Stock Prices and Foreign Exchange Rates: The Case of Iceland, Norway, Sweden and Hungary

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Abstract

The relationship between domestic stock prices and real exchange rates in Iceland, Norway, Sweden and Hungary is studied using two different methodologies. What makes this study unique is the fact that all four countries are small European countries with independent currencies. Previous studies have focused mainly on emerging markets. The sample period under analysis is Jan 2003 – Jan 2014. The sample period for Iceland is divided into two sub-periods representing periods pre- and post capital controls. A co-integration method is used to examine the channels for the dynamic linkage of the relationship. Additionally, a dynamic conditional correlation (DCC) method is used to estimate the source of the dynamic relationship with regards to the US market. The empirical results suggest a co-integrated relationship between domestic stock prices and real exchange rates. When comparing results between the two sub-periods for Iceland a stronger co-integrating relationship is detected in the state of capital controls. A significant time-varying correlation is established but the driving force of the relationship cannot be determined. In other words, no “clean” channels are established as a linkage for the co-integrating relations.

Keywords: Stock Prices, Foreign Exchange Rates, Capital Controls, Co-integration, Dynamic Conditional Correlation.

Declaration of Research Work Integrity

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature of any degree. This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. A bibliography is appended.

By signing the present document I confirm and agree that I have read RU's ethics code of conduct and fully understand the consequences of violating these rules in regards of my thesis.

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Introduction

During the short history of the Icelandic stock market its prices have been very volatile. The rapid price increases grew exponentially until mid-year 2007 but resulted in a crash of the Icelandic stock market following the global financial crisis of 2008. Presumably, there are various reasons for a high volatility in Icelandic stock prices. In fact it is unlikely that the reasons will ever be known to full extent. The inspiration for this thesis is the involvement of the Icelandic currency, the Icelandic Krona (ISK), on these price changes. Stock prices are driven by many factors but this paper will study the relationship between real exchange rates and stock prices. This relationship has been well documented in previous studies for several countries, especially in countries with emerging markets. This study will focus on a small group of European countries that all have their own independent currencies. In addition to Iceland, which will serve as the focal point, the relationship of real exchange rates and stock prices in three other independent European countries will be examined. These countries are Norway, Sweden and Hungary.

The focal point of this analysis, the case of Iceland, is especially interesting for two main reasons. One of the reasons is the recent implementation of capital controls in Iceland. In November of 2008, following the economic crisis, the Icelandic government implemented capital controls after consolidating with the International Monetary Fund. The reason for the capital controls, as explained by the governor of the Central Bank of Iceland, M. Guðmundsson (2010), was to prevent difficulties with the balance of payments and stabilize the exchange rate. Since Iceland is part of the European Economic Area (EEA) these capital controls can only be viewed as a temporary measure since it is in breach with the obligations deriving from the EEA Agreement. Now, almost 6 years have passed from the inception of the capital controls and they are still in place. In this study an attempt will be made to utilize the situation in Iceland in an effort to capture the effects of the capital controls on the relationship between real exchange rates and stock prices. In order to achieve this, the sample period for Iceland will be divided into two sub-periods, representing the periods of pre- and post capital controls. Subsequently, two separate analysis of the relationship will be performed and the results will be compared.

Another interesting aspect of the Icelandic case is the fact that the Icelandic stock market largely consists of companies with majority of its income in foreign currencies.

Landsbankinn Economic Research (2013) reveals that in late 2013, around 72% of the market capitalization of the Icelandic stock market consisted of companies with majority of their income in foreign currencies. These companies even use foreign currencies in their accounting books for better transparency of their businesses. As of May 2014, five out of twelve listed companies in Iceland use foreign currencies in their accounting books. Three of them use Euros but two companies use US Dollars (USD). The high ratio of foreign income versus domestic income for companies on the market suggests that stock prices should be influenced by the real exchange rate. At least to a higher extent than if their income was only domestic. To illustrate this, it can be assumed that if the real exchange rate of the ISK against the Euro goes up, it would at least have a partially positive impact on stock prices of companies with their main income in Euros because now every Euro they earn is worth more in ISK than before due to the changes in the real exchange rate.

The main purpose of this paper is to detect if there is any relationship between stock prices and foreign exchange rates in Iceland, Sweden, Norway or Hungary. Other questions that this study will try to answer are: What effects do capital controls have on the relationship between stock prices and foreign exchange rates? How is the direction of causality between the two? How is the dynamic conditional correlation derived? In efforts to answer these questions two separate methods will be used. The first method that will be used is the co-integration method, as suggested by Phylaktis and Ravazzolo (2005). An attempt will be made to estimate through which channels stock prices and exchange rates are linked together and how shocks impact the linkage between them. The purpose is to find the direction of the causality between the different components in the model. The relationship dynamics will be estimated for short-term given that there is a long-term relationship. The co-integration technique eliminates the problem of non-stationarity and works well when analyzing both levels and differences. In this method, both US markets and Euro area markets will be used with the purpose of representing world markets. It has been established in previous studies that influences of world markets are an important variable in the relationship between real exchange rates and stock prices. The US market and the Euro area market are both valid representatives of world market influences and can be viewed as a passage for the effects of real exchange rates on the stock market.

The other method that will be used when examining the dynamics between exchange rates and stock prices will be a Dynamic Conditional Correlation (DCC) method, as suggested by Moore and Wang (2014). This method has a similar agenda when estimating the relationship between stock prices and exchange rates as the co-integration method but it uses a different technique. It follows a DCC-GARCH model as proposed by Engle (2002). The DCC method gives a more direct indication of the linkage between stock prices and exchange rates since the dynamics of correlation are modeled simultaneously with the volatility dynamics of the series. Unlike the co-integration method, the sample period for Iceland will not be divided into smaller sub-periods to represent samples pre- and post capital controls. The reason for this is that when the state of the economy changes over time the possible changes in the conditional correlation can be detected by using the DCC method. The DCC method therefore works properly despite the fact that it is dealing with a very volatile series for the stock market or the real exchange rates. The DCC method will only use the US market to represent world markets. The most important contribution of the DCC method is estimating the determinants of the dynamic linkage between stock prices and real exchange rates.

The paper will be structured as follows: Chapter 1 will be devoted to clarifying the main economic theories behind the relationship between exchange rates and stock prices. Further, Chapter 1 also discusses the theory behind how these two components are linked and through which channels. Chapter 2 will introduce the methodologies used in the empirical analysis, i.e. the co-integration method and the DCC method. The results of the empirical analysis will be presented and discussed in Chapter 3. Finally, in Chapter 4 the results will be summarized and suggestions for further studies will be discussed.

1 Theory[1]

The relationship between stock prices and exchange rates has been a disputed topic in economic literature throughout the years. It is evident that classical economic theory suggests a relationship between the two but academic literature differs in views on how these two objects are connected to each other and through which channels. To illustrate this controversy with some examples it should be mentioned that Aggarwal (1981) and Roll (1992) found a positive relationship between the stock prices and exchange rates when examining the US market. Soenen and Hennigar (1988) on the other hand found a negative relationship when examining a different time interval. Some studies have found a very weak or none relationship at all when performing an empirical analysis. The works of Chow (1997) is a good example of such results. Two schools of thought are prevalent in the literature on the dynamics between stock prices and real exchange rates, that is, “flow-oriented” models and “stock-oriented” models.

1.1 Flow Oriented Models

The “flow-oriented” models rely on two pillars of economic theory. The first pillar is the relationship between real exchange rates and economic activity which has been well covered by previous studies such as the ones by Cornell (1983) and Wolff (1988). This relationship implies that when real exchange rate decreases it causes a rise in competitiveness of domestic goods versus foreign goods and increases the level of domestic aggregate demand and output. The second pillar is the relationship between economic activity and stock markets which has also been well covered by previous academics such as Schwert (1990), Roll (1992) and Canova and DeNicolo (1995). The relationship holds because in theory stock prices of firms are influenced by expected future cash flows, which is again affected by economic activity through aggregate demand. With these two pillars in mind it has been documented in studies by the likes of Fama (1981) and Geske & Roll (1983) that real economic growth, employment rate, corporate profits, present- and expected future economic activity (measured in industrial production) are all incorporated in stock prices. Therefore, if the theory of “flow-oriented” models holds it should result in increased domestic exports when foreign imports increase, given that there are trade links between the two economic areas. This would bring on an appreciation of the domestic currency which forces the

[1] This chapter follows Phylaktis and Ravazzolo (2005)

real exchange rate to rise and domestic economic activity increases, which should result in domestic stock prices rising. In summary, an increase in real exchange rate could cause stock prices to rise because of its effect on economic activity.

1.2 Stock Oriented Models

"Stock-oriented" models rely on the portfolio approach when determining the exchange rate. The model assumes that agents allocate their wealth between different types of assets. These classes consist of various types of assets such as domestic money, domestic bonds and foreign securities etc. The exchange rate will balance the demand and supply for these assets. If the supply or demands of assets change it will also alter the true state of equilibrium of the real exchange rate. Therefore, if the "stock-oriented" model is applicable to the domestic market, a price rise in the foreign stock market will increase the price of domestic stocks due to increased integration between the domestic- and world markets. This results in a so-called "wealth effect" which increases wealth and demand for all assets. Subsequently, interest rates will rise because of excess demand for money. Agents will substitute foreign securities out for domestic assets. That will lead to appreciation in the domestic currency and real exchange will rise up. In contrast, the "wealth effect" will also have a reverse effect on the demand for foreign assets, which results in the exchange rate appreciating to some extent. Because of the two opposite effects it is uncertain if the real exchange rate will rise or fall. The movement will depend on the various components of the model and their relative strengths.

2 Methodology[2]

2.1 Co-integration

The former methodology of two that will be used to estimate the dynamic between stock prices and real exchange rates is based on co-integration. The term co-integration was first introduced by Engle and Granger (1987). Co-integration refers to when two or more time series share the same stochastic drift. If they do so, the time series are said to be co-integrated.

The relationship between stock prices of two economies and real exchange rates can be defined, following Phylaktis and Ravazzolo (2005), as:

$$P_t^D = \alpha_0 + \alpha_1 S_t^D + \alpha_2 P_t^{US} + v_t \tag{1}$$

where P_t^D : Domestic stock price in real terms

P_t^{US} : US stock price in real terms

S_t^D : Real exchange rate

v_t : Disturbance term

All the data is presented in real terms but then transformed by natural logarithms. Real exchange rates are preferred over nominal exchange rates as suggested by Chow et al. (1997) since it is a better indicator of the competitive position of an economy when compared to world markets. As suggested by previous studies, the US market (or the Euro area market) will serve as a replacement variable for the world market influences. The US market is included in the analysis based on the presumption that it works as a passage for the linkage between foreign exchange and local stock markets. As previously mentioned, two models will be considered when it comes to exchange rate determination, "flow-oriented models" and "stock-oriented models". The coefficient α_1 represents the effects of these two different models and can be either positive or negative.

When testing for co-integration, a likelihood ratio test is performed as illustrated by Johansen (1988) and Johansen & Juselius (1990). To begin with, the following relationship can be defined:

$$Y_t \equiv (P_D, S_D, P_{US}) \tag{2}$$

[2] This chapter follows Phylaktis & Ravazzolo (2005) and Moore & Wang (2014)

where P_D: Domestic stock price index in real terms

S_D: Real exchange rate for domestic currency versus US dollar

P_{US}: US stock price index in real terms

If Y_t is co-integrated it can be produced by a vector error correction model (VECM). VECM takes into account both short term and long term connection between variables. The VECM model is defined as:

$$\Delta Y_t = \mu + \sum_{i=1}^{k-1} G_i \Delta Y_{t-i} + G_k Y_{t-1} + \varepsilon_t \quad (3)$$

where μ: 3×1 vector of constant

G: 3×3 matrices of parameters

ε_t: 3×1 white noise vector

Finally, the trace statistic as presented by Johansen of the null-hypothesis of maximum r co-integrating vectors $0 \leq r \leq n$ and $(n - r)$ common stochastic trend can be defined as:

$$trace = -T \sum_{i=r+1}^{n} ln\,(1 - \hat{\lambda}_i) \quad (4)$$

where $\hat{\lambda}_i$: $n - r$ smallest squared canonical corrections of Y_{t-1} with respect to ΔY_t corrected for lagged differences

T: Sample size used for estimation

2.2 Multivariate Granger Causality Test

Following the initial co-integration process of estimating the co-movements of stock prices and the exchange rate, the long- and short-run dynamics of the two are examined by performing a multivariate Granger causality test. The test results will clarify how each variable impacts the relationship on a wider scale. More importantly, the test results will provide a better understanding of what type of channel is at work, “flow channel” or “stock channel” as explained in Chapter 1. The foundation of the theory behind Granger causality can be found in Granger (1969), but Granger, Huang & Yang (2000) laid the foundation for examining the bivariate causality between stock prices and exchange rates.

Following Phylaktis and Ravozzolo (2005), a multivariate Granger causality test for co-integrating systems is used to estimate the causality between stock prices and exchange rates. The specifics of the test are based on the works of Dolado and Lutkepohl (1996). The methodology they suggest has several advantages. First off all, the Wald tests will have standard asymptotic χ^2- distributions. This will eliminate the possibility of a pretest bias that often occurs when standard procedure is followed. The standard procedure would be to estimate a first order differenced VAR with I(1) and non-integrated variables or an error correction model when they are co-integrated. The method used is carried out in levels on least squares estimators of the parameters of the VAR process. This methodology allows for variables to be co-integrated, but since it is not assumed the variables do not in fact need to be co-integrated for the method to work. Testing for unit roots is therefore not necessary in essence but will be performed nonetheless for transparency. The methodology is based on the assumption that non-standard asymptotic properties of the Wald test on the parameters of co-integrated VAR systems are caused by the singularity of the asymptotic distribution of the estimators of the least squares. The singularity vanishes when a VAR process, with order exceeding its true order, is fitted. This will lead to a non-singular distribution of relevant parameters.

To implement the method, the following procedure will be undertaken. To begin with, the lag structure of the VAR is produced by testing a VAR(k) against a VAR$(k+1), k \geq 1$ with a standard Wald test. After confirming that the true data generating process is a VAR(k), the next step is to fit a VAR$(k+1)$ and apply standard Wald tests on the first k VAR coefficient matrix. In other words, the undifferenced VAR of the VECM of equation (3) is estimated:

$$Y_t = \mu + A_1 Y_{t-1} + \cdots + A_p Y_{t-k} + \varepsilon_t \quad (5)$$

where A_i: 3×3 coefficient matrix

When Eq. (5) is expanded for our case we get:

$$\begin{bmatrix} P_D \\ S_D \\ P_{US} \end{bmatrix} = \begin{bmatrix} A_{10} \\ A_{20} \\ A_{30} \end{bmatrix} + \begin{bmatrix} A_{11}(L) & A_{12}(L) & A_{13}(L) \\ A_{21}(L) & A_{22}(L) & A_{23}(L) \\ A_{31}(L) & A_{32}(L) & A_{33}(L) \end{bmatrix} \begin{bmatrix} P_{D,t-1} \\ S_{D,t-1} \\ P_{US,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{PD} \\ \varepsilon_{SD} \\ \varepsilon_{PUS} \end{bmatrix} \quad (6)$$

where A_{i0}: Intercept terms

A_{ij}: Polynomial in the lag operator L

A Wald test is performed to select the lag structure following a re-estimation of the VAR, adding one extra lag. OLS is used when estimating the three equations, as the estimates are consistent and asymptotically efficient because each equation has the same lag length. Three hypotheses are tested in an effort to explore the type of channel the linkage between stock prices and exchange rates work through. The three hypotheses are the following:

(i) "flow" channel: $A_{12}(L) \neq 0, A_{13}(L) \neq 0$ and $A_{23}(L) \neq 0$;

(ii) "stock" channel: $A_{13}(L) \neq 0, A_{21}(L) \neq 0$ and $A_{23}(L) \neq 0$;

(iii) "flow" and "stock" channels: $A_{12}(L) \neq 0, A_{13}(L) \neq 0, A_{21}(L) \neq 0$ and $A_{23}(L) \neq 0$

2.3 Dynamic Conditional Correlation

2.3.1 The Foundation of the DCC method

The second methodology used for estimating the relationship between stock prices and exchange rates is a dynamic conditional correlation (DCC) method. The DCC was first introduced by Engle (2002) as a new class of multivariate models. Engle described the DCC as having the flexibility of the univariate GARCH models and the parsimonious parametric models for the correlation. The DCC models are not linear but can be estimated with univariate or two step methods and generally perform well in various situations.

The blueprint of the DCC method used in this study can be laid out by following Malliaropulos (1998). He derives a theoretical model of the relationship between real exchange rate and the stock return differentials between two countries. Providing a definition of the relative stock price between the two countries, domestic and foreign, expressed in the currency of the home country, with all variables in logarithms: [3]

$$\rho_t = s_t - s_t^* - e_t \tag{7}$$

where s_t: Domestic stock price

s_t^*: Foreign stock price

e_t: Number of domestic currency per unit of foreign currency

Next, the real exchange rate is defined as[4]:

$$q_t = e_t + p_t^* - p_t \tag{8}$$

where p_t: Domestic price

p_t^*: Foreign price

Further, it can be stated that the real exchange rate composes of both permanent (q_t^P) and temporary (q_t^T) factors, as suggested by Baxter (1994) and Huizinga (1987):

$$q_t = q_t^P + q_t^T \tag{9}$$

where the two components on the RHS of Eq. (9) can be defined as:

$$q_t^P = \mu + q_{t-1}^P + \varepsilon_t^P \tag{10}$$

$$q_t^T = \theta q_{t-1}^T + \varepsilon_t^T \tag{11}$$

The temporary component in Eq. (11) follows a first order autoregressive process with $0 < \theta < 1$ plus serially uncorrelated innovations ε_t^T. The permanent component in Eq. (10) is a random walk process with drift μ and serially uncorrelated innovations ε_t^P. Stock prices can also be split into permanent and temporary components, ρ_t^P and ρ_t^T, as suggested by Fama & French (1988) and Poterba & Summers (1987):

$$\rho_t = \rho_t^P + \rho_t^T \tag{12}$$

where each component in Eq. (12) can be defined as:

[3] Note: A different notation is used for stock prices and real exchange rates in this chapter compared to the notation used in the co-integration methodology.

[4] Note: This is a reversed definition of the real exchange rate compared to the definition used in the co-integration method.This will not affect parameter consistancy but only change the sign of the coefficients.

$$\rho_t^P = \nu + \rho_{t-1}^P + \eta_t^P \tag{13}$$

$$\rho_t^T = \phi\rho_{t-1}^T + \eta_t^T, \quad 0 < \phi < 1 \tag{14}$$

The serially uncorrelated innovations η_t^P and η_t^T are assumed to be uncorrelated with ρ_t^P and ρ_t^T as well. Additionally, the expected changes in the real exchange rate and stock price differential can be defined as:

$$E_{t-1}\Delta\rho_t = E_{t-1}\Delta(s_t - s_t^* - e_t) \tag{15}$$

$$E_{t-1}\Delta q_t = E_{t-1}\Delta(e_t + p_t^* - p_t) \tag{16}$$

where E_{t-1}: expectations at time $t-1$ given all available information

Eq. (15) and (16) can be perceived similar as the uncovered interest rate parity, where the risk premium $E_{t-1}\Delta\rho_t$ can contain both a foreign exchange risk as well as relative stock return risk. The latter equation demonstrates the expected deviation from relative purchasing power parity (PPP). Having established this, the real stock return differential in the model can be defined as:

$$\Delta z_t = \Delta(s_t - p_t) - \Delta(s_t^* - p_t^*) \tag{17}$$

Now from Eq. (15) and (16) the following equation can be defined after re-arranging the components:

$$E_{t-1}\Delta\rho_t = E_{t-1}\Delta z_t - E_{t-1}\Delta q_t \tag{18}$$

It can be derived from Eq. (18) that the expected stock return differential is equal to the expected real stock differential, but subtracted by the expected change in the real exchange rate. It is possible to substitute the unobservable expected change with a temporary component of the series. Following this, using Eq. (10), (11), (13) and (14), these expressions can be affirmed:

$$E_{t-1}\Delta q_t = \mu + (\theta - 1)q_t^T \tag{19}$$

$$E_{t-1}\Delta\rho_t = \nu + (\phi - 1)\rho_t^T \tag{20}$$

The temporary component of the real exchange rate affects the expected real depreciation but the temporary component of the stock price differential affects the expected risk premium. Eq. (19) and (20) provide the dynamic relationship:

$$\rho_t^T = -\frac{\mu+\upsilon}{\phi-1} - \left\{\frac{\theta-1}{\phi-1}\right\} q_t^T + \left\{\frac{1}{\phi-1}\right\} E_t \Delta z_t \tag{21}$$

The parameters of the autoregressive terms are $0 < \theta < 1$ and $0 < \phi < 1$. Hence, the temporary component of the relative stock price is more likely to have negative correlation with the temporary deviations of the real exchange rate from PPP. A negative relationship would suggest that when we get increases in stock prices, an appreciation of exchange rates would follow and vice versa. As previously stated, empirical studies differ substantially on the causal direction of the relationship and whether it is positive or negative.

2.3.2 The DCC Model

The DCC model can be explained in detail by following Engle (2002). He proposed a bivariate GARCH model with DCC specification that will be utilized to estimate the relationship between stock price differentials (ρ_t) and real exchange rates (q_t). From this relationship the conditional mean equation can be defined as:

$$y_t = \mu + \varepsilon_t\,,\, \varepsilon_t | \xi_{t-1} \sim N(0, H_t) \tag{22}$$

where y_t: $[y_{1t}, y_{2t}]'$ a 2×1 vector

μ: 2×1 vector of a constant

ε_t: $[\varepsilon_{1t}, \varepsilon_{2t}]$ vector of innovations conditional on time $t - 1(\xi_{t-1})$

Additionally, the error term is considered to be conditionally multivariate normal with mean zero and variance-covariance matrix that will be defined as:

$$H_t = D_t C_t D_t \tag{23}$$

where D_t: 2×2 diagonal matrix of the time varying standard deviations from

univariate GARCH models with $\sqrt{h_{i,t}}$ on the i^{th} diagonal

C_t: 2×2 time varying symmetric conditional correlation matrix

Further it can be stated that D_t follows the following univariate GARCH process:

$$h_{i,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1} \tag{24}$$

where ω_i: Constant term

α_i: The conditional volatility (ARCH effect)

β_i: Volatility persistence

Now, the evolution of the DCC model correlation may be defined as:

$$Q_t = (1 - q_a - q_b)\bar{Q} + q_a \varepsilon_{t-1}\varepsilon'_{t-1} + q_b Q_{t-1} \quad (25)$$

where Q_t: $\{qij\}_t$ a 2×2 conditional variance-covariance matrix of residuals

with its time-invariant variance-covariance matrix $Q = E(\varepsilon_t \varepsilon'_t)$

q_i: Non-negative scalar parameters satisfying $q_a + q_b < 1$

Finally, Q_t is scaled to supply a proper correlation matrix C_t since it has no unit diagonal elements in Eq. (24).

$$C_t = diag(Q_t)^{1/2} Q_t diag(Q_t)^{-1/2} \quad (26)$$

This element has the form of $\rho_{ij} = q_{ij,t}/\sqrt{q_{ii,t}q_{jj,t}}$, $i,j = 1{,}2$ and $i \neq j$. This represents the conditional correlation between stock price differentials and real exchange rates, which is a key element in the DCC methodology.

3 Empirical Analysis

3.1 The Data

Four countries were chosen as subjects of the empirical analysis, i.e. Iceland, Norway, Sweden and Hungary. All of these four countries are European and relatively small on the global spectrum, or at least non-dominant on world markets. They all have independent currencies: Iceland has the ISK, Norway has the Norwegian Krone (NOK), Sweden has the Swedish Krone (SEK) and Hungary has the Hungarian Forint (HUF). Moreover, these countries are not involved in the European Exchange Rate Mechanism (ERM). This is relevant since countries that are a part of the ERM have their currencies pegged in one way or another to the Euro, which would lead to biased estimates in the analysis since links with world markets are a part of the analyzed model. Data for the United States and the Euro area will be used as a representative of world markets. The

US market is often used as representatives of world markets and rightfully so. The reason for this is that many countries do most of their trade or at least a large portion it with the US. However, since all of the countries subjected in this study trade heavily with countries within the Euro area, data for the Euro area markets will also be included in the analysis. The importance of including the effects of world markets in this analysis is evident because omission of an important variable such as effects of world markets will give biased estimates. Previous studies have demonstrated this. It is nearly impossible to capture all world market effects into a single variable, but as demonstrated by previous studies, the US market is a prime candidate to act as a representative of world markets because of its status in international trades.

Due to asymmetric availability of data, different kind of sample periods will be used between different empirical methods. Having said that, consistency within each method is withheld for unbiased estimates. The sample period chosen for the co-integration analysis, where monthly data is used, is Jan 2003 – Jan 2014 for all countries subject to the analysis. The case of Iceland will be special since its sample period will be split up into two sub-periods, representing pre- and post capital controls. Although the sample period will be divided for the case of Iceland it will also be analyzed for the sample as a whole. The cutoff date chosen to split up the two sub-periods is Dec 2008. Thus, the pre capital controls sub-period will range from Jan 2003 - Nov 2008 and the post capital controls sub- period will range from Dec 2008 – Jan 2014. When applying the DCC method, similar sample periods will be analyzed. In the bivariate DCC-GARCH model, the same periods will be analyzed as before for Iceland, Norway and Sweden, that is from Jan 2003 – Jan 2014. In the case of Hungary, this sample period will be reduced to Oct 2003 – Jan 2014 due to less availability of data. Finally, in the instrument variables estimates, where quarterly data is used, the sample periods will be reduced for all the countries to Q1 2003 – Q4 2012 where Q1 and Q4 represent the first and fourth quarters of their relevant years.

The time series used in the co-integration analysis are the following: Monthly stock market index prices expressed in a local currency, local bilateral spot exchange rates as domestic currency per world market currency (USD or Euro) and consumer price index. The data used in the co-integration analysis was obtained from Macrobond except for domestic consumer price indices, which were obtained from the Statistics Iceland, Statistics Norway, Statistics Sweden and Statistics Hungary. The data is all end-of-month observations, expressed in a logarithmic form. The real exchange rate is calculated in the following way:

$$ln\, S_t^D = ln\, e_t^D \times ln \frac{CPI_t^D}{CPI_t^F} \tag{27}$$

where e_t^D: Nominal exchange rate

CPI_t^D: Domestic consumer price index

CPI_t^F: Foreign consumer price index

Time series used for the DCC analysis are the following: Monthly closing stock price indices and end-of-period nominal exchange rates (compared to USD or Euro). For the instrument variable estimates, three variables are used in addition to the product of the DCC estimation. These variables are ratio of the current account to GDP, real interest rate differential between each country and the US and finally sum of stock market capitalization to GDP, ratio of M3 to GDP and ratio of credit to the private sector to GDP. In order for the product of the DCC estimation to work in the instrument variable estimates it will be transformed from monthly observations to quarterly observations. This will be achieved by defining the first observation for every quarter a representative for the whole quarter. All data used in the DCC was obtained from The World Bank except for the real interest rate differentials, which were obtained from OECD Statistics.

Table 1
Cointegrations tests of Eq. (1) (USA represents world markets)

	Johansen test statistics H_0: r = 0	H_0: r ≤ 1	H_0: r ≤ 2
Iceland			
Jan 2003-Jan 2014	37.34**	8.34	2.03
Jan 2003-Dec 2008	30.27*	7.94	0.00
Dec 2008-Jan 2014	131.96**	20.45**	2.29
Norway			
Jan 2003-Jan 2014	25.51	9.62	0.42
Sweden			
Jan 2003-Jan 2014	32.26*	5.28	1.15
Hungary			
Jan 2003-Jan 2014	15.97	3.80	0.27

Note: ** and * denote 1% and 5% significance levels. The critical values are 29.68 and 35.65 for r = 0, 15.41 and 20.04 for r ≤ 1 and finally 3.76 and 6.65 for r ≤ 2.

3.2 Co-integration results

Eq. (1) is tested for co-integration relations for the cases of Iceland, Norway, Sweden and Hungary. After testing and confirming that the series for domestic prices, foreign stock prices and real exchange rates are all I(1), by performing unit root tests,[5] we start off by using a Johansen trace statistic test to identify the number of co-integrating relationships within our series.

The results are illustrated in Table 1 and Table 2, where Table 1 shows the scenario where the US represents the world markets and Table 2 shows the scenario where the Euro area represents world markets.[6] In addition to estimating a co-integration relation for the whole sample period for all countries, a test is performed for co-integrating relations for the two sub-periods of Iceland. The two sub-periods represent pre- and post capital controls implemented in Iceland in late 2008 and the results confirm the relevance of the division of periods since they yield different results.

[5] See Appendix A: Unit root test results
[6] The results from a Johansen trace statistic test when excluding foreign stock markets is presented in Appendix B.

Table 2
Cointegrations tests of Eq. (1) (Euro area represents world markets)

	Johansen test statistics		
	H_0: r = 0	H_0: r ≤ 1	H_0: r ≤ 2
Iceland			
Jan 2003-Jan 2014	44.23**	6.75	1.33
Jan 2003-Dec 2008	43.31**	12.30	0.00
Dec 2008-Jan 2014	70.83**	24.99**	2.67
Norway			
Jan 2003-Jan 2014	22.32	8.41	1.91
Sweden			
Jan 2003-Jan 2014	21.31	7.72	2.50
Hungary			
Jan 2003-Jan 2014	25.44	5.76	1.81

Note: ** and * denote 1% and 5% significance levels. The critical values are 29.68 and 35.65 for r = 0, 15.41 and 20.04 for r ≤ 1 and finally 3.76 and 6.65 for r ≤ 2.

In the US scenario (see Table 1) the null-hypothesis cannot be rejected, using 5% significance level, that there is no co-integrating vectors for Norway and Hungary. However, the null-hypothesis can be rejected for Iceland (including both sub-periods) and Sweden. For the null-hypothesis of one co-integrating relationship or less the post capital controls period in Iceland is the only one rejected. A rejection for the null hypothesis of one co-integrated relation or less is unusual. In previous studies this hypothesis is almost never rejected. Phylaktis and Ravazzolo (2005) get no rejection for this hypothesis when examining five Pacific Basin countries. They reject the former hypothesis though for four out of five countries.

In the Euro area scenario (see Table 2) the null-hypothesis is rejected, using 1% significance level, of zero co-integrating vectors for the case of Iceland (including both sub-periods). Furthermore, we also reject the null-hypothesis of one co-integrating relationship for the post capital controls era, indicating two co-integrating vectors. It is not possible to reject the null-hypothesis of zero co-integrating vectors for Norway, Sweden and Hungary at the 5% significant level.

The results of the Johansen trace test reveal that there is at least a partially co-integrating relationship in the case of Iceland for both scenarios and also for Sweden in the US scenario. On the other hand, the possibility of zero co-integrating vectors cannot be rejected for the cases of Norway and Hungary for both scenarios based on these results. When pre- and post capital controls sub-periods for Iceland are compared it can

Table 3
The long-run co-integration vector $P_t^D = \alpha_0 + \alpha_1 S_t^D + \alpha_2 P_t^{US} + v_t$ (World markets: USA)

	α_0	α_1	α_2
Iceland			
Jan 2003-Jan 2014	-25.52	8.70	-2.71
Jan 2003-Dec 2008	-19.32	14.82	-11.23
Dec 2008-Jan 2014	-1.72	0.59	0.51
Norway			
Jan 2003-Jan 2014	-86.85	18.31	0.57
Sweden			
Jan 2003-Jan 2014	-518.45	120.61	-13.57
Hungary			
Jan 2003-Jan 2014	45.89	-7.75	-1.21

be seen that the post capital controls period appears to be more co-integrated since it cannot reject the null-hypothesis of one co-integrating vector or less.

Despite mixed results, the possibility of co-integrating vectors cannot be ruled out completely for the cases of Norway, Sweden and Hungary. In fact results of previous studies indicate that co-integration relations are more likely to be present than not for Eq. (1) when estimated for various countries and sample periods. Yet this study is not able to suggest that relationship with the Johansen test.

The long-run co-integrating vectors of Eq. (1) are presented in Tables 3 (US scenario) and 4 (Euro area scenario). Results are similar between the two different scenarios. The real exchange rate seems to be positively related to the domestic stock market in Iceland (all sample periods) and Norway, but Sweden shows mixed results and Hungary shows a negative relationship. Foreign stock market coefficients show a similar story. Stock prices in world markets seem to be positively related to domestic stock prices for Iceland (all periods) and Norway, but the cases of Sweden and Hungary suggest a negative relationship. The results for Sweden appear to contain some type of bias in the US scenario. The Swedish case shows abnormal values in the US scenario and should be taken with a grain of salt since there is a chance they contain an undetected bias. Previous studies suggest a positive relationship between both real exchange rate and domestic stock price as well as for foreign stock price and domestic stock price. Phylaktis and Ravazzolo (2005) find a positive relationship between both relationships for five out of five Pacific Basin countries examined.

Table 4
The long-run co-integration vector $P_t^D = \alpha_0 + \alpha_1 S_t^D + \alpha_2 P_t^{US} + v_t$ (World markets: Euro Area)

	α_0	α_1	α_2
Iceland			
Jan 2003-Jan 2014	-26.16	6.21	0.81
Jan 2003-Dec 2008	-24.51	5.32	1.40
Dec 2008-Jan 2014	-3.96	1.36	0.33
Norway			
Jan 2003-Jan 2014	-21.96	5.01	1.00
Sweden			
Jan 2003-Jan 2014	20.12	-3.26	-0.30
Hungary			
Jan 2003-Jan 2014	140.35	-27.81	-1.33

For a better understanding of the co-integrating relations a test for exclusion of variables from the co-integrating relationship is performed.[7] An exclusion of real exchange rate is rejected for all countries in both scenarios. Further, exclusion of domestic stock prices is rejected for all countries except Hungary for both scenarios. There seem to be mixed results concerning the exclusion of foreign stock prices. When the US represent world markets an exclusion of foreign stock prices are rejected strongly for Iceland (all sample and post capital controls sub-period) and vaguely rejected for Norway. The same exclusion test cannot be rejected for Sweden, Hungary and the pre capital controls sub-period for Iceland. When examining the Euro area scenario the exclusion test for foreign stock prices is only vaguely rejected for the Norwegian case. For all other cases the null-hypothesis of exclusion of foreign stock prices from the co-integrating relationship cannot be rejected. These results might suggest that world stock markets are not contributing to the co-integrated vector. At least, significantly less than the real exchange rate seems to be doing. When the two sub-periods for Iceland are compared some discrepancies can be observed. The pre capital controls sub-period only rejects one exclusion restriction vaguely out of possible six over the two scenarios. The post capital controls sub-period however rejects all exclusion restrictions strongly, except one. This suggests that the co-integrating relationship examined is much stronger post implementation of capital controls.

[7] See results in Appendix C: Test of Exclusion Restrictions

Table 5
Multivariate Granger causality tests (Euro area represents world markets)

		$A_{12}(L) = 0$	$A_{13}(L) = 0$	$A_{21}(L) = 0$	$A_{23}(L) = 0$	$A_{31}(L) = 0$
Iceland						
Jan 2003-Jan 2014	$\chi 2(2)$	171.96****	7.52***	14.88****	1.12	3.14
	P value	(0.00)	(0.02)	(0.00)	(0.57)	(0.21)
Jan 2003-Dec 2008	$\chi 2(2)$	16.81****	2.64**	8.42****	0.23	1.91*
	P value	(0.00)	(0.10)	(0.00)	(0.63)	(0.17)
Dec 2008-Jan 2014	$\chi 2(2)$	14.04*	14.91*	56.55****	41.92****	10.89
	P value	(0.17)	(0.14)	(0.00)	(0.00)	(0.37)
Norway						
Jan 2003-Jan 2014	$\chi 2(2)$	2.91**	4.95***	0.17	0.09	0.71
	P value	(0.09)	(0.03)	(0.68)	(0.76)	(0.40)
Sweden						
Jan 2003-Jan 2014	$\chi 2(2)$	0.36	1.43	4.39*	2.39	4.00*
	P value	(0.84)	(0.49)	(0.11)	(0.30)	(0.14)
Hungary						
Jan 2003-Jan 2014	$\chi 2(2)$	0.26	0.79	0.07	2.54*	1.75*
	P value	(0.61)	(0.37)	(0.79)	(0.11)	(0.19)

Note: ****, ***, ** and * denote the significance at levels 1%, 5%, 10% and 20% respectively.

3.3 Multivariate Granger causality test results

A multivariate Granger causality test is used to investigate the dynamics between the domestic stock prices and foreign exchange markets. As mentioned earlier, there are two main theories regarding this linkage. The components can be linked either through the „stock“ channel or the „flow“ channel. In an effort to examine this dynamic the following restrictions are tested for Eq. (6) by using a Wald test: $A_{12}(L) = 0, A_{13}(L) = 0, A_{23}(L) = 0$ for the „flow“ channel and $A_{13}(L) \neq 0, A_{21}(L) = 0, A_{23}(L) = 0$ for the „stock“ channel. It is also interesting to examine whether the domestic stock markets feedback to world markets. That is examined by testing the restriction $A_{31}(L) = 0$. The test results are shown in Table 5 and Table 6. The results in the Euro area scenario are shown in Table 5 and the results of the US scenario are shown in Table 6. We again add the two sub-periods, pre- and post capital controls, for Iceland into our analysis.

Table 6
Multivariate Granger causality tests (USA represents world markets)

		$A_{12}(L) = 0$	$A_{13}(L) = 0$	$A_{21}(L) = 0$	$A_{23}(L) = 0$	$A_{31}(L) = 0$
Iceland						
Jan 2003-Jan 2014	χ2(2)	51.71****	11.18*	38.40****	2.57	18.24***
	P value	(0.00)	(0.19)	(0.00)	(0.96)	(0.02)
Jan 2003-Dec 2008	χ2(2)	49.20****	19.17**	18.91**	2.19	23.82***
	P value	(0.00)	(0.08)	(0.09)	(1.00)	(0.02)
Dec 2008-Jan 2014	χ2(2)	1.43	10.95****	2.63	0.68	0.58
	P value	(0.49)	(0.00)	(0.27)	(0.71)	(0.75)
Norway						
Jan 2003-Jan 2014	χ2(2)	1.12	6.51****	4.91***	3.22**	0.41
	P value	(0.29)	(0.01)	(0.03)	(0.07)	(0.52)
Sweden						
Jan 2003-Jan 2014	χ2(2)	0.50	1.23	4.90***	3.46**	2.22*
	P value	(0.48)	(0.27)	(0.03)	(0.06)	(0.14)
Hungary						
Jan 2003-Jan 2014	χ2(2)	0.14	0.01	1.51	0.03	0.09
	P value	(0.70)	(0.94)	(0.22)	(0.87)	(0.77)

Note: ****, ***, ** and * denote the significance at levels 1%, 5%, 10% and 20% respectively.

The results show a rejection for $A_{13}(L) = 0$ for all cases except Hungary and Sweden for both scenarios. This means that stock prices in the countries that reject this restriction should be affected by foreign stock prices. This understanding is based on interpretation of the results of previous studies is what economic theories for open economies suggest. The reverse of this restriction, $A_{31}(L) = 0$, or the „feedback" restriction is only strongly rejected for two cases of Iceland in the US scenario and vaguely rejected for Sweden in the same scenario. The results show also three vague rejections for the same parameter in the Euro area case for Sweden, Hungary and the pre capital controls sub-period for Iceland. A rejection for the post capital controls sub-period is achieved in neither case. These different results between sample periods of Iceland make sense because the Icelandic stock market was more globalized pre capital controls and more open to world markets. After the stock market crash and more importantly following the isolation of the capital controls that were implemented by the Icelandic government, the feedback factor seems to have diminished.

The biggest problem with the results appears to be regarding the real exchange rate of the ISK. On one hand, a strong rejection is achieved for both scenarios of $A_{21}(L) = 0$ for the whole sample and at least vague rejections for the two sub-periods except for post capital controls period in the US scenario. This would mean that Icelandic stock prices have a very significant affect on the real exchange rate of the ISK versus the

Table 7
DCC-GARCH model parameters (Euro area representes world markets)

	Iceland	Norway	Sweden	Hungary
Δρ (stock price differential)				
μ	0.02****	0.00	0.00	0.00
	(0.01)	(0.00)	(0.00)	(0.01)
ω	0.00***	0.00*	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
α	0.56	0.14****	0.08*	0.12*
	(0.85)	(0.05)	(0.05)	(0.08)
β	0.38	0.83****	0.88****	0.65***
	(0.36)	(0.04)	(0.07)	(0.30)
Δq (real exchange rate)				
μ	0.00***	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
ω	0.00***	0.00***	0.00*	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
α	0.32**	0.26***	0.18***	0.19***
	(0.18)	(0.11)	(0.12)	(0.09)
β	0.69****	0.65****	0.40	0.63****
	(0.09)	(0.10)	(0.33)	(0.17)
DCC parameters				
q_a	-0.02**	0.03*	0.08**	0.12*
	(0.01)	(0.02)	(0.04)	(0.07)
q_b	0.99****	0.98****	0.89****	-0.40
	(0.07)	(0.04)	(0.12)	(0.40)
Log Likelihood	-363.34	-370.07	-344.57	-285.30
Diagnostic test				
Stock Q(4)	9.32	4.55	7.56	6.15
Stock $Q(4)^2$	13.11	2.97	2.17	7.10
Exchange rate Q(4)	5.40	2.24	6.05	9.34
Exchange rate $Q(4)^2$	0.85	2.51	1.10	8.50

Note: Q(4) and $Q(4)^2$ are the Ljung-Box Q-statistics. Standard errors are in parenthesis. ****, ***, ** and * denote significance levels of 1%, 5%, 10% and 20% respectively.

USD. On the other hand, a rejection in $A_{23}(L) = 0$ is not achieved for any sample period in both scenarios except for post capital controls era in the Euro area scenario. This indicates that stock prices in the US and the Euro area have very little or no affect on the real exchange rate of the ISK versus the USD and Euro respectively. The reason for these results could be due to the extremely high volatility of the ISK. Since the ISK

Table 8

DCC-GARCH model parameters (USA represents world markets)

	Iceland	Norway	Sweden	Hungary
Δp (stock price differential)				
μ	0.02****	0.00	0.00	0.01
	(0.00)	(0.00)	(0.00)	(0.01)
ω	0.00***	0.00*	0.00**	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
α	0.59	0.11**	0.20**	0.25
	(0.52)	(0.05)	(0.12)	(0.20)
β	0.49***	0.81****	0.46**	0.56**
	(0.21)	(0.08)	(0.24)	(0.30)
Δq (real exchange rate)				
μ	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
ω	0.00**	0.00	0.00***	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
α	0.23****	0.07*	0.23***	0.16
	(0.07)	(0.05)	(0.12)	(0.1313)
β	0.68****	0.80****	0.47****	0.75****
	(0.10)	(0.14)	(0.24)	(0.17)
DCC parameters				
q_a	-0.02***	0.09****	0.01****	0.12***
	(0.01)	(0.03)	(0.00)	(0.06)
q_b	1.00****	0.91****	1.02****	0.74****
	(0.00)	(0.04)	(0.00)	(0.13)
Log Likelihood	-363.40	-337.69	-344.72	-282.11
Diagnostic test				
Stock Q(4)	11.78	3.80	16.00	4.31
Stock $Q(4)^2$	16.77	0.83	1.17	1.27
Exchange rate Q(4)	4.99	2.72	2.05	5.05
Exchange rate $Q(4)^2$	1.42	0.84	4.49	2.26

Note: Q(4) and $Q(4)^2$ are the Ljung-Box Q-statistics. Standard errors are in parenthesis. ****, ***, ** and * denote significance levels of 1%, 5%, 10% and 20% respectively.

is constantly fluctuating and the USD or Euro are more stable currencies, the model might give the ISK more credit than it deserves regarding the causality of the real exchange rate. This fact makes it impossible to establish „clean“ channels of stock or flow type since the restriction $A_{23}(L) = 0$ needs to be rejected in both cases to get a „clean“ channel where all three restrictions are rejected.

Table 9
Instrument variable estimate results: Dependant DCC_t

	Iceland	Norway	Sweden	Hungary
Constant	-0.08*	-0.06	0.07****	0.68*
	(0.05)	(0.05)	(0.02)	(0.35)
DCC_{t-1}	0.85****	0.91****	1.12****	0.13
	(0.11)	(0.09)	(0.04)	(0.16)
$\Delta(cas/gdp)_t$	0.00**	-0.00	0.00	-0.01
	(0.00)	(0.01)	(0.00)	(0.02)
$\Delta(r-r^*)_t$	-0.01	0.06	0.00	-0.01
	(0.02)	(0.07)	0.00	(0.04)
ΔFD_t	0.00	0.00	0.00	-0.04
	(0.00)	(0.00)	(0.00)	(0.13)
Serial Corr. (1)	[0.85]	[0.08]	[0.89]	[0.40]
Serial Corr. (2)	[0.98]	[0.17]	[0.01]	[0.02]
Heterosced.	[0.03]	[0.56]	[0.25]	[0.95]

Note: ****, ***, **, * define significance at 1%, 5%, 10% and 20%. Standard errors are in parenthesis Instrument variables used are the following: Constant, DCC_{t-1}, DCC_{t-1}, $(cas/gdp)_{t-1}$, $(r-r^*)_{t-1}$, FD_{t-1}, $(cas/gdp)_{t-2}$, $(r-r^*)_{t-2}$ and FD_{t-2}. P-values for Breusch-Godfrey serial correlation tests and Breusch-Pagan-Godfrey heteroscedasticity tests are shown in brackets

Last but not least we can reflect on the restriction of $A_{12}(L) = 0$. That restriction is rejected for the case of Iceland and Norway in the Euro area scenario but only for two cases of Iceland in the US scenario (all sample and pre capital controls). This indicates that the real exchange rate of the ISK has an impact on Icelandic stock prices. This addresses the original inspiration for this study, that is whether the real exchange rate in Iceland affects the Icelandic stock market more heavily than is normal within other independent currency zones in Europe. This seems to be the case since this restriction is strongly rejected. The fact that companies on the Icelandic stock market have historically had abnormally high ratio of foreign income versus domestic income yields the results of the real exchange rate affecting the domestic stock price more heavily in Iceland than in its foreign counterparties that are subject to our analysis.

To summarize the results from the multivariate Granger causality test it can be established that only one clean „stock“ channel is detected, that is in the case of Norway in the US scenario. No other clean channel is detected. A mixed signal appears in the post capital controls era for Iceland in the Euro scenario where the results give a vaguely clean channel for both „stock“ and „flow“. Since the results are seemingly biased regarding the impact of domestic and foreign stock prices on the real exchange rate as previously mentioned, it is necessary to rely on the restriction of $A_{12}(L) = 0$ in efforts to estimate if the „stock“ channel or „flow“ channel might be at works.

Subsequently, since the restriction for Iceland is only rejected but not for the other countries it can be assumed that it is more likely for the dynamic of stock prices and the real exchange rate to be linked through the „flow“ channel in Iceland (except post capital controls era). But, through the „stock“ channel for the other countries subject to our study as well as for the post capital controls era in Iceland.

3.4 DCC results

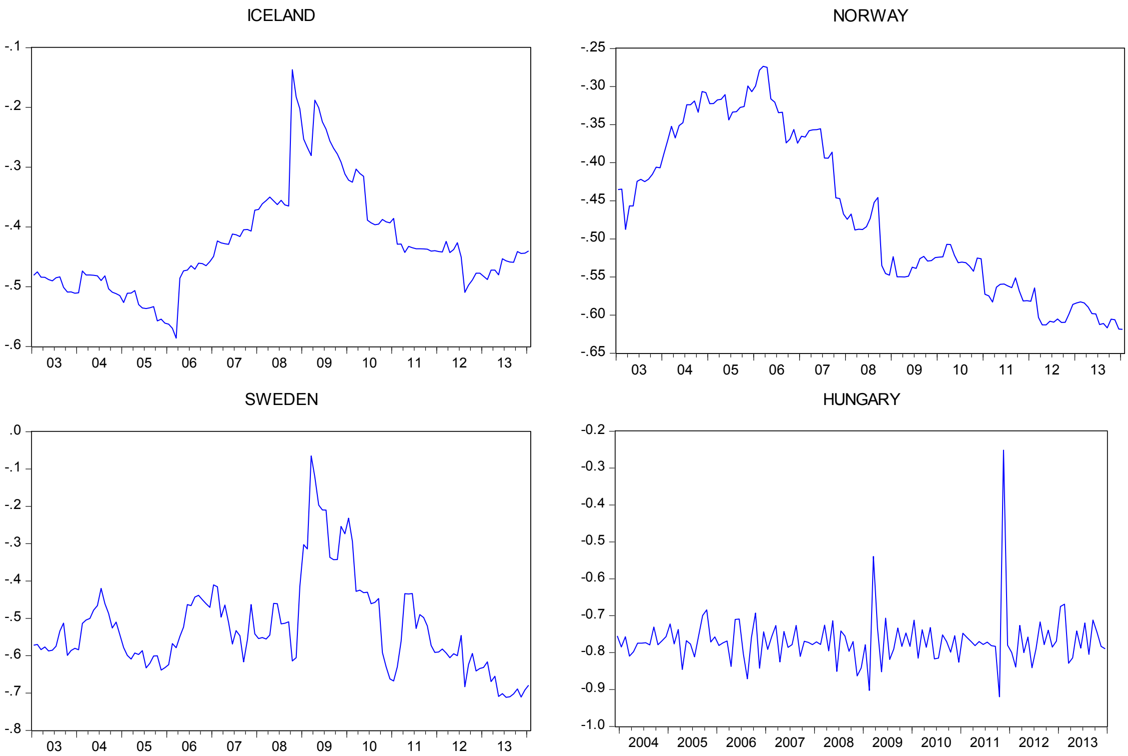
3.4.1 DCC-GARCH model

For the second methodology used to examine the relationship between stock prices and exchange rates a bivariate DCC-GARCH model, presented in Chapter 2.3.2. is estimated. This method is used in efforts to get a better understanding of what components of the relationship are affecting the correlation of stock prices and real exchange rates. The results can be seen in Table 7 (Euro area scenario) and Table 8 (US scenario). In the Euro area scenario the null-hypothesis of no ARCH components (α) is rejected for the stock price differential in all countries except Iceland, but only vaguely for Sweden and Hungary while Norway is strongly rejected. In the US scenario only Norway and Sweden are rejected. The same null-hypothesis is rejected for the real exchange rate for all countries in the Euro area scenario. While Iceland and Sweden are strongly rejected in the US scenario, vaguely for Norway but no rejection is achieved in Hungary. These results appear to be relatively mixed. A rejection of the absence of ARCH components confirms that the variance of the error term is a function of squares of previous error terms. For the cases where a rejection is not achieved, this property cannot be established.

When looking at the results for β, which is the coefficient for the lagged conditional volatility, a rejection appears for every country in both scenarios except for the case of Iceland in the Euro area scenario. A rejection suggests some persistence in conditional volatility shocks, in cases where they occur.

A strong rejection is achieved in the case of the US for all countries in both of the DCC parameters. In the Euro area scenario we cannot reject $q_b = 0$ for Sweden and Hungary. A significant DCC parameter implies persistence in the conditional volatility. Figure 1 shows graphically how the time-varying correlation behaves during our sample period. In all cases the conditional correlation is negative (staying between -1 and 0) with one exception of a single positive outlier for the case of Hungary. We can see some behavioral changes in the figures around the 2008 crisis period. In the case of

The Euro Area as a world market representative:



The US as a world market representative:

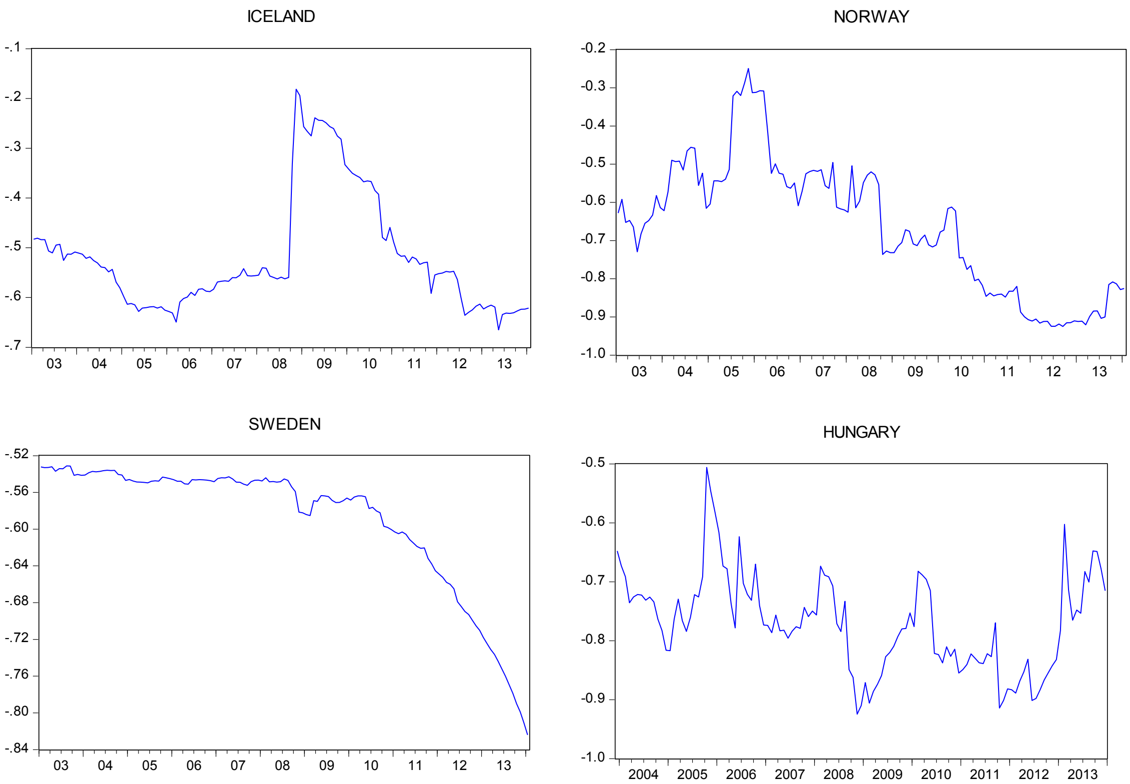


Figure 1: DCC Time-varying correlations.

Iceland the negative correlation seems to be impacted by the crisis and it moves closer to 0, but starts to converge back to its original trend in the following years. Before the crisis, Norway seems to have been experiencing an upward trend. But shortly before the crisis this trend seems to reverse and continue that development for the following years. Sweden shows similar behavior as Iceland, especially in the Euro area scenario. On the other hand, the conditional correlation in the Swedish case in the US scenario shows a suspiciously odd trend, a spiral of some kind, downwards. This might be an indicator of some undetected bias in the estimation and should be interpreted with caution. Possibly because of parameter stability since the sum of the DCC parameters exceed one. The sample period for Hungary is a bit shorter than other sample periods. Overall it seems to be some increase in volatility of the dynamic correlation around the crisis period.

3.4.2 Sources of Dynamic Linkage

The result of the estimated DCC-GARCH model suggests that the time-varying correlation between stock return differentials and changes in real exchange rate is significant. To explore the cases even further the sources of the dynamic linkage are examined. As suggested by Moore and Wang (2014) two proxies are used to examine the linkage. One of the proxies used is the current account surplus (or deficit), this proxy will measure the influence of economic integration on the correlation through international trade. The other proxy used is interest rate differentials, that proxy will measure the effects of financial integration on the correlation through international capital mobility. More control variables will be used that are likely to affect the relationship. Market capitalization relative to GDP will be included because of influence on stock market returns. M3 and credit to private sector (as percentage of GDP) will also be included in the analysis. Eq. (28) shows the linear equation suggested by Moore and Wang (2014).

$$DCC_{i,t} = \beta_{0i} + \beta_{1i} DCC_{it-1} + \beta_{2i} \Delta(\frac{cas}{gdp})_{it} + \beta_{3i} \Delta(r - r*)_{it} + \beta_{4i} \Delta FD_t + u_{it} \qquad (28)$$

The time-varying conditional correlation found when estimating the DCC-GARCH model is used as a dependent variable. Regarding the other variables, $(\frac{cas}{gdp})$ is current account to GDP ratio, $(r - r*)$ is the real interest rate differential between a domestic country and world markets (the US market in this analysis). FD represents the sum of the stock market capitalization to GDP ratio, M3 to GDP ratio and credit in private sector to GDP ratio. Because of restrictions in availability of data this analysis will only be performed for the scenario where the US market represents world markets. Further, all data will be quarterly time series opposed to monthly as in previous analysis. The DCC was converted from monthly to quarterly observations. Because of the problem of endogeneity of the explanatory variables an instrument variable approach is used for the estimation. All instrumental variables used are listed in the notes under Table 9 where the results are the estimation results are presented.

The results suggest that the lagged dependent variable is highly significant for Iceland, Norway and Sweden but not for Hungary. High significance suggests a strong persistence in the dynamic correlation. Other variables for all 4 countries do not seem to be significant except for $(\frac{cas}{gdp})$ in the Icelandic case. This suggests that the dynamic linkage between the Icelandic stock market and real exchange rate is driven by the trade balance, at least at some extent. No other significant relationship can be taken from these results. Previous studies have had more significant results, for example Moore and Wang (2014) find the current account to GDP ratio to be significant for five emerging markets and one developed market as well. Their results also suggest significant control variables for both emerging and developed markets.

4 Conclusion

This study has estimated the long- and short-run relationship between stock prices and exchange rates for Iceland, Norway, Sweden and Hungary. Also, an attempt was made in efforts to discover the dynamic linkage between the two. For the estimation process, two different methodologies were used. Special attention was paid to the case of Iceland and the difference between results for its two sub-periods, pre- and post capital controls. This was done to examining whether the presence of capital controls affected the relationship between stock prices and real exchange rates.

To summarize the results from the co-integration method, one “clean” channel was detected for the case of Norway in the US scenario where a “clean” stock channel was detected. The results did not provide any other “clean” channel but the results showed mixed signals for the post capital controls period in Iceland when the Euro area acted as world market influences. An indication of a bias regarding the significance of the coefficients driving the real exchange rate maid it necessary to focus more on other parts of the channels for interpretation. When only focusing on the influence of the exchange rate on domestic stock prices it seemed more likely for the "flow" channel to be at works in Iceland (except for the post capital controls era). On the contrary, in the other countries there were indications of the "stock" channel being in works as well as in the post capital controls era in Iceland. If these interpretations are close the real behavior of the linkage it is interesting to see the linkage switch channels in Iceland in the state of capital controls. In general, the results of the estimation of the long-run co-integrating vectors of Eq. (1) suggested a positive relation between domestic stock prices and real exchange rates. Hungary is the only country showing a negative relationship between the two components. The same story goes for foreign stock prices, which seemed to be positively related to domestic stock prices, at least for Iceland and Norway. Sweden seemed to show spurious results but Hungary also showed a negative relationship.

The possible co-integrating relations were tested for exclusion. The exclusion of the influences of the real exchange rate was rejected for all countries in both scenarios. Further, the exclusion of domestic stock prices was rejected in most cases with Hungary being the only case that did not reject this hypothesis. The exclusion of foreign stock prices got mixed results. It was only strongly rejected for two periods of Iceland in the US scenario and vaguely rejected for Norway in both scenarios. According to these results the real exchange rate seems to be of more importance to the relationship then foreign stock prices. When the two sub-periods of Iceland are compared it shows that the co-integrating relationship under examination is much stronger in the state of capital controls.

The main finding of the DCC approach was that a significant time-varying correlation between domestic prices and real exchange rates was established. Only one DCC parameter did not test significant in the case of Hungary. This suggests that a DCC approach is useful for establishing a time-varying conditional correlation for the relationship. The importance of world markets as a variable is also established and in our case both the US market and the Euro area markets tested significant. All time-varying correlations estimated showed a strong negative relationship between stock prices and exchange rates. On the contrary, the DCC method did leave some unanswered questions since no strongly significant driving force of the relationship could be established. A solution to that problem and a possible task for further studies may be to add new variables to the model and switch out others. Since the time-varying correlations suggest a strong relationship there should exist a model that includes significant variables driving the relationship.

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Appendix A: Unit root test results

Table 10

Augmented Dickey-Fuller unit root test results (Euro area as world markets)

	S_t^D	P_t^D	P_t^{EUR}
Iceland			
Jan 2003-Jan 2014	-1.4457	-0.9438	-1.6930
Jan 2003-Dec 2008	0.1643	1.0501	-0.6985
Dec 2008-Jan 2014	-1.3653	-1.4798	-1.8235
Norway			
Jan 2003-Jan 2014	-3.2519**	-2.5147	-1.7781
Sweden			
Jan 2003-Jan 2014	-2.0047	-1.9789	-1.7781
Hungary			
Jan 2003-Jan 2014	-3.1363**	-2.0258	-1.5917

Note: Lag length is based on SIC. Critical values are -3.4847 (1%), -2.8852 (5%) and -2.5795 (10%) respectively. ** and * denote 1% and 5% significant levelsThe Constant is an exogenous variable. No trend included.

Table 11

Augmented Dickey-Fuller unit root test results (USA as world markets)

	S_t^D	P_t^D	P_t^{EUR}
Iceland			
Jan 2003-Jan 2014	-1.5549	-1.7885	-0.9438
Jan 2003-Dec 2008	-1.1671	-1.3943	1.0501
Dec 2008-Jan 2014	-1.2296	-0.7849	-2.7369*
Norway			
Jan 2003-Jan 2014	-2.7906*	-1.5286	-2.5147
Sweden			
Jan 2003-Jan 2014	-3.2470**	-1.7885	-1.9789
Hungary			
Jan 2003-Jan 2014	-2.9941**	-1.0232	-2.0258

Note: Lag length is based on SIC. Critical values are -3.4847 (1%), -2.8852 (5%) and -2.5795 (10%) respectively. ** and * denote 1% and 5% significant levelsThe Constant is an exogenous variable. No trend included.

Appendix B: Johansen co-integration test statistics

Table 12
Cointegrations tests (Excluding the USA as a representative of world markets)

	Johansen test statistic H_0: r = 0	H_0: r ≤ 1
Iceland		
Jan 2003-Jan 2014	13.18	1.28
Jan 2003-Dec 2008	10.33	0.14
Dec 2008-Jan 2014	42.12**	0.76
Norway		
Jan 2003-Jan 2014	20.44**	6.03*
Sweden		
Jan 2003-Jan 2014	23.94**	4.17*
Hungary		
Jan 2003-Jan 2014	19.79*	2.37

Note: ** and * denote 1% and 5% significance levels. The critical values are 15.41 and 20.04 for r = 0 and 3.76 and 6.65 for r ≤ 1.

Table 13
Cointegrations tests (Excluding the Euro area as a representative of world markets)

	Johansen test statistic H_0: r = 0	H_0: r ≤ 1
Iceland		
Jan 2003-Jan 2014	33.56**	1.13
Jan 2003-Dec 2008	13.12	0.23
Dec 2008-Jan 2014	27.79**	0.09
Norway		
Jan 2003-Jan 2014	19.60*	7.71**
Sweden		
Jan 2003-Jan 2014	9.45	3.48
Hungary		
Jan 2003-Jan 2014	18.11*	2.16

Note: ** and * denote 1% and 5% significance levels. The critical values are 15.41 and 20.04 for r = 0 and 3.76 and 6.65 for r ≤ 1.

Appendix C: Test of exclusion restrictions

Table 14

Test of exclusion restriction where USA represents world markets

	P^D	S^D	P^{US}
Iceland			
Jan 2003-Jan 2014	16.12****	16.54****	7.63****
Jan 2003-Dec 2008	0.08	0.85	0.31
Dec 2008-Jan 2014	32.76****	5.57***	10.97****
Norway	8.16****	4.18***	2.36*
Sweden	3.52**	2.91**	0.21
Hungary	1.15	8.47****	0.45

Note: Values are Chi-square statistics with one degree of freedom.1%, 5%, 10% and 20% respectively
****,***,**,* denote 1%, 5%, 10% and 20% significance levels respectively

Table 15

Test of exclusion restriction where Euro area represents world markets

	P^D	S^D	P^{EU}
Iceland			
Jan 2003-Jan 2014	11.74****	14.12****	0.53
Jan 2003-Dec 2008	0.25	2.30*	0.06
Dec 2008-Jan 2014	14.75****	16.72****	1.41
Norway	8.16****	4.18***	2.36*
Sweden	3.52**	2.91**	0.21
Hungary	0.16	13.64****	0.11

Note: Values are Chi-square statistics with one degree of freedom.1%, 5%, 10% and 20% respectively
****,***,**,* denote 1%, 5%, 10% and 20% significance levels respectively