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TITLE:

**Returns and volatility spillover effect between foreign exchange and stock market; Analysis on Norway, Sweden and Denmark**


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**Abstract**

This thesis examines the return and volatility effects between the foreign exchange and stock markets in three Scandinavian countries—Norway, Sweden, and Denmark. VAR models, Granger causality tests, impulse response functions, BEKK-GARCH(1,1) models are employed in addition to the return and volatility spillover index developed by Diebold and Yilmaz (2009) to analyze the return and volatility spillover effect within the three economies. The empirical analysis identifies a weak relationship between the two markets in the three countries. The results from the BEKK-GARCH(1,1) model suggest a bi-directional volatility spillover between the two markets. The results from the Diebold Yilmaz model suggest a bi-directional relationship as well. However, the overall results indicate that the stock market plays a more significant role than the foreign exchange market and that the spillover effects in the Scandinavian markets are asymmetrical.

## Preface

This thesis is a finishing part of my master’s degree in economics and business administration, in which I have specialized in applied finance. Writing of this thesis has been both challenging yet highly educational.

I would like to thank my supervisor, Associate Professor Siri Valseth, for her constant support and feedback during the writing of this thesis.

Additionally, I would like to express my gratitude to my family and friends who have supported me throughout my education and the writing of this thesis. Without your support and faith in me, I would not be where I am today.

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# 1. Introduction

The dynamic relationships between foreign exchange and the stock market hold interest for investors, academics, and policymakers. This paper seeks to investigate the interdependence of the stock market and exchange rate returns within the same economy. I will consider three Scandinavian countries—Norway, Sweden, and Denmark and examine the linkages between the stock market and exchange rate returns in terms of the return and volatility spillover effects within these economies. A BEKK-GARCH(1,1) model is adopted to analyze the volatility transmission between the markets along with the volatility and return spillover index introduced by Diebold and Yilmaz (2009). The level of integration, or the extent to which a certain movement in one market tends to affect the subsequent period in other markets, can significantly impact investors' decisions. Diversification can help to manage the risk of a portfolio; an investor who holds an international portfolio often uses currency as a tool for diversification. The mean-variance approach to portfolio analysis suggests that the expected return is implied by the variance of the portfolio. This requires an accurate estimate of the variability of a given portfolio, which subsequently requires an estimate of the correlation between stock prices and exchange rates. Hence, an understanding of the relationship between exchange rates and stock prices can help fund managers to manage and hedge the risk effectively (Dimitrova, 2005). International investors have to exchange their currency with domestic currency to invest in the local stock market; therefore, the linkages between the two markets can be of interest. According to Kanas (2000), a high level of cross-border equity flows creates a higher demand for and supply of currencies where international equity prices are denominated, thereby creating some degree of interdependence between the stock and foreign exchange market. International investors often face non-systematic residual international portfolio risk; positive and significant spillovers can increase this risk and hence reduce the gains from international portfolio diversification (Kanas, 2000). An understanding of the linkages between the two markets can also be beneficial for multinational corporations (MNCs) who can be vulnerable to exchange rates movements since a predominant section of their sales might be based abroad. Hence, knowledge regarding the relationship between the stock market and foreign exchange can improve MNCs' ability to manage their exchange rate exposures (Kanas, 2000).

Several studies have been undertaken on the subject of spillover effects, both between the stock markets of different countries and different markets within and between countries. A significant number of studies adopt univariate and multivariate GARCH models for investigating financial spillovers. Although there are studies conducted on Scandinavian countries, there exists a paucity of research focused on the spillover effects between the foreign exchange and stock markets within these countries.

This thesis will analyze the volatility and return spillover effect between and within three Scandinavian countries: Norway, Sweden, and Denmark. A review of the existing literature did not yield any study that focuses on these three countries, and I thought it would be informative to determine how the currency and stock market within these three countries are affecting each other. My formal research question will therefore be: How much interdependence exists between the stock and foreign exchange market within the three Scandinavian countries?

I will utilize a VAR framework and the spillover measure proposed by Diebold and Yilmaz (2009) and a BEKK GARCH(1,1)-model to examine the returns and volatility spillover between the exchange rates and stock prices of the three Scandinavian nations. The structure of this thesis is as follows: chapter 2 provides the theoretical background and literature review and chapter 3 describes the data and methodology followed. In chapter 4, the analysis is undertaken, and the concluding remarks are provided in chapter 5.

# 2. Theory and Literature

This chapter will briefly introduce the three Scandinavian countries being investigated. Furthermore, the theory pertaining to the relationship between the foreign exchange and stock market will be described and the previous studies deliberating on the relationship will be reviewed. Finally, the theory behind the return and volatility spillover index and the BEKK GARCH(1,1) models are also given in this chapter.

## 2.1 The Scandinavian Countries

The three Scandinavian countries under investigation in this thesis are Norway, Sweden, and Denmark, which are three countries that share several similarities. They have a long common history, shared cultural values, and considerably small and homogeneous populations. All of the countries have similar socio-economic models where they combine free-market capitalism with a comprehensive welfare state.

Despite such similarities, the countries are witness to some differences as well. Sweden and Denmark are both members of the European Union (EU), but none of them belong to the eurozone. Norway is not a member of the EU, but a member of the European Economic Area (EEA). Both Sweden and Norway follow a free-floating currency, while Denmark pegs its currency to the Euro.

Norway, Sweden, and Denmark, along with Finland and Iceland form the Nordic region. The Nordic countries are performing extremely well from a European perspective. The average employment rate in the region in 2017 was 76,5 % with a GDP growth rate that has outperformed the EU in 16 out of the 20 last years. This trend is forecasted to continue over the next few years (Lugaro, 2018).

Norway, Sweden, and Denmark are also a hub for innovations and as of 2017, the three countries were ranked among the higher ranks in innovation performance—this statistic is true both within the EU and globally (Lugaro, 2018). These positive aspects of the countries are some factors that make them attractive to international investors.

## 2.2 The Relationship Between Stock and Foreign Exchange Market

There are several classical theories that express the linkages between exchange rates and stock prices. The flow-oriented or microeconomic approach was proposed by Dornbusch and Fischer (1980), which in summary suggests that the exchange rate leads the stock market. This approach postulates that changes in the exchange rates affect international competitiveness and trade balances, thereby influencing real economy and output. Stock prices, typically interpreted as the present value of future cash flows, react to exchange rate changes and form the link among future income, interest rate innovations, current investment, and consumption decisions (Zhao, 2010). Gavin (1989), contrarily, argues that innovations in the stock market affect aggregate demand through wealth and liquidity effects and subsequently influence money demand and exchange rates. Stock-orientated models of exchange rates, or portfolio-balance approaches, are also available that view exchange rates as equating the supply and demand for assets such as bonds and stocks. This view allots the capital account an important role in determining exchange rate dynamics. Since the values of financial assets are determined by the present values of their future cash flows, the expectations of the relative currency values play a significant role in their price movements; this especially holds for internationally held financial assets. Therefore, stock movements innovations may affect, or be affected by, exchange rate dynamics (Ajayi & Mougoué, 1996). As evident from the empirical evidence regarding the relationship between the foreign exchange market and stock market, the relationship has been given a lot of attention. Most studies support that there is a dynamic and coexisting relationship between the markets, although the sign and direction of the relationship is not universal. By using an error correction model (ECM) on international stock market and foreign exchange, Ajayi and Mougoué (1996) observe in their study that an increase in aggregate domestic stock price has a negative short-run effect on domestic currency value and a positive effect in the long-run. Contrariwise, they show that currency depreciation has a negative short- and long-run effect on the stock market. In a study of seven East Asian countries, Pan, Fok, and Liu (2007) locate mixed relationships between the two markets before the Asian financial crisis (1997); during the crisis, however, they found that exchange rates significantly impact stock prices. Chkili and Nguyen (2014) use a regime-switching model approach and show the significant impact of stock market returns on exchange rates for all BRICS countries, except South Africa. They further indicate that it is more distinct during periods of high volatilities. Zhao (2010) conclude that a stable long-term equilibrium relationship does not exist between the two markets and that there are no mean spillovers between foreign exchange and stock markets in the Chinese market. However, he shows that there exists a bidirectional volatility spillover effect; this indicates that past innovations in the stock market have an effect on future volatility in foreign exchange market, and vice-versa.

Inci and Lee (2014) show that exchange rates significantly impact stock returns. They also find that the dynamic relationship has been more significant and stronger in the recent years.

### 2.3 Studies on the Return and Volatility Spillover Effects Between Foreign Exchange and Stock Market

Spillover effects between the two markets (foreign exchange and stock market) has been studied extensively over the years, both within economies and across different countries. Engle, Ito, and Lin (1990) propose two hypotheses—heat wave and meteor showers regarding how volatility in one market spills over to another. By examining the intra-daily exchange rate, they studied whether the volatility was confined within the same market similar to a heat wave or if it spills over to other markets. Hence, the heat wave hypothesis proposes that a volatile day in market A will probably be followed by a volatile day in A but typically not in market B. On the other hand, the meteor shower hypothesis posits that a volatile day in market A will be followed by a volatile day in market B; hence, the volatility spills over from one market to another. Yang and Doong (2004) investigated the nature of the mean and volatility transmission mechanism between stock and foreign exchange markets for the G-7 countries. The findings of the study indicate asymmetric volatility spillover effects and that the movements of stock prices will affect future exchange rate movements; however, changes in exchange rates were concluded to have less direct impact on future changes in stock prices. Kanas (2000) conducted a study on six industrialized countries (US, UK, Japan, Germany, France, and Canada) to examine the nature of volatility transmission mechanism within the same economy. Using an EGARCH model, evidence of volatility spillovers were located from stock returns to exchange rate changes for all of the countries except Germany; however, such volatility spillovers from exchange rate changes to stock returns was insignificant for all of the six countries studied (Kanas, 2000). Aloui (2007) explored the nature of the mean and volatility transmission mechanism between the stock and foreign exchange markets for the United States and some major European markets for both pre- and post-euro period. The findings of the study detect a bidirectional relationship between the two markets for both of the two subsamples. However, the findings show that stock price has a more significant effect on foreign exchange rate.

### 2.4 Previous Empirical Findings on the Scandinavian Market

The literature examined above indicate linkages between the foreign exchange market and stock market. This explains extensive studies have been conducted on the two markets. Even the interdependence in the Scandinavian markets have been studied. However, the preliminary investigations undertaken as a part of this study reveal that not so much attention has been given to the link between the foreign exchange market and stock market in the Scandinavian countries. Most studies on the Scandinavian markets have limited their focus to the interdependence between the stock markets. Booth, Martikainen, and Tse (1997) adopt an extended multivariate EGARCH model to investigate the dynamic interaction between the four Scandinavian stock markets. They found that volatility transmission is asymmetric, spillovers are more pronounced for bad than good news, each of the markets is strongly dependent on their own past values, and that the four markets are—at best—weakly related. Nielsson (2007) included two neighboring countries in the model (Iceland and Estonia) and also observed the limited interdependence between the markets.

A more recent study by Dengjun (2015) evaluates the long-run and short-run structures of interdependence between Sweden, Denmark, Norway, and Finland. The empirical findings of the study indicate the existence of two integrating relationships between the markets and that the markets are co-dependent to some extent and that there are spillover effects.

### 2.5 Return and Volatility Spillover Index

In this thesis, I will use the spillover index methodology proposed by Diebold and Yilmaz (2009). This method is based on the vector autoregressive (VAR) models and focuses on variance decompositions. This allows for aggregating spillover effects across markets, thereby distilling a wealth of information into a single spillover measure (Diebold & Yilmaz, 2009) To illustrate how the spillover index is created, the index creation below is followed as presented by Kumar (2013):

Consider a co-variance stationary first order bi-variate VAR model represented as:

$$y_t = \Psi y_{t-1} + \varepsilon_t \tag{1}$$

where $y_t = (y_{1t}, y_{2t})'$ is a $2X1$ matrix and $\Psi_i$ is a $2X2$ coefficient matrix. According to Wold's decomposition theorem, if $y_t$ is covariance stationary, the above model can be written as an infinite moving average process of its innovation process. Formally:

$$y_t = \sum_{i=1}^{\infty} \phi_i \, \mu_{t-1} \tag{2}$$

where $\phi_i$ is coefficient matrix, and $\mu_t$ is vector of white noise. The h-step-ahead forecast of $y_t$ is denoted by:

$$\hat{y}_{t+h} = \sum_{i=h}^{\infty} \phi_i \, \mu{:}\, t - i \tag{3}$$

The forecast error and its variance matrix can be calculated as:

$$y_{t+h} - \hat{y}_{t+h} = \sum_{i=0}^{h-1} \phi \, \mu_{t+h-1}$$

$$var(y_{t+h} - \hat{y}_{t+h}) \tag{4}$$

Consider $y_{1,t}$ as the first element of the $y_t$ matrix. Its h-step-ahead forecast error is given by:

$$\begin{aligned} y_{1,t+h} - \hat{y}_{1,t+h} \quad &= (\phi_{0,11}\mu_{1,t+h} + \phi_{1,11}\mu_{1,t+h-1} + \cdots \phi_{h-1.11}\mu_{1,t+1}) \\ &+(\phi_{0,12}\mu_{2,t+h} + \phi_{1,12}\mu_{2,t+h-1} + \cdots \phi_{h-1,12}\mu_{2,t+1}) \end{aligned} \tag{5}$$

and the variance of its h-step-ahead forecast error is given by:

$$\sigma^2_{y_1,h} = \underbrace{\sigma^2_{y_1}(\phi^2_{0,11} + \phi^2_{1,11} + \cdots \phi^2_{h-1,11})}_{\text{Proportion of variance due to own shock}} + \underbrace{\sigma^2_{y_2}(\phi^2_{0,12} + \phi^2_{1,12} + \cdots \phi^2_{h-1,12})}_{\text{Proportion of variance due to } y_2 \text{ shock}} \tag{6}$$

For a two variable system, hence, the total forecast variance of variable $y_{1,t}$ is equal to the sum of the variance in $y_{1,t}$ due to shocks in $y_{1,t}$ and the variance in $y_{1,t}$ due to shocks in $y_{2,t}$.

Thus, the total spillover$(TS_1)$ is given by:

$$\phi_{0,11}^2 + \phi_{1,11}^2 + \cdots \phi_{h-1,11}^2 + \phi_{0,12}^2 + \phi_{1,12}^2 + \cdots \phi_{h-1,12}^2 \tag{7}$$

Equivalently, the total spillover $(TS_2)$ of variable $y_{2,t}$ is given by:

$$\phi_{0,21}^2 + \phi_{1,21}^2 + \cdots + \phi_{h-1,21} + \phi_{0,22}^2 + \phi_{1,22}^2 + \cdots \phi_{h-1,22}^2 \tag{8}$$

Thus, the variance decomposition allows us to split the forecast error variance of each variable into parts attributable to the various system shocks. The total forecast error variation $\{trace(\phi_i\phi_i^{'})\}$, in the case of a two-variable system is given by:

$$\begin{gathered}\phi_{0,11}^2 + \phi_{1,11}^2 + \cdots \phi_{h-1,11}^2 + \phi_{0,21}^2 + \phi_{1,21}^2 + \cdots \phi_{h-1,21}^2 + \\ \phi_{0,12}^2 + \phi_{1,12}^2 + \cdots \phi_{h-1,12}^2 + \phi_{0,22}^2 + \phi_{1,22}^2 + \cdots \phi_{h-1,22}^2\end{gathered} \tag{9}$$

By expressing this spillover, i.e. the total forecast error variation relative to the total forecast error variation, it can be converted into an easily interpretable index. The ratio is represented as:

$$S = \frac{TS_i}{trace(\phi_i\phi_i^{'})} \tag{10}$$

**2.6 BEKK-GARCH Model**

This thesis will adopt a multivariate GARCH with a time varying variance-covariance BEKK model. The BEKK-GARCH(1,1) model is used because of its ability to analyze the returns and volatility linkages i.e., the returns and volatility spillover effect. It has the attractive property which suggests that the conditional covariance matrices are positive definite by construction. The BEKK-GARCH(1,1) model is an extension of the Bollerslev (1986) GARCH model that was suggested by Engle & Kroner (1995), where the number of parameters is reduced and allows interaction among conditional variances and covariance. The BEKK process allows me to examine the volatility transmission. The model below is the one presented by Kumar (2013) in his paper on the return and volatility spillover between exchange rate and stock market indices in the IBSA countries:

When extending the univariate GARCH model to an n-dimensional multivariate model, it requires the estimation of n different mean and corresponding variance equations and $(n^2 - n)/2$ covariance equations. Our interest is the time-varying covariance matrix, and the mean equation is defined as:

$$r_t = \mu + \varepsilon_t, \quad \varepsilon_t | \Omega_{t-1} \sim N(0, H_t) \tag{11}$$

where $r_t$ is a vector of appropriately defined returns and $\mu$ a $(N * 1)$ is the vector of the parameters that estimates the mean of the return series. The residuals vector is $\epsilon_t$, with the corresponding conditional covariance matrix $H_t$ given the available information set $\Phi_{t-1}$. The covariance matrix of the unrestricted BEKK model in bi-variate case is represented as:

$$H_t = B'B + C'\epsilon_{t-1}\epsilon'_{t-1}C + G'H_{t-1}G \tag{12}$$

where $H_t$ is the conditional covariance matrix and $B$ denotes the $2\ X\ 2$ upper triangular matrices. The above equation indicates that the covariance matrix is guaranteed to be a positive definite as long as $B'B$ is positive definite. The element $C_{ij}$ of the $2\ X\ 2$ matrix C indicates the impact of market $i$ volatility on market $j$ and reflects the ARCH effect of volatility. The element $G_{ij}$ of the $2\ X\ 2$ matrix G indicates the persistence of volatility transmission between market $i$ and market $j$ and reflects the GARCH effect of volatility (Kumar, 2013). The total estimated parameters in the bi-variate BEKK-GARCH(1,1) model are 11 and can be written as:

$$\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} b_{11,t} & b_{12,t} \\ b_{21,t} & b_{22,t} \end{bmatrix}' \begin{bmatrix} b_{11,t} & b_{12,t} \\ b_{21,t} & b_{22,t} \end{bmatrix} + \begin{bmatrix} c_{11,t} & c_{12,t} \\ c_{21,t} & c_{22,t} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}, \varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}, \varepsilon_{1,t-1} & \varepsilon_{2,t-1} \end{bmatrix} \begin{bmatrix} c_{11,t} & c_{12,t} \\ c_{21,t} & c_{22,t} \end{bmatrix} + \begin{bmatrix} g_{11,t} & g_{12,t} \\ g_{21,t} & g_{22,t} \end{bmatrix}' \begin{bmatrix} g_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{bmatrix} \begin{bmatrix} g_{11,t} & g_{12,t} \\ g_{21,t} & g_{22,t} \end{bmatrix} \tag{13}$$

where $h_{11,t}$ denotes the variance of the change rate of stock index returns, $h_{12,t}$ denotes the covariance of the change rate of stock index and exchange rate returns, and $h_{22,t}$denotes the variance of exchange rate returns. When testing for the volatility spillover effects from the *stock market* to *foreign exchange market*, the coefficients $c_{12}$ and $g_{12}$ are tested to be statistically significantly different from zero. When testing for the volatility spillover effects from the *foreign exchange market* to the *stock market*, the coefficients $c_{21}$ and $g_{21}$ are tested. If the non-diagonal elements $c_{21}$, $g_{21}$, $c_{12}$, and $g_{12}$ of matrices $c$ and $g$ are not statistically significantly different from zero, there are no volatility spillover effects between the foreign exchange and stock markets. I will use the package mgarchBEKK (Schmidbauer, Roesch, & Tunalioglu, 2016) in R version 1.1.463 (R Core Team, 2018) to estimate the BEKK-GARCH(1,1) model.

## 3. Data and Methodology

This thesis analyzes the return and volatility spillover effects in the three Scandinavian countries Norway, Sweden, and Denmark. The stock market is represented by the Oslo Børs Benchmark index (OSEBX), Stockholm index (OMXS30), and Denmark index (OMXC20). The foreign exchange market is represented by the NOK/USD, SEK/USD, and DKK/USD. The data consists of daily observations made between October 2005 to December 2019. Data for the three stock indices is collected from DataStream (Eikon, 2019), and the foreign exchange rates are collected from Norges Bank (Bank, 2019), Sveriges Riksbank (Riksbank, 2019), and Denmark's Nationalbank (Nationalbank, 2019). The daily observations only include the days when both the markets are open for trading; for example, OSEBX is closed for trading on New Year's eve but the foreign exchange is not. Resultantly, the data for days when no trading was done in one market is eliminated. According to Hamao, Masulis, and Ng (1990), this processing method does not affect the results.

### 3.1 Returns

In this thesis, I will use logarithmic returns which is defined as and can be observed as the continuous compounded market return:

$$r_t = ln(\frac{P_t}{P_{t-1}}) = lnP_t - lnP_{t-1} \tag{14}$$

where $P_t$ is the price of an asset at time $t$.

Figure 1 plots the daily returns for each market. It can be observed that the series volatilities do not remain constant over time and that high returns tend to be followed by high returns and low returns tend to be followed by low returns. This is in accordance with the volatility clustering property.

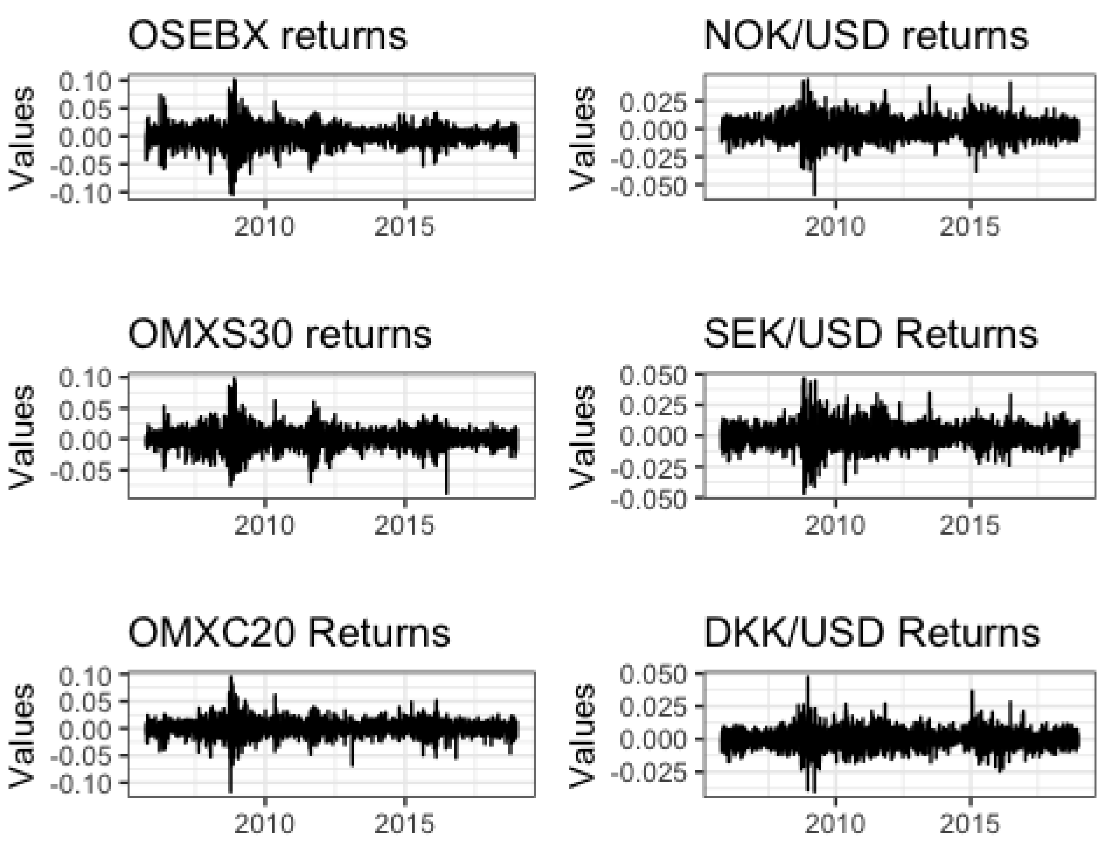


*Figure 1* - Plots of daily returns for each market

## 3.2 Volatility

To study the volatility spillover effects in the spillover index,  a measure of the volatility must be recorded. According to Kuepper (2019), volatility is *"a statistical measure of the dispersion of returns for a given security or market index. In most cases, the higher the volatility, the riskier the security."* Volatility can be calculated in several different ways; perhaps the most common way is by using the standard deviation of the asset returns. This thesis, however, uses the method followed by Antonakakis, Cunado, Filis, Gabauer, and Perez de Garcia (2018); these researchers define price volatility as the absolute return:

$$V_{i,t} = |lnP_{t-1} - lnP_t| \tag{15}$$

A detailed discussion of the advantages of using absolute return as a measurement of volatility can be found in the paper by Forsberg and Ghysels (2007).

It is evident from the plots of volatility in Figure 2 that all markets share some common peaks and troughs in their volatilities, with the most striking peaks being exhibited during the financial crisis period 2007–2009.

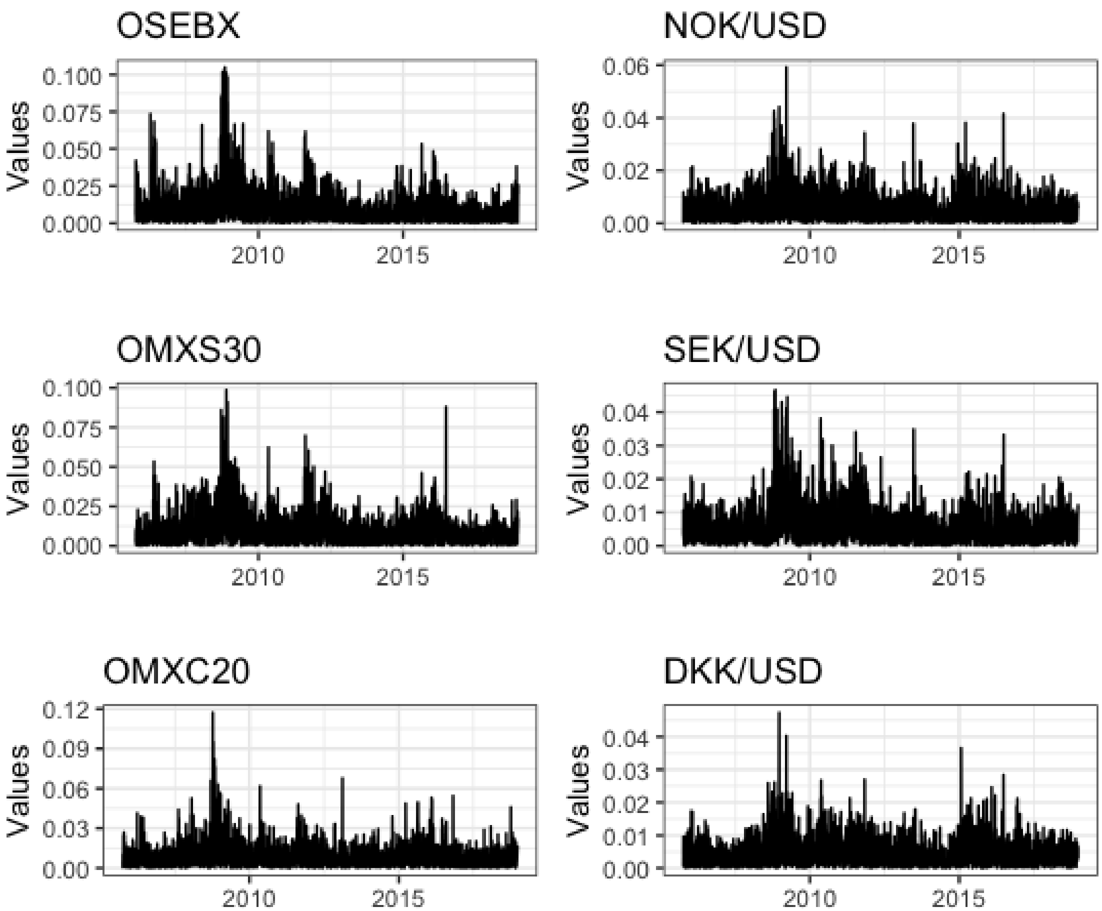


*Figure 2* - Volatility (absolute returns)

### 3.3 Descriptive Statistics of Returns

Table 1 below shows the descriptive statistics on the returns from the three markets. It can be observed from the standard deviation that the indices OSEBX are more volatile than the two other indices and that among the foreign exchange, the Norwegian and Swedish krona is almost as volatile and slightly more volatile than the Danish krona.

Analyzing the skewness and kurtosis, it can be seen that all of the series has excess kurtosis; this indicates fat tails and a leptokurtic distribution. The three indices are negatively skewed and OSEBX seems to be more skewed than the other two. Among the foreign exchange, it can be seen that they are all positively skewed and all three of the currency pairs seem to have approximately the same level of skewness. The descriptive statistics suggest that all the time series are skewed and show high kurtosis—this is common in financial time series. The Jarque-Bera statistics reject the null hypothesis of Gaussian distribution in all cases.[1]

***Table 1*** *- Descriptive Statistics*

| | Norway | | Sweden | | Denmark | |
|---|---|---|---|---|---|---|
| | OSEBX | NOK/USD | OMXS30 | SEK/USD | OMXC20 | DKK/USD |
| Mean | 0,00027 | 8,26e-05 | 0,00013 | 4,29e-05 | 0,000267 | 1,26e-05 |
| SD | 0,01539 | 0,00784 | 0,01382 | 0,00786 | 0,01309 | 0,00610 |
| Skewness | -0,54823 | 0,05879 | -0,03013 | 0,22672 | -0,28690 | 0,18232 |
| Kurtosis | 9,78123 | 6,25749 | 9,15266 | 6,86891 | 8,02385 | 6,92328 |
| Excess Kurtosis | 6,77535 | 3,25373 | 5,01903 | 3,86478 | 6,14712 | 3,91910 |
| Jarque-Bera | 6539,5 | 1472,5 | 3499,3 | 2103,5 | 5264,7 | 2140,5 |
| No of observations | 3326 | | 3327 | | 3309 | |

### 3.4 Stationarity

An important assumption made when working with time series data is that the data are stationary. A time series is an example of a stochastic process, which is a sequence of random variables ordered in time. If the time series is nonstationary, its behavior can only be studied for the period under consideration; each time series will, therefore, be a particular episode. Resultantly, it cannot be generalized to also accommodate other time periods. Nonstationary time series can also lead to spurious regression, thereby implying that a high $R^2$ value might be obtained and some or all of the regression coefficients may be statistically significant on the basis of the usual $t$ and $F$ tests. Tests undertaken with nonstationary time series are not reliable since they assume that the underlying time series is stationary (Gujarati, 2011).

Time series data is said to be strictly stationary if for any values of $(j_1, j_2, j_3, \dots, j_n)$, the joint destribution of $(y_t,\ y_{t+j_1},\ y_{t+j_2},\ y_{t+j_3}, \dots,\ y_{t+j_n})$ depends only on the intervals separating the dates $(j_1, j_2, j_3, \dots, j_n)$ and not the date itself $(t)$. If neither the mean $(\mu)$ nor the covariances $cov(y_t,\ y_{t-j})$ depend on the date $(t)$, then the precess for $y_t$ is said to be weakly stationary (Bjørnland & Thorsrud, 2014):

[1] Jarque-Bera is a test of normality. In the JB-test, the null hypothesis: $H_0$: skewness and kurtosis is zero, normal distribution is tested against the alternative hypothesis $H_1$: non-normal distribution (Belasri & Ellaia, 2017).

$$E[y_t] = \mu \quad (16)$$

$$E[(y_t - \mu)(y_{t-j} - \mu)] = cov(y_t, y_{t-j}) \quad (17)$$

for all $t$ and any $j$.

A non-stationary variable can be transformed to stationary trough differencing, if $Y_t$ follows a random walk; if $Y_t = \beta_0 + Y_{t-1} + u_t$, then $\Delta Y_t = \beta_0 + u_t$ is stationary. When using financial time series, the first difference of the data can be comprehended as the continuous compounding market return:

$$R_t = lnP_t - lnP_{t-1} \quad (18)$$

There are different ways to test for stationarity:

1. Graphical analysis
2. Autocorrelation test
3. Unit root tests

This thesis will use unit root and stationarity tests to examine whether the time series of stock indices and exchange rate in the Scandinavian countries are stationary. Two tests will be used—the augmented Dickey-Fuller (ADF) test developed by Dickey and Fuller (1981), and the KPSS-test developed by Kwiatkowski, Phillips, Schmidt, and Shin (1992). The two tests are used to complement each other.

The null hypothesis in the ADF test is $H_0\colon \phi_1 = 1$; the process contains a unit root and is therefore nonstationary and the alternative hypothesis is $H_1\colon \phi_1 < 1$, i.e., the process does not contain a unit root and is stationary. On the other hand, the null hypothesis for the KPSS test is $H_0\colon Staionary\ time\ series$ against the alternative that the time series is nonstationary.

The variables are first tested at their first level. Table 2 shows the results of the ADF and KPSS tests. Both tests indicate that all the variables are non-stationary. To avoid this, the fist-differences of each variable are generated using eq. 18, the variables are written as dOSEBX, dNOK/USD, dOMXS30, dSEK/USD, dOMXC20, and dDKK/USD.

**Table 2** - *ADF and KPSS Test Results (level)*

| | ADF test<br>*t-statistics* | KPSS test<br>*t-statistics* |
|---|---|---|
| *Norway* | | |
| OSEBX | -0,6044 | 5,6142 |
| NOK/USD | -0,7545 | 4,5629 |
| *Sweden* | | |
| OMXS30 | -1,4745 | 5,5027 |
| SEK/USD | -1,4553 | 3,0710 |
| *Denmark* | | |
| OMXC20 | -0,6053 | 6,3034 |
| DKK/USD | -1,6760 | 3,7439 |

*Note: The critical values for ADF and KPSS test at 1 % level are -3.4327 and 0.739, respectively. *** - indicates significant on 1 % level*

Table 3 presents the results from the ADF and KPSS tests on the stock-index and exchange rate returns. As can be seen in the table, based on the results of the ADF and KPSS unit root, all of the time series are stationary in their first difference and these are used further on in this thesis. For the ADF test, the absolute values of t-statistics are greater than the absolute critical value at the 1% level; furthermore, the t-statistics for the KPSS-test are smaller than the critical value at the 1% level. According to the tests, all of the time series used in this study are first difference stationary. Therefore, the cointegration test need not be performed and the models can be developed directly to check the return and volatility spillover effects.

**Table 3** - *ADF and KPSS Test (First Difference)*

| | ADF test *t-statistics* | KPSS test *t-statistics* |
|---|---|---|
| *Norway* | | |
| dOSEBX | -42,1524*** | 0,0594*** |
| dNOK/USD | -41,5652*** | 0,1927*** |
| *Sweden* | | |
| dOMXS30 | -43,7569*** | 0,0603*** |
| dSEK/USD | -42,6522*** | 0,1489*** |
| *Denmark* | | |
| dOMXC20 | -40,8185*** | 0,1055*** |
| dDKK/USD | -40,4943*** | 0,1285*** |

*Note: The critical values for ADF and KPSS test at 1 % level are -3.4327 and 0.739, respectively. *** - indicates significant on 1 % level.*

### 3.5 BEKK-GARCH(1,1) Model

To analyze the volatility spillover, three bi-variate BEKK-GARCH(1,1) equations are estimated. These can be represented by the following univariate model (Kumar, 2013):

$$\begin{aligned} h_{11,t} &= b_{11}^2 + c_{11}^2\varepsilon_{1,t-1}^2 + 2c_{11}c_{21}\varepsilon_{1,t-1} + c_{21}^2\varepsilon_{2,t-1}^2 \\ &\quad + g_{11}^2 h_{11,t-1} + 2g_{11}g_{21}h_{12,t-1} + g_{21}^2 h_{22,t-1}, \\ h_{12,t} &= b_{11}b_{12} + c_{11}c_{12}\varepsilon_{1,t-1}^2 + (c_{21}c_{12} + c_{11}c_{22})\varepsilon_{1,t-1}\varepsilon_{2,t-1} + c_{21}c_{22}\varepsilon_{2,t-1}^2 \\ &\quad + g_{11}g_{12}h_{11,t-1} + (g_{11}g_{12} + g_{11}g_{22})h_{12,t-1} + g_{21}g_{22}h_{22,t-1}, \\ h_{22,t} &= b_{21}^2 + b_{22}^2 + c_{12}^2\varepsilon_{1,t-1}^2 + 2c_{12}c_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ &\quad + c_{22}^2\varepsilon_{2,t-1}^2 + g_{12}^2 h_{11,t-1} + 2g_{12}g_{22}h_{12,t-1} + g_{21}^2 h_{22,t-1}, \end{aligned} \tag{19}$$

The model indicates that the variances and covariance of assets depend on constants, lagged squared residual ($\varepsilon_{1,t-1}^2, \varepsilon_{2,t-1}^2$), products of the lagged cross resudual ($\varepsilon_{1,t-1}\varepsilon_{2,t-1}$), lagged variances ($h_{11,t-1}, h_{22,t-1}$), and lagged covariance ($h_{12,t-1}$) term. To discover volatility spillover among or between different asset classes, it is instrumental to evaluate the impact of lagged squared and cross residuals or the effect of the lagged variance and covariance terms (Kumar, 2013). The results from the BEKK-GARCH(1,1) model is presented in Table 4

# 4. Analysis

## 4.1 VAR models

The term "spillover effect between two markets" refers to the fact that the return or volatility in one market is affected by not only its own previous movements but also by the previous movements in other markets. To initiate the analysis, VAR models are estimated for each of the three Scandinavian countries:

$$Y_t = k_0 + \sum_{i=1}^{m} k_1 Y_{t-1} + \sum_{i=1}^{m} s_j X_{t-1} + \varepsilon_t \qquad (20)$$

$$X_t = k_0 + \sum_{i=1}^{m} k_1 X_{t-1} + \sum_{i=1}^{m} s_j Y_{t-1} + \varepsilon_t \qquad (21)$$

where $Y_t$ denotes the stock market and $X_t$ denotes the foreign exchange market at time $t$. The parameter $m$ is the optimal lag length; in this thesis, the optimal lag length is determined by the Akaike Information Criterion (AIC) and has shown that optimal lag length is 1.

The models are tested for stationarity and by using AR roots table, the roots of the system can be derived. Table 4 indicates that the modulus is smaller than one, thus implying that the system is stationary.

**Table 4** - *AR Roots Table*

| | |
|---|---|
| Roots of Characteristic Polynomial<br>Exogenous variables: C<br>Lag specification: 1 2 | |
| **Norway** | |
| Endogenous variables: dOSEBX dNOK/USD | |
| Root | Modulus |
| 0,002656 - 0,158358i | 0,15837982 |
| 0,002656 + 0,158358i | 0,15837982 |
| -0,040048 - 0,049364i | 0,06356582 |
| -0,040048 + 0,049364i | 0,06356582 |
| **Sweden** | |
| Endogenous variables: dOMXS30 dSEK/USD | |
| 0,042596 - 0,259068i | 0,262546 |
| 0,042596 + 0,259068i | 0,262546 |
| -0,097770 - 0,087949i | 0,131507 |
| -0,097770 + 0,087949i | 0,131507 |
| **Denmark** | |
| Endogenous variables: dOMXC20 dDKK/USD | |
| 0,010590 - 0,156762i | 0,157120 |
| 0,010590 + 0,156762i | 0,157120 |
| 0,133567 | 0,133567 |
| -0,130796 | 0,130796 |

### 4.1.1 Granger causality test.

To gather a better understanding of how the two markets affect each other, the Granger causality test is used. The results are presented in Table 5. In the Granger causality test, the predictive ability of the independent variable to the dependent variable is tested. The null hypothesis for the test is no Granger causality against the alternative that there is granger causality.

**Table 5** - *Results of Granger Causality Tests*

| VAR Granger Causality/Block Exogeneity Wald Tests<br>Sample: 10/04/2005 12/28/2018 | | | |
|---|---|---|---|
| | Norway | | |
| | Dependent variable: dOSEBX | | |
| Excluded | Chi-sq | df | Prob. |
| dNOK/USD | 1,762804 | 2 | 0,4142 |
| All | 1,762804 | 2 | 0,4142 |
| | Dependent variable: dNOK/USD | | |
| Excluded | Chi-sq | df | Prob. |
| dOSEBX | 31,05572 | 2 | 0,0000*** |
| All | 31,05572 | 2 | 0,0000*** |
| | Sweden | | |
| | Dependent variable: dOMXS30 | | |
| Excluded | Chi-sq | df | Prob. |
| dSEK/USD | 7,949135 | 2 | 0,0188** |
| All | 7,949135 | 2 | 0,0188** |
| | Dependent variable: dSEK/USD | | |
| Excluded | Chi-sq | df | Prob. |
| dOMXS30 | 101,6700 | 2 | 0,0000*** |
| All | 101,6700 | 2 | 0,0000*** |
| | Denmark | | |
| | Dependent variable: dOMXC20 | | |
| Excluded | Chi-sq | df | Prob. |
| dDKK/USD | 1,775894 | 2 | 0,4115 |
| All | 1,775894 | 2 | 0,4115 |
| | Dependent variable: dDKK/USD | | |
| Excluded | Chi-sq | df | Prob. |
| dOMXC20 | 5,974025 | 2 | 0,0504* |
| All | 5,974025 | 2 | 0,0504* |

*Note*: ***, **, * indicates significant on 1%, 5%, and 10% respectively.

Considering the p-values, it can be observed from the results that for Norway, the change in the stock market does Granger cause the foreign exchange market, and the same occurs for Denmark; however, the changes in the foreign exchange market do not Granger cause the stock market. In the Swedish market, it can be seen that the stock market Granger cause the foreign exchange market and that the foreign exchange market is the Granger cause for the stock market. These results indicate that there only exists a unidirectional spillover effect from the stock market to the foreign exchange market in Norway and Denmark, and a bi-directional spillover effect in Sweden.

### 4.1.2 Impulse response function.

Next, the impulse response function (IRF) is analyzed to reveal the VAR models' reaction to the shocks. The IRF examines the reaction of the dependent variable when one standard deviation shock occurs in the residual. Figure 3 presents the plots for the entire sample period for the three Scandinavian countries and the two markets. As can be observed from the graphs, the stock market shows no reaction to a one standard deviation shock from the foreign exchange market. On the other hand, looking at the foreign exchange market in all of the three countries, the foreign exchange market reacts negatively to the innovations from the stock market. In Norway, the foreign exchange market reacts negatively to the innovation of OSEBX for two periods. The foreign exchange market in Sweden reacts negatively to innovations from the stock market for three periods and in Denmark, the foreign exchange market is observed to react negatively for only one period.

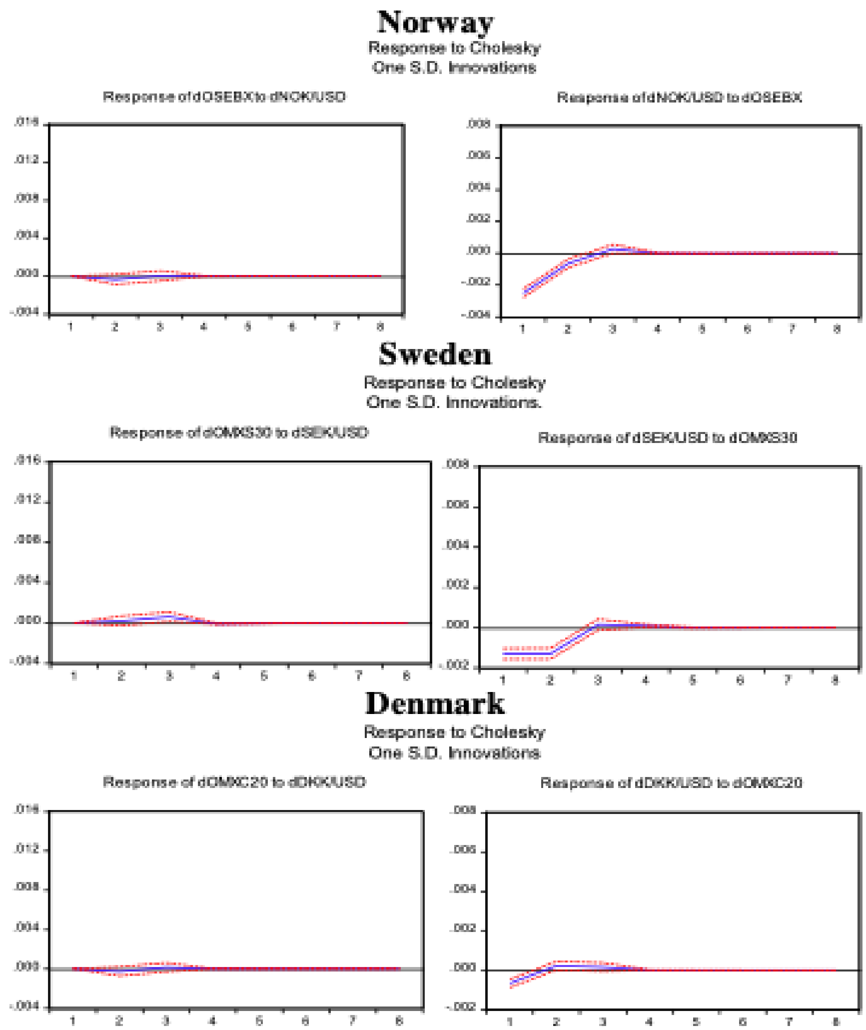


*Figure 3 - Impulse responses*

Above results of Granger causality tests and IRF are all results of the entire sample period. However, in appendix 1 and 2, results of three different subsamples are presented. As can be seen from these results, they are quite similar to the results from the entire sample period. Given this information the rest of this thesis will use the entire sample period for the rest of this analysis.

### 4.2 Returns and Volatility Spillover Index

In addition to the BEKK-GARCH(1,1), the return and volatility spillover indices proposed by Diebold and Yilmaz (2009) is used to analyze the spillover effects between the two markets in the countries being studied. Table 4 shows the spillover index for returns and Table 5 reports the spillover index for volatility.

Optimal lag-length for the VAR model is determined by the Akaike Information Criterion (AIC) and following Diebold and Yilmaz (2009) the 10-step-ahead forecasts error variance decomposition associated with the two variables are analyzed.

Contribution from others is the estimated contribution *to* the forecast error variance of market *m* (returns in Table 4, volatility in Table 5) emerging *from* market *n.* The numerator of the spillover index (eq. 10) is given by the sum total of the cells in the contribution from the others column or that of the contribution to the others row. The denominator of the spillover index is given by the sum total of the cells in the contribution, including its own row.

**Table 6** - *Returns Spillover index*

| | Norway | | |
|---|---|---|---|
| | dOSEBX | dNOK/USD | *Contribution from others* |
| OSEBX | 99,95 | 0,05 | 0,05 |
| NOK/USD | 11,03 | 88,97 | 11,03 |
| *Contribution to others* | 11,03 | 0,05 | 11,08 |
| *Contribution including own* | 110,98 | 89,02 | Total spillover index= 5,54 |
| *Net spillover* | 10,98 | -10,98 | |
| | **Sweden** | | |
| | dOMXS30 | dSEK/USD | *Contribution from others* |
| dOMXS30 | 99,77 | 0,23 | 0,23 |
| dSEK/USD | 5,48 | 94,52 | 5,48 |
| *Contribution to others* | 5,48 | 0,23 | 5,71 |
| *Contribution including own* | 105,26 | 94,74 | Total spillover index= 2,86 |
| *Net spillover* | 5,26 | -5,26 | |
| | **Denmark** | | |
| | dOMXC20 | dDKK/USD | *Contribution from others* |
| dOMXC20 | 99,95 | 0,05 | 0,05 |
| dDKK/USD | 1,41 | 98,59 | 1,41 |
| *Contribution to others* | 1,41 | 0,05 | 1,46 |
| *Contribution including own* | 101,36 | 98,64 | Total spillover index= 0,73 |
| *Net spillover* | 1,36 | -1,36 | |

Note: Variance decomposition based on a 10-days-ahead forecast. VAR lag length order 1 was selected by the Akaike Information Criterion (AIC)

The first thing to be noticed from the results in Table 4 is that most of the return shocks are internal and that cross-market spillovers are infrequent, thereby suggesting that the two markets in the three Scandinavian countries are weakly integrated. The total spillover index is 5,54 % for Norway, 2,86 % for Sweden, and only 0,73 % for Denmark.

It can be seen from Table 3 that the stock market is the largest contributor of return spillovers for all of the three countries. The largest spillover is found in Norway, where the innovations to OSEBX returns explain 11,03 % of the forecast error variance of NOK/USD at the ten-day horizon. However, the innovations to NOK/USD only explain 0,05 % of the forecast error variance of the OSEBX at the ten-day horizon. The least spillover is found in Denmark, thereby implying that the foreign exchange and stock markets are the least integrated where innovations in OMXC20 returns only explain 1,41 % of the forecast error variance of DKK/USD at the ten-day horizon, and innovations to DKK/USD returns explain 0,05 % of the forecast error variance of the OMXC20 at the ten-day horizon.

Table 5 shows the spillover index for volatility; even here, it can be seen that most of the shocks are internal and that the total spillover index is considerably low, thereby indicating that the two markets are weakly integrated.

The results suggest that innovations to the stock market volatility spillover from the stock market is 1,45 %, 2,81 %, and 1,09 % for Norway, Sweden, and Denmark respectively. The volatility spillover from the foreign exchange market to the stock market is 7,88 %, 7,09 %, and 3,81 % for Norway, Sweden, and Denmark respectively.

**Table 7** - *Volatility Spillover index*

| | | | |
|---|---|---|---|
| | | **Norway** | |
| | dOSEBX | dNOK/USD | *Contribution from others* |
| dOSEBX | 98,55 | 1,45 | 1,45 |
| dNOK/USD | 7,88 | 92,12 | 7,88 |
| *Contribution to others* | 7,88 | 1,45 | 9,33 |
| *Contribution including own* | 106,43 | 93,57 | Total spillover index= 4,67 |
| *Net spillover* | 6,43 | -6,43 | |
| | | **Sweden** | |
| | dOMXS30 | dSEK/USD | *Contribution from others* |
| dOMXS30 | 97,19 | 2,81 | 2,81 |
| dSEK/USD | 7,09 | 92,91 | 7,09 |
| *Contribution to others* | 7,09 | 2,81 | 9,89 |
| *Contribution including own* | 104,28 | 95,72 | Total spillover index= 4,95 |
| *Net spillover* | 4,28 | -4,28 | |
| | | **Denmark** | |
| | dOMXC20 | dDKK/USD | *Contribution from others* |
| dOMXC20 | 98,91 | 1,09 | 1,09 |
| dDKK/USD | 3,81 | 96,19 | 3,81 |
| *Contribution to others* | 3,81 | 1,09 | 4,90 |
| *Contribution including own* | 102,71 | 97,29 | Total spillover index= 2,45 |
| *Net spillover* | 2,71 | -2,71 | |

*Note:* Variance decomposition based on a 10-days-ahead forecast. VAR lag length order 1 was selected by the Akaike Information Criterion (AIC).

The results for the returns spillovers suggest that it is the stock market that is the biggest contributor of returns spillover to the foreign exchange market for all the three countries under investigation. Further, the results suggest that the magnitude of innovations originates from the stock market, thereby explaining the forecast error variance of foreign exchange is strongest in Norway (11,03 %) followed by Sweden (5,48 %), and Denmark (1,41 %). Moreover, the degree of innovations originating from the foreign exchange market and explaining the forecast error variance of stock market is the strongest in Sweden (0.23 %), followed by Norway (0.05%) and Denmark (0.05 %). In line with the results for the return spillover, the results in Table 5 suggest that the magnitude of the innovations originating from the stock market and explaining the forecast error variance is again the strongest for Norway (7.88 %), followed by Sweden (7.09 %), and Demark (3.81 %) and from foreign exchange to stock market, it is the strongest for Sweden (2.81 %), followed by Norway (1.45 %), and Denmark (1.09 %).

The result presented in Tables 4 and 5 are the results from the full sample and static. However, the returns and volatility spillovers may be different at a given time. I will therefore adopt a dynamic rolling-sample analysis to determine if and how the results vary over time.

**4.3 Rolling Sample Analysis**

The sample period (2005–2018) used in this study witnessed the global financial crisis (2007–2009), the eurozone crisis (2012–2014), and other significant turbulent events that shook the financial world. Given this background, I believe it would be highly informative to see how the returns and volatility spillovers are affected during this time. Figure 4 shows the total return (left) and volatility (left) spillover indices based on a 200-day rolling window and a 10-day ahead forecast. The first thing to notice is that the static total spillover index for returns is estimated to be 5.54 %, 2.86 %, and 0.73 % for Norway, Sweden, and Denmark respectively. When this index is examined over time, it can be observed that it fluctuates from approximately 0 to almost 20 % for Norway, from approximately 0 to almost 14 % for Sweden, and from approximately 0 to almost 12 % for Denmark. Furthermore, the static volatility spillover index is estimated to be 4.67 % for Norway, 4.07 % for Sweden, and 2.45 % for Denmark. Examining Figure 4 for volatilities (left), we can see that it fluctuates from approximately 0 to almost 12 % for Norway, from approximately 0 to almost 14 % for Sweden, and from approximately 0 to almost 7 % for Denmark.

Several cycles can be observed in the time-varying spillover indices presented in Figure 4. For all the three countries, the first cycle starts in the beginning of 2006 and ends in 2007, this was the pre-crisis period of the financial crisis that began in 2008. The second observable cycle starts at the end of 2007 and ends in mid-2008, which was the time of the US sub-prime mortgage crisis. The third cycle that can be observed begins in mid-2008 and ends in mid-2009 for the volatility spillovers; this was the worst period in the global financial crisis. It would be beneficial to point out here that the returns' spillover effect is not fading out directly after the financial crisis but persists until mid-2010. A possible reason for this is the uncertainty that followed the crisis. The euro crisis can be observed starting in mid-2009 and ending in mid-2011.

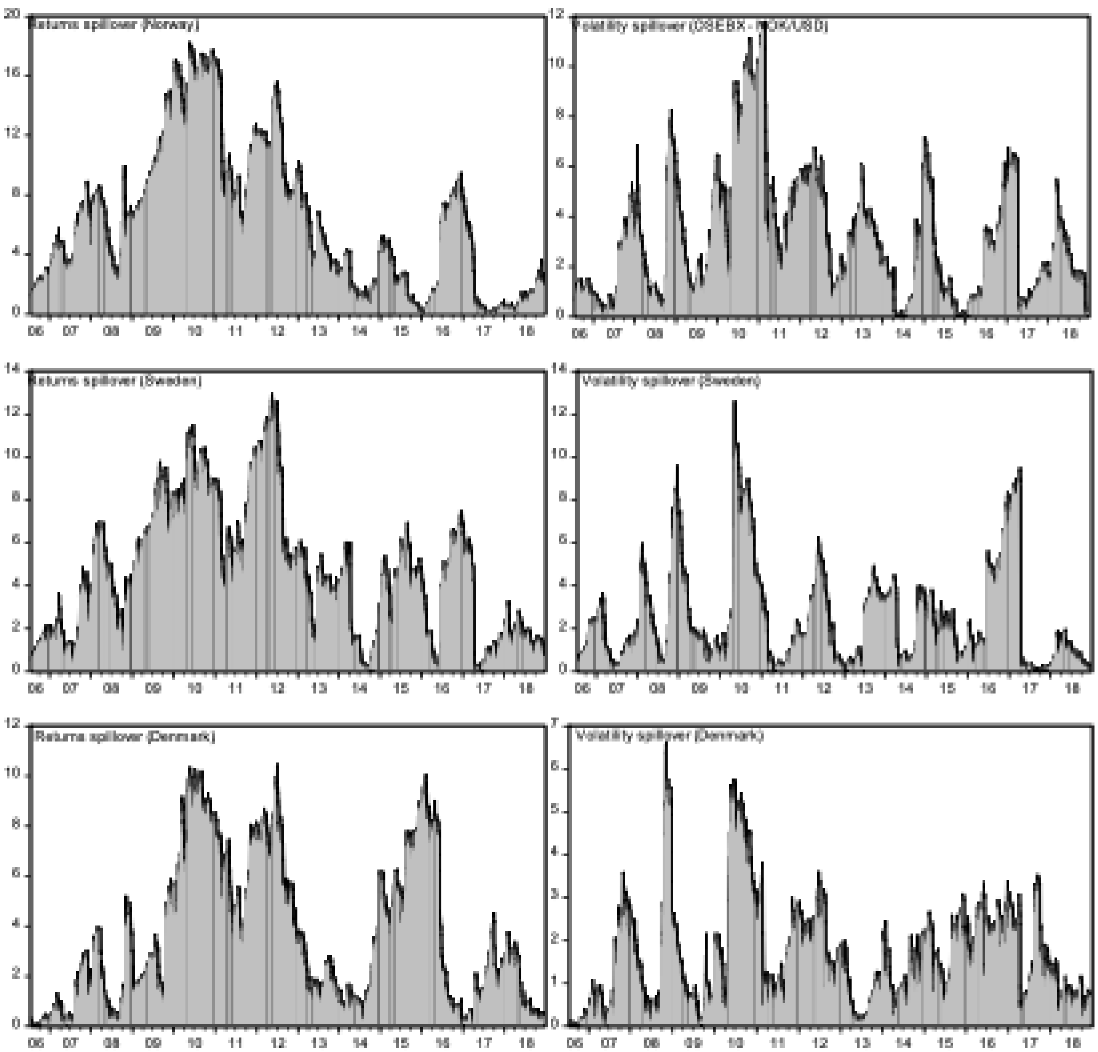


*Figure 4* - Total returns (left) and volatility (right) spillover (rolling sample). Norway, Sweden and Denmark respectively

### 4.4 BEKK-GARCH(1,1) Results

Table 8 summarizes the estimation results of the bivariate BEKK-GARCH(1,1) model in a pairwise manner. As shown in Table 3, the estimated diagonal elements $c_{11}$, $c_{22}$, $g_{11}$, and $g_{22}$ are all statistically significant at the 5% level. This indicates the presence of ARCH and GARCH effects. The conditional variance of stock indices and exchange rates in the Scandinavian countries are affected by their past shocks and volatility effects. The results for the coefficient $g_{11}$ also indicate that the markets present volatility persistence. For example, 0.81% for the OSEBX index in OSEBX – NOK/USD implies that 81% of the volatility of the previous day persists the next day. BEKK-GARCH(1,1)

**Table 8** - *Parameter Estimates*

| | **dOSEBX – dNOK/USD** | | **dOMXS30 – dSEK/USD** | | **dOMXC20 – dDKK/USD** | |
|---|---|---|---|---|---|---|
| | Estimate | t-stat | Estimate | t-stat | Estimate | t-stat |
| $b_{11}$ | 0,00069* | 11,1545 | -0,00265* | -11,49475 | -0,00284* | -12,20536 |
| $b_{12}$ | -0,00171* | -13,8312 | -0,00261* | -5,24331 | -0,00175* | -1,55373 |
| $b_{22}$ | -0,00537* | -12,1811 | -0,00610* | -17,71812 | -0,00517* | -11,19323 |
| $c_{11}$ | 0,42541* | 14,4602 | -0,46859* | -25,23119 | -0,36961* | -21,11516 |
| $c_{12}$ | 0,01278* | 15,3711 | 0,14507* | 8,17503 | -0,10587* | -5,70647 |
| $c_{21}$ | 0,08787* | 3,12637 | 0,14963* | 3,72279 | 0,15975* | 4,18872 |
| $c_{22}$ | 0,38828* | 11,5572 | 0,22111* | 4,72586 | 0,27889* | 10,29198 |
| $g_{11}$ | 0,81008* | 386,7283 | 0,84611* | 168,27255 | -0,89128* | -106,25492 |
| $g_{12}$ | -0,28515* | -5,23432 | -0,19640* | -18,92154 | 0,12293* | 6,88254 |
| $g_{21}$ | -0,45924* | -6,96413 | -0,21929* | -4,75793 | -0,30008* | -8,11939 |
| $g_{22}$ | -0,42079* | -17,4692 | -0,06191* | -6,1566 | 0,02560* | 1,68506 |

*Note: * - indicates significant on 5 % level or better*

Cross-market effects or the shocks and volatility spillovers between foreign exchange and stock markets are measured by the off-diagonal elements of matrices C and G. The results indicate evidence of bi-directional shocks transmission between the stock prices and exchange rates for all the countries being studied in this paper, as the pair of off-diagonal elements $c_{12}$ and $c_{21}$ are both statistically significant. This means that the shocks originating in the stock market affect the volatility of the exchange market, and similarly, the shocks originating in the foreign exchange market effectively influence the stock market. The results further indicate bidirectional volatility transmissions between the two financial markets in the three countries, since both $g_{12}$ and $g_{21}$ are statically significant on the 5 % level. These two variables capture the cross-market volatility spillover between asset classes and the results suggest that the stock markets in the Scandinavian countries are affected by the past volatilities originating in their foreign exchange markets and vice versa. Furthermore, the results indicate that the stock market is the primary volatility transmitter and that the spillover effects are asymmetrical. For example, $g_{12}$ (-0,28515) and $g_{21}$ (0,45924) in dOSEBX-dNOK/USD indicate the level of volatility transmission. Volatility transmission from the stock market to the foreign exchange market is 45.92 %, which implies that a 1 % increase in the returns of OSEBX transmits 45.92 % volatility to the foreign exchange market. On the other hand, the volatility spillover from the foreign exchange market to OSEBX is only 28.52 %.

The overall results indicate that the two markets, however asymmetrical, are integrated and that the news originating in the stock market impacts the volatility in the foreign exchange market and information contained in the stock market affects the behavior of the foreign exchange market. The results are consistent with the results found from the spillover index, where it can be seen that the stock market is the predominant contributor of spillovers to the foreign exchange market.

The results presented in Table 3 suggest that the heat wave and meteor shower as presented by Engle et al. (1990) is present in the Scandinavian countries. The two markets are affected by news originating in their own markets (heat wave) as well as the news emerging in other markets (meteor shower).

The results from the BEKK-GARCH model is consistent with the findings of Yang and Doong (2004), who detect asymmetric spillover effects between the stock market and foreign exchange and claim that stock market movements have a larger effect on the foreign exchange market than vice versa. The results are also consistent with the findings of Aloui (2007), who reached the same conclusion.

## 5. Conclusion

This thesis examines the return and volatility spillover effect between the foreign exchange and stock markets in three Scandinavian markets—Norway, Sweden, and Denmark. VAR models, Granger causality tests, impulse response functions, return and volatility spillover indices, and a BEKK-GARCH(1,1) model are employed in this work. The primary conclusion drawn from the results is that there is a weak linkage between the two markets in the three countries under study.

The results from the spillover index developed by Diebold and Yilmaz (2009) imply a weak bi-directional spillover between the stock and foreign exchange markets, in terms of both return and volatility. However, the Granger causality tests show that the stock market is the predominant contributor of spillover to the foreign exchange market. These results are confirmed with the BEKK-GARCH(1,1) model, that shows that there is a bi-directional yet asymmetrical relationship between the two markets in the three countries, and that most of the shocks are internal. The results suggest that the two hypotheses heat wave and meteor shower proposed by Engle et al. (1990) are present in the Scandinavian markets. The two markets are affected by the news originating in the own market (heat wave) and the news emerging in the other markets (meteor shower).

Overall, the results indicate weak return and volatility spillover effects in the Norway, Sweden, and Denmark and suggest that the stock market plays a more important role than foreign exchange markets.

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## Appendix 1

## Granger causality tests - subsamples

***Table 9*** *- Results of Granger causality test 2005 - 2009*

| VAR Granger Causality/Block Exogeneity Wald Tests | | | |
|---|---|---|---|
| Sample: 10/04/2005 12/28/2009 | | | |
| Norway | | | |
| Dependent variable: dOSEBX | | | |
| Excluded | Chi-sq | df | Prob. |
| dNOK/USD | 4,223695 | 2 | 0,1210 |
| All | 4,223695 | 2 | 0,1210 |
| Dependent variable: dNOK/USD | | | |
| Excluded | Chi-sq | df | Prob. |
| dOSEBX | 15,59386 | 2 | 0,0004** |
| All | 15,59386 | 2 | 0,0004** |
| Sweden | | | |
| Dependent variable: dOMXS30 | | | |
| Excluded | Chi-sq | df | Prob. |
| dSEK/USD | 1,642196 | 2 | 0,4399 |
| All | 1,642196 | 2 | 0,4399 |
| Dependent variable: dSEK/USD | | | |
| Excluded | Chi-sq | df | Prob. |
| dOMXS30 | 60,10693 | 2 | 0,0000*** |
| All | 60,10693 | 2 | 0,0000*** |
| Denmark | | | |
| Dependent variable: dOMXC20 | | | |
| Excluded | Chi-sq | df | Prob. |
| dDKK/USD | 3,703802 | 2 | 0,1569 |
| All | 3,703802 | 2 | 0,1569 |
| Dependent variable: dDKK/USD | | | |
| Excluded | Chi-sq | df | Prob. |
| dOMXC20 | 1,919274 | 2 | 0,3830 |
| All | 1,919274 | 2 | 0,3830 |

*Note*: ***, **, * indicates significant on 1%, 5%, and 10% respectively.

***Table 10*** *- Results of Granger causality test 2010 - 2013*

| VAR Granger Causality/Block Exogeneity Wald Tests | | | |
|---|---|---|---|
| Sample: 1/04/2010 12/28/2018 | | | |
| Norway | | | |
| Dependent variable: dOSEBX | | | |
| Excluded | Chi-sq | df | Prob. |
| dNOK/USD | 0,992776 | 2 | 0,6087 |
| All | 0,992776 | 2 | 0,6087 |
| Dependent variable: dNOK/USD | | | |
| Excluded | Chi-sq | df | Prob. |
| dOSEBX | 17,60687 | 2 | 0,0002** |
| All | 17,60687 | 2 | 0,0002** |
| Sweden | | | |
| Dependent variable: dOMXS30 | | | |
| Excluded | Chi-sq | df | Prob. |
| dSEK/USD | 4,450745 | 2 | 0,1080 |
| All | 4,450745 | 2 | 0,1080 |
| Dependent variable: dSEK/USD | | | |
| Excluded | Chi-sq | df | Prob. |
| dOMXS30 | 93,51991 | 2 | 0,0000*** |
| All | 93,51991 | 2 | 0,0000*** |
| Denmark | | | |
| Dependent variable: dOMXC20 | | | |
| Excluded | Chi-sq | df | Prob. |
| dDKK/USD | 1,368614 | 2 | 0,5044 |
| All | 1,368614 | 2 | 0,5044 |
| Dependent variable: dDKK/USD | | | |
| Excluded | Chi-sq | df | Prob. |
| dOMXC20 | 3,982578 | 2 | 0,1365 |
| All | 3,982578 | 2 | 0,1365 |

*Note*: ***, **, * indicates significant on 1%, 5%, and 10% respectively.

***Table 11*** *- Results of Granger causality test 2014 - 2018*

| VAR Granger Causality/Block Exogeneity Wald Tests<br>Sample: 1/02/2014 12/28/2018 | | | |
|---|---|---|---|
| Norway | | | |
| Dependent variable: dOSEBX | | | |
| Excluded | Chi-sq | df | Prob. |
| dNOK/USD | 0,066042 | 2 | 0,9675 |
| All | 0,066042 | 2 | 0,9675 |
| Dependent variable: dNOK/USD | | | |
| Excluded | Chi-sq | df | Prob. |
| dOSEBX | 4,531406 | 2 | 0,1038 |
| All | 4,531406 | 2 | 0,1038 |
| Sweden | | | |
| Dependent variable: dOMXS30 | | | |
| Excluded | Chi-sq | df | Prob. |
| dSEK/USD | 5,793462 | 2 | 0,0552* |
| All | 5,793462 | 2 | 0,0552* |
| Dependent variable: dSEK/USD | | | |
| Excluded | Chi-sq | df | Prob. |
| dOMXS30 | 17,01390 | 2 | 0,0002** |
| All | 17,01390 | 2 | 0,0002** |
| Denmark | | | |
| Dependent variable: dOMXC20 | | | |
| Excluded | Chi-sq | df | Prob. |
| dDKK/USD | 2,123291 | 2 | 0,3459 |
| All | 2,123291 | 2 | 0,3459 |
| Dependent variable: dDKK/USD | | | |
| Excluded | Chi-sq | df | Prob. |
| dOMXC20 | 26,34014 | 2 | 0,0000*** |
| All | 26,34014 | 2 | 0,0000*** |

*Note*: ***, **, * indicates significant on 1%, 5%, and 10% respectively.

# Appendix 2

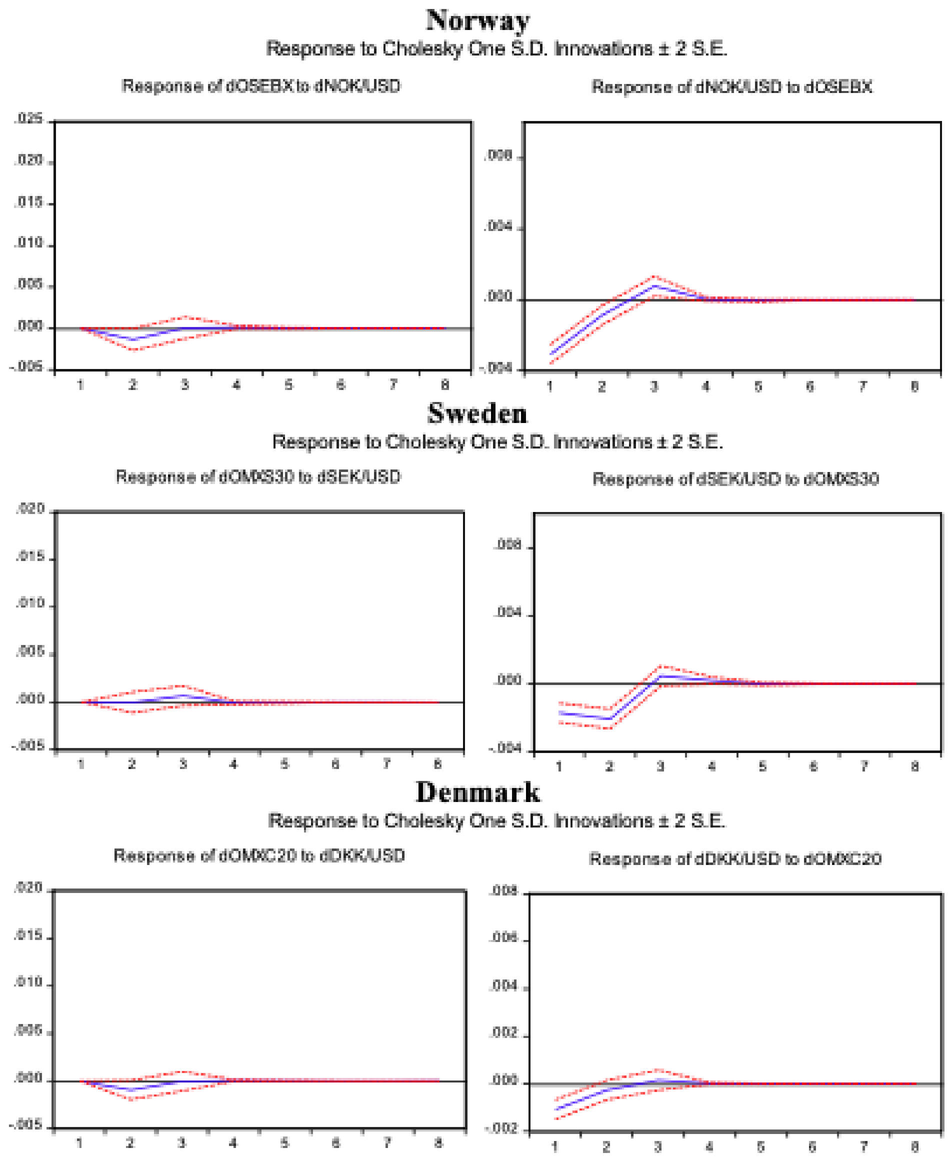


*Figure 5 - Impulse Responses 2005 - 2009*

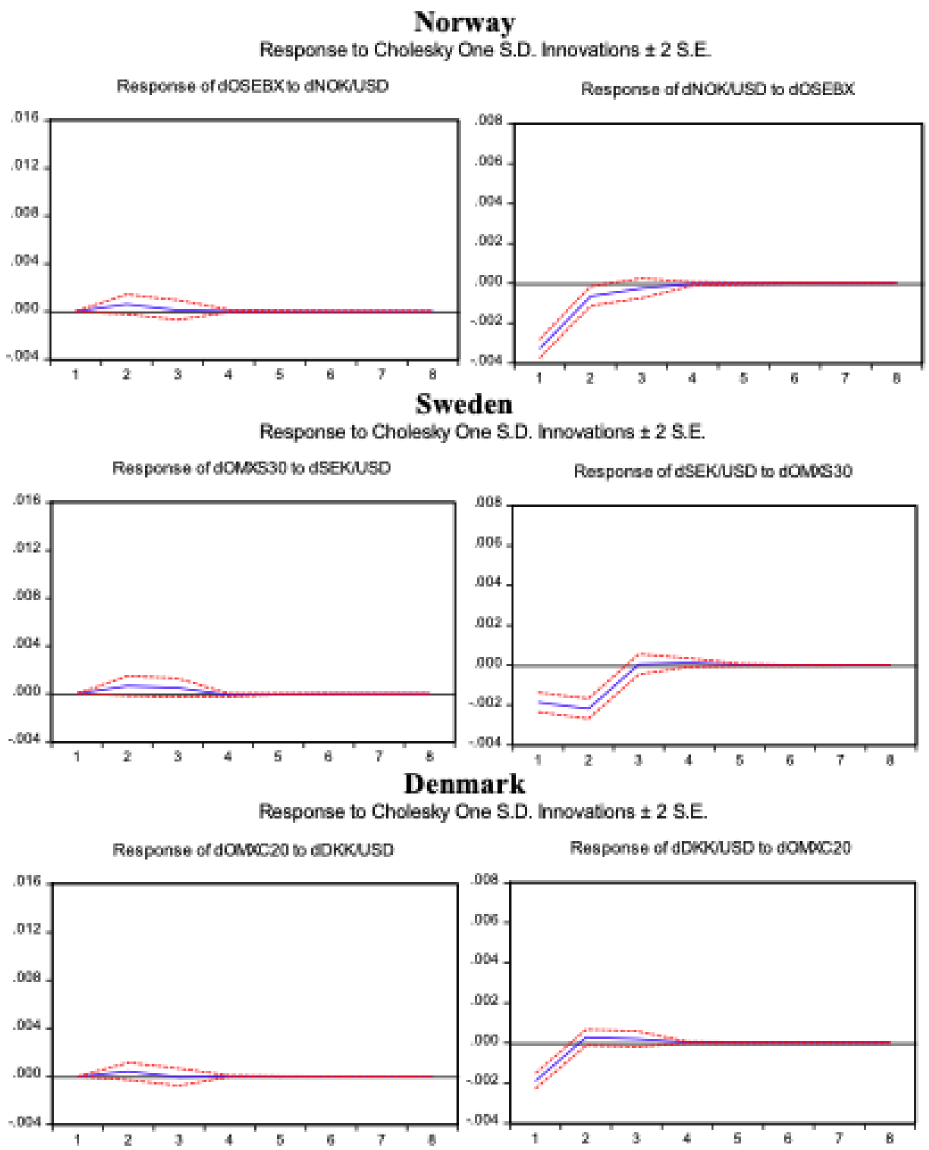


*Figure 6 - Impulse Responses 2010 - 2013*

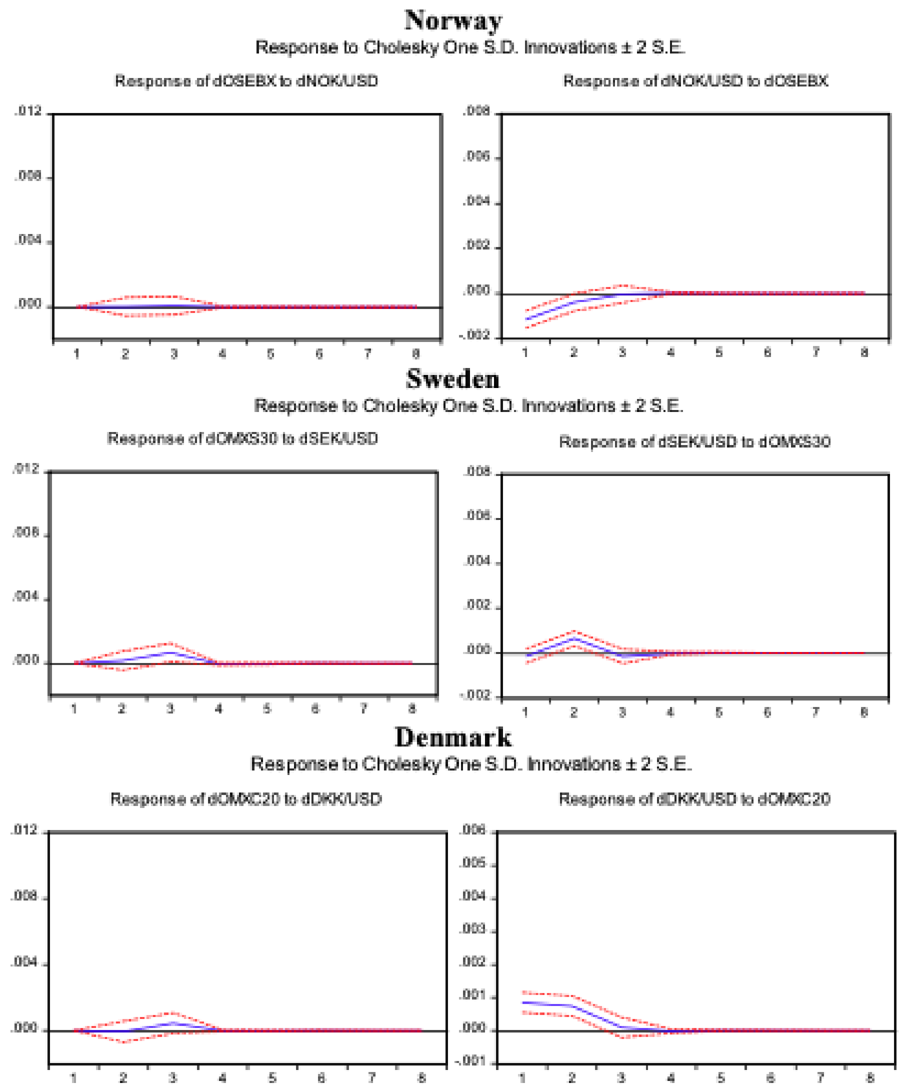


*Figure 7 - Impulse Responses 2014 - 2018*