impulse response and variance decomposition were used to strengthen the results of Granger causality test.

The first research question was:

1. Is there long-run relationship between Finnish stock market and commodities?

The most stable long-run relationship is found between OMX Helsinki and industrial metals since cointegration was found in every sample period. This leaves a little room for diversification and industrial metals should not be included into a portfolio when hoping to gain diversification benefits. The results of cointegration test between OMX Helsinki and agricultural commodities are interesting. They do not exhibit long-run relationship in the full sample period. However, long-run relationship was found in both sub-samples. This implies that the long-run relationship is not stable or it could be considered as a medium-run relationship. The results might be also due to common trends which are not covered in this thesis. The results indicate that there might be diversification benefits between Finnish stock market and agricultural commodities since the variables are not completely integrated.

The long-run relationship between Finnish stock market and energy commodities is not as stable as the long-run relationship between Finnish Stock market and industrial metals. Cointegration was found in the full sample period and in the first sub-sample. However, no cointegration was detected during the financial crisis period. This implies that during the financial turmoil stocks and energy commodities do not converge with each other in the long-run. The results indicate that there are diversification opportunities during the crisis period. However, cointegration was found in the full sample period which covers the financial crisis and hence the results have a small discrepancy. Hence, the diversification between stocks and energy commodities in the long run is not effective.

The best diversification benefits among the commodities and stocks can be achieved by including precious metals into portfolio. This is evident from the results since no long-run relationship was detected between Finnish stock market and precious metals in none of the sample periods. There is also evidence that gold could act as a safe haven during the financial crisis since significant negative short-run relationship is running from gold to Finnish stock market. This is also confirmed by the results of the Granger causality test, impulse response and variance decomposition.

The second research question was:

2. Is there short-run relationship between Finnish stock market and commodities?

When analyzing short-run dynamics between Finnish stock market and different commodity groups some interesting results were found. In the full sample period there is a short-run relationship from Finnish stock market to energy commodities and industrial metals. The causality between Finnish stock market and agricultural commodities and precious metals is almost non-existent during the full sample period which means that neither equities nor commodities can lead each other in the short-run. However, during the crisis period gold had a negative short-run relationship with OMX Helsinki indicating that rising gold prices depress stock prices. This result also gives support for the belief that gold could serve as a safe haven during the financial crises.

The third research question was:

3. What is the direction of causality between Finnish stock market and commodities? Is it unidirectional or bi-directional?

Depending on the market conditions the direction of causality might change. In the case of energy commodities during the pre-crisis there is a negative unidirectional causality running from Brent oil to Finnish stock markets which implies that increasing oil prices depress stock prices. An opposite situation is during the full sample period and crisis period where there is a positive unidirectional causality from Finnish stock market to Brent oil. This implies that positive signals in stock markets would increase the price of Brent oil.

OMX Helsinki has bi-directional causal relationship with nickel in the full sample period but the causality turns unidirectional from nickel to OMX Helsinki and from OMX Helsinki in the first sub period and second sub period, respectively. In addition direction of the causality between OMX Helsinki and platinum varies. In the first sub period causality runs from OMX Helsinki to platinum while direction is opposite in the second sub period.

The fourth research question was:

4. Are the dynamic relationships between Finnish stock market and commodities time-varying?

The long-run relationship remains stable between OMX Helsinki and industrial metals and no long-run relationship was detected between OMX Helsinki and precious metals. The long-run relationship between OMX Helsinki and energy commodities was found in the full sample period and in the first sub period. However, no long-run relationship was found during the second sub period indicating that diversification benefits could exits during the financial crises. OMX Helsinki and agricultural commodities are not completely integrated to each other since no long-run relationship was found in the full sample period. However, cointegration was found from the both sub periods which indicates that relationship between variables could be referred as medium-run relationship or the variables following same common trend.

In order to deepen the results of short-run relationship, the impulse response function and variance decomposition was employed. The impulse response function showed that shocks to variables work out their way from the system within 2-4 periods regardless of the sample period used. This means that market conditions do not play a key role on shock persistency. However, during the crisis period the shock persistency is slightly longer compared to the pre-crisis period and the full sample period. Furthermore, during the different market conditions the sign of the shock might be different. When examining the variation of Finnish stock markets due to its own shocks or shocks to commodities, it can be seen that OMX Helsinki is more independent in the full sample period and pre-crisis period than during the financial crisis. This indicates that during the financial turmoil Finnish stock markets become more dependent on shocks to different commodities, especially on industrial metals and precious metals.

This thesis makes a contribution to the existing literature by examining the dynamic relationship between Finnish stock market and commodities. Majority of the existing literature is focusing on long-run relationship between oil and stock markets and many commodities are excluded from research. In addition, studies are focused on merely either long-run or short-run relationship. More recently, the relationship between stock markets and different commodities has been examined. However, the commodities are often presented as a commodity index where a particular commodity has its own weight. This makes difficult to interpret whether a particular commodity has effect on stock markets or not. However, in this master's thesis both short-run and long-run dynamics are accounted between the Finnish stock market and wide range of different commodities under the different market conditions.

Albeit this master's thesis brings more light on the dynamics between stock markets and commodities, it also has limitations. For instance, it excludes possible common trends out of the data. Furthermore, the results of cointegration test for Finnish stock market and agricultural commodities might imply that variables follow same common trend in the sub-samples since no cointegration was detected in the full sample. In addition, from the results of impulse response function it is not determined whether the shock is demand or supply shock.

Recently, the volatility has increased in stock markets and commodity markets due to the uncertainties in Greece and China and whether the FED raises the interest rates or not. For the future research it would be interesting to investigate volatility spillovers between stock markets and commodities with the GARCH family models under the different market conditions. In addition, more research with the possible common trends could be done.

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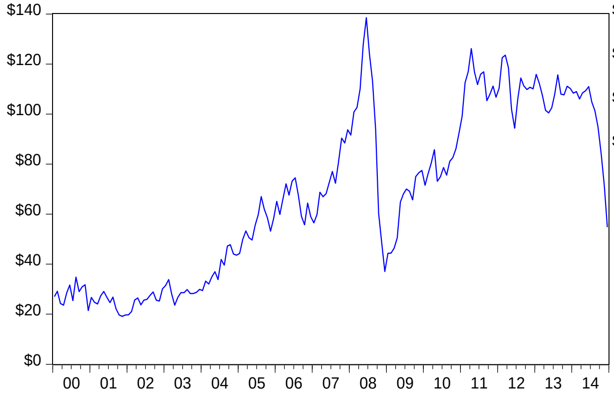
Appendices

Appendix 1. Response of Brent oil to innovations to OMX Helsinki

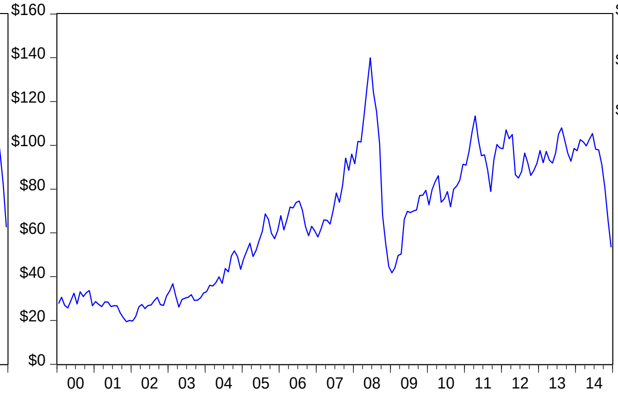
Response of Brent	Periods						
	1	2	3	4	5	6	7
Full sample							
OMX	0.00	2.62	0.37	0.12	0.01		
1/2000-12/2007							
OMX	0.00	1.14	-0.27	0.11	-0.04		
1/2008-12/2014							
OMX	0.00	2.86	1.40	0.60	0.29	0.14	0.06

Appendix 2. Graphs of the commodity prices

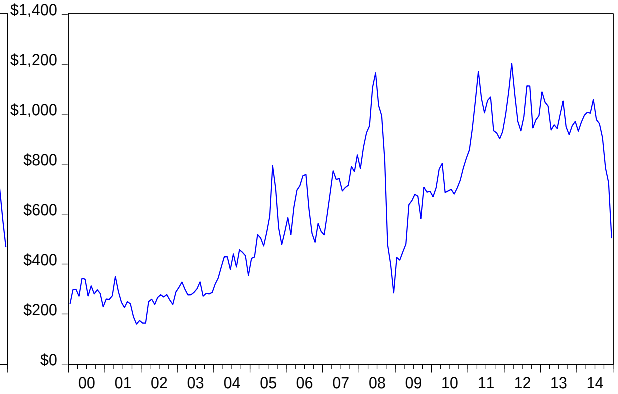
Brent
$/bbl



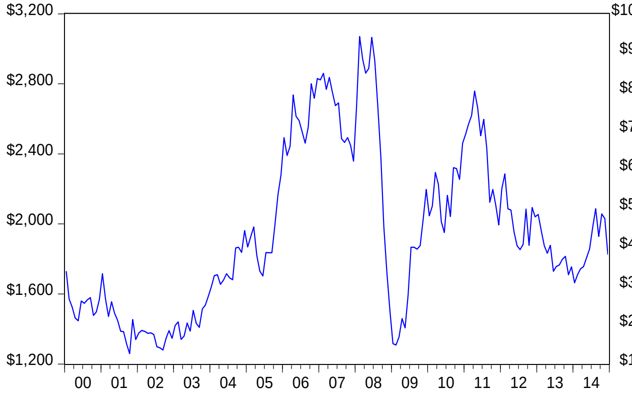
WTI
$/bbl



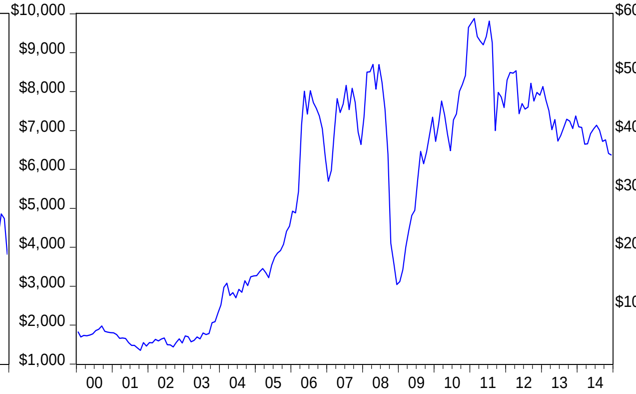
Gas
$/mt



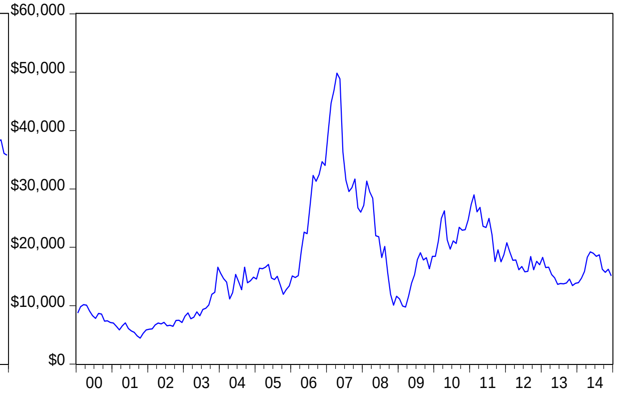
Al
$/MT

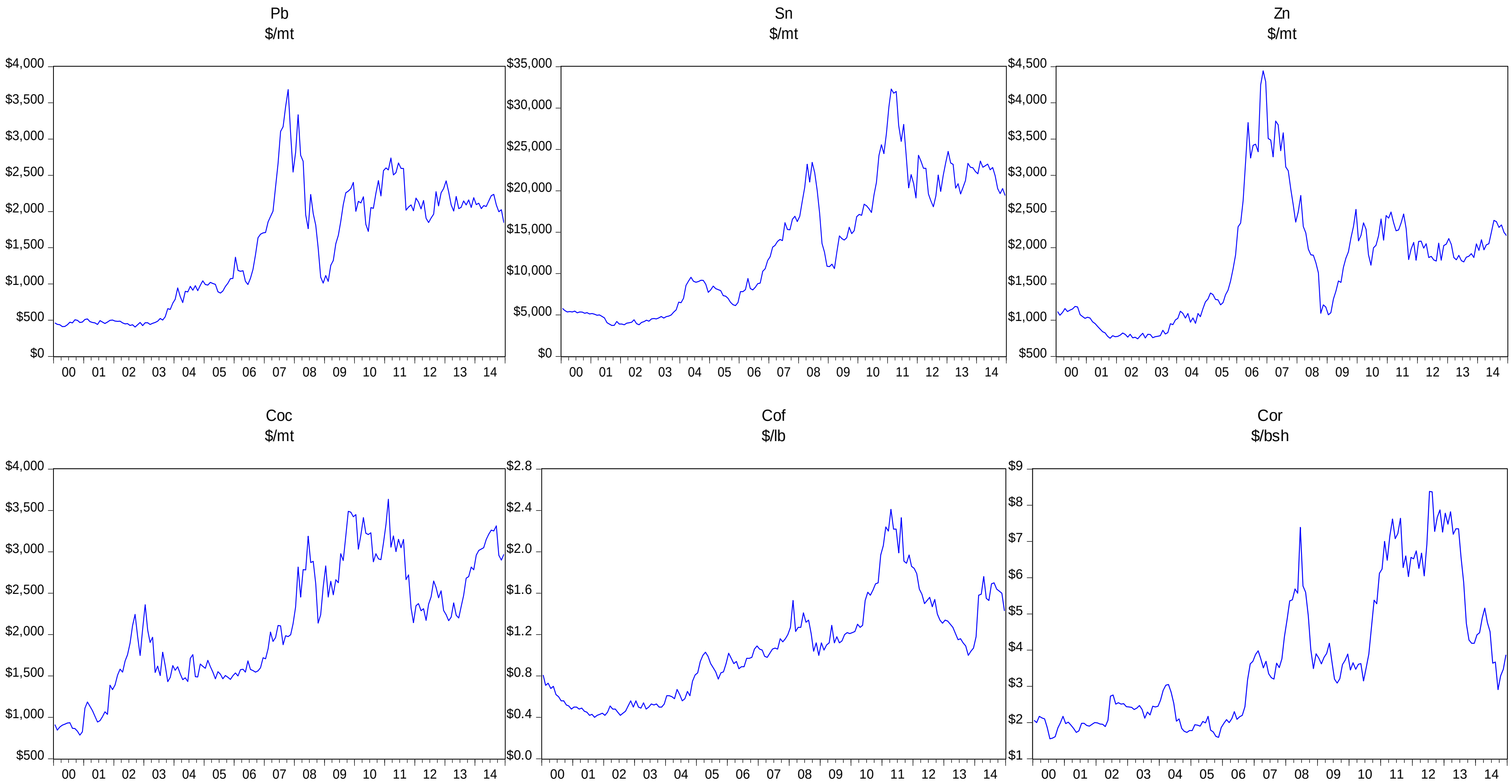


Cu
$/mt

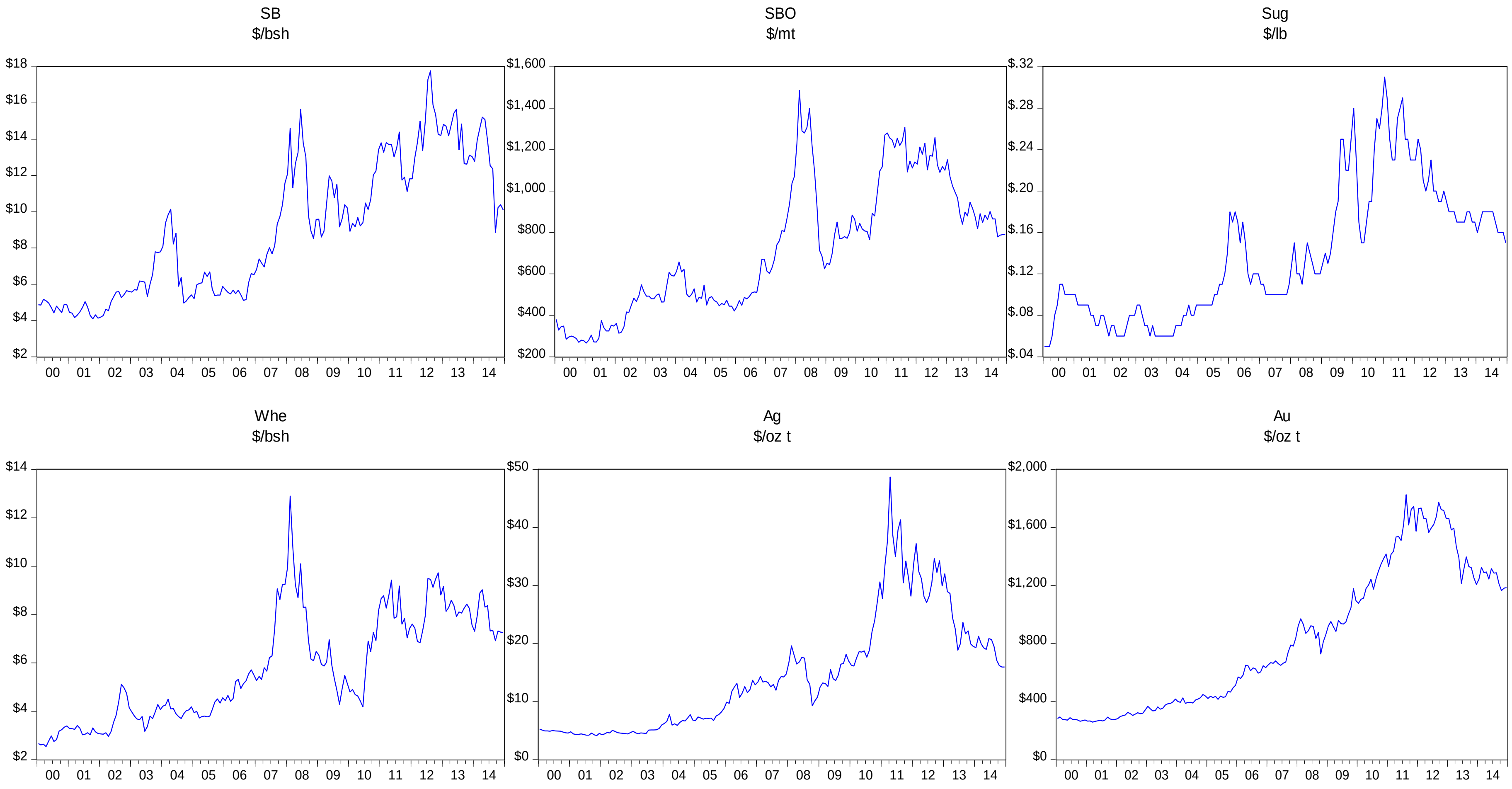


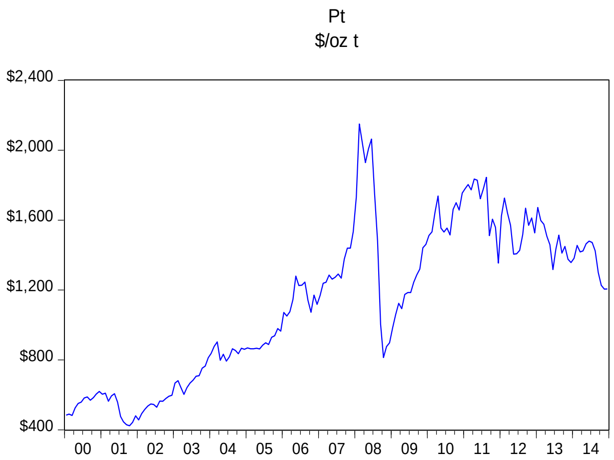
Ni
$/mt





Pb
$/mt
Sn
$/mt
Zn
$/mt
Coc
$/mt
Cof
$/lb
Cor
$/bsh
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14


SB
$/bsh
$18
$16
$14
$12
$10
$8
$6
$4
$2
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14
SBO
$/mt
$1,600
$1,400
$1,200
$1,000
$800
$600
$400
$200
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14
Sug
$/lb
$.32
$.28
$.24
$.20
$.16
$.12
$.08
$.04
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14
Whe
$/bsh
$14
$12
$10
$8
$6
$4
$2
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14
Ag
$/oz t
$50
$40
$30
$20
$10
$0
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14
Au
$/oz t
$2,000
$1,600
$1,200
$800
$400
$0
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14


Pt
$/oz t
$2,400
$2,000
$1,600
$1,200
$800
$400
00
01
02
03
04
05
06
07
08
09
10
11
12
13
14