VSB – TECHNICAL UNIVERSITY OF OSTRAVA
FACULTY OF ECONOMICS

DEPARTMENT OF ECONOMY

The Relationship Between the Exchange Rate and Financial Markets

Vzájemné souvislosti mezi měnovým kurzem a finančními trhy

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1 Introduction

Over the past few decades, many countries have adopted floating exchange rates and there has been an increased interest among academics, economic policy makers and investors in research on the relationship between exchange rates and the stock markets (Dahir *et al*. 2018). The interest of these groups is understandable. Knowing whether there is a negative or positive relationship between the exchange rate and the stock market in some countries, or knowing which variable is leading and which is lagging is useful in several respects. For investors who invest in financial markets, this information can help them to choose a better investment strategy and to make better profits on their investments. It is important to know the relationship between these variables at different periods, as institutional investors are likely to invest over longer periods than, for example, short-term speculators, who often use financial derivatives in their speculation and are likely to have shorter periods than institutional investors. To identify short-term and long-term co-movements between the exchange rate and the stock market, it is important to use a more advanced analytical method to identify co-movements over different periods. Another group for whom it is important to know the relationship between the exchange rate and the stock market are economic policy makers. For example, if it is true that one variable leads the other during financial crises, then based on these findings economic policy makers can take measures to improve the stability of the financial market in a given country. If, for example, the exchange rate is lagging and the stock market is leading, economic policy makers can be better prepared for a possible exchange rate fluctuation in advance and ensure better exchange rate stability. Ultimately, these findings serve to enrich scientific knowledge and better understand how the economic system around us works.

The research objective of the thesis is to empirically investigate the relationship between exchange rate and stock market. Empirical research is conducted for four countries, namely Brazil, Canada, Norway, and Russia. These are countries that are major crude oil exporters (Jiang *et al*. 2022), and their stock markets are dependent on the energy sector more than in non-oil producing countries (MSCI 2023f). For investors looking to invest in the energy sector it is good to know to if there is a positive or negative co-movement between the exchange rate and the stock market in these countries, and if the exchange rate lags behind the stock market, or conversely the stock market lags behind the exchange rate. Moreover, with time-frequency analysis, we can determine at which periods the co-movement is present and whether the leading variable is the exchange rate or the stock market.

There are two main concepts that explain the relationship between the exchange rate and the stock market, namely the flow-oriented model and the stock-oriented model. Under the flow-oriented model, the exchange rate affects the stock prices, while under the stock-oriented model the stock prices affect the exchange rate. The first concept is the flow-oriented model, which was introduced by Dornbusch and Fischer (1980), also called as the goods market approach or balance of trade model. The flow-oriented model tells us that as the domestic currency depreciates, domestic exports will become more competitive, leading to higher output of pro-exporting companies in the domestic economy and higher exports, which will translate into higher profits for pro-exporting companies and thus higher stock prices. Conversely, the appreciation of the domestic currency will lead to a decline in the stock prices of pro-exporting companies (Wong 2017). On the other hand, for pro-importing companies, the polarity is reversed. If the domestic currency appreciates, imports become cheaper, which will lead to an increase in the profitability of pro-importing companies, which in turn will lead to an increase in their stock prices. In the context of currency depreciation, the situation is reversed (Salisu & Ndako 2018).

The second concept is the stock-oriented model. This concept is divided into two strands, namely the portfolio balance model and the monetary model. The portfolio balance model was introduced by Branson (1983) and Frankel (1983). This theory is based on the fact, that investors follow the growth of the stock prices (Salisu & Ndako 2018). Increased capital flows into the domestic country will cause the domestic currency to appreciate through increased demand for money. This indicates a negative relationship between the exchange rate and stock prices. On the other hand, the monetary model (Gavin 1989) tells us that an increase in stock prices will increase the rate of return, which translates into money becoming less attractive, causing the demand for money to fall (Xie *et al.* 2020). This phenomenon will cause a subsequent increase in the exchange rate. In this case, this indicates a positive relationship between the exchange rate and the stock prices.

In the thesis, the currencies of the analyzed countries are used against the US dollar. The exchange rates used are BRL/USD, CAD/USD, NOK/USD, and RUB/USD. The stock markets are represented by stock indices. Specifically, these are the MSCI Brazil

Index, the MSCI Canada Index, the MSCI Norway Index and the MOEX Russia Index. Monthly data from January 2000 to January 2023 are used in the thesis.

In the thesis the time series are transformed using logarithmic differences. Based on Jarque-Bera test, the time series show better normality distribution after transformation. Therefore, the transformed time series are used in the analytical part of the thesis.

Wavelet analysis is used as a main research method in the thesis. It is a time-frequency analysis. Since it is a time-frequency analysis, its advantage over the standard methods used in econometrics, that work only in the time domain, is that wavelet analysis works also in the frequency domain. Wavelet analysis has been used to assess the relationship between the exchange rate and the stock market in several studies, for example, Andrieș *et al*. (2014) investigated the co-movement between the exchange rate, the interest rate, and the stock market using monthly data in India during the period from July 1997 to December 2010. In the study of Dahir *et al*. (2018), they investigated the co-movement between the exchange rate and the stock market using daily data in BRICS countries during the period from January 1, 2006, to December 31, 2016. Another study that investigated the co-movement between the exchange rate and the stock market using wavelet analysis is the study of Afshan *et al*. (2018), which investigated the co-movement in Pakistan using weekly data from 1997 (w1) to 2016 (w14) for the USD/PKR exchange rate, for the EUR/PKR, the YEN/PKR and the GBP/PKR exchange rates from 1999 (w1) to 2016 (w14) and for the CNY/PKR exchange rate from 2009 (w36) to 2016 (w14).

The results of the wavelet analysis show that there are statistically significant co-movements between the exchange rate and the stock market, represented by the stock index, for all countries. In most cases, there is a negative co-movement between the exchange rate and the stock index. In some cases, the leading variable is the stock index, but it seems in most cases the leading variable is the exchange rate. The co-movement is most pronounced around the global financial crisis from 2007 to 2010; when at a period of about 8 to 32 months, in all countries the exchange rate is the leading variable, and the stock index is lagged, indicating the flow-oriented model. Furthermore, during major events such as the dot-com bubble in the early 2000s, the already mentioned global financial crisis around 2007-2010, the commodity price slump from mid-2014 to early 2016, the covid shock around 2020 or the very recent event of the Russian invasion of Ukraine which started in February 2022 and is still ongoing these days, statistically significant co-movements occur at short periods.

The remainder of the thesis is organized as follows. Chapter 2 presents the theoretical background of the exchange rate. This chapter also presents the theoretical concepts of the relationship between the exchange rate and the stock market, including empirical evidence from high quality impacted journals. Chapter 3 introduces the stock indices and exchange rates that are used in the analysis. In addition, descriptive statistics are performed in this chapter. Chapter 4 presents empirical results from the wavelet analysis, including a robustness analysis section. The conclusion is contained in chapter 5.

2 Theory of the Exchange Rate and Its Determinants

The theoretical background of the exchange rate is presented in this chapter. The difference between the nominal and the real exchange rate and the form of exchange rate quotation in direct and indirect form is presented in subsection 2.1.

The difference between fixed and floating exchange rate regimes is discussed in subsection 2.2. For clarity, the current IMF classification of currency regimes is presented.

Subsection 2.3 presents the theoretical concepts of exchange rate determination. The theoretical concepts of uncovered interest rate parity (UIRP), covered interest rate parity (CIRP) and the Fisher effect are introduced. The theory of purchasing power parity in its various forms is presented. The Balassa-Samuelson effect is also presented.

Subsection 2.4 presents two main theoretical concepts that explain the relationship between the exchange rate and the stock market, which are the flow-oriented model and the stock-oriented model. This subsection is also presenting the empirical evidence on this topic. Considering the topic, the thesis deals with, this subchapter is crucial. To ensure the quality of the empirical evidence, only reputable, impacted journals are used. Since the topic of the relationship between exchange rate and stock market is not so widespread in academic spheres, this part of the chapter may be enriching even for experienced academics who are working on exchange rate issues and will gain important insights in their future academic career.

2.1 Nominal and Real Exchange Rates

This subsection introduces the nominal and real exchange rates. The difference between the direct and indirect form of quotations is also presented. For the Czech Republic, the direct quotation is typical, where we express the number of units of domestic currency for one unit of foreign currency. In assessing exchange rate changes, the issue of direct or indirect quotation is important because in direct quotation, when the exchange rate rises, the domestic currency depreciates and, conversely, when the exchange rate falls, the domestic currency appreciates. Appreciation means that we can buy more foreign goods per unit of domestic currency, whereas depreciation means that we can buy less foreign goods per unit of domestic currency (Mankiw 2020). In an indirect quotation, when the exchange rate rises, the currency appreciates and when the exchange rate falls, the currency depreciates. Direct quotation is used in the empirical analysis of the thesis and therefore it is important to keep in mind the inverse relationship between exchange rate rise and currency appreciation.

2.1.1 Nominal Exchange Rate

We can easily say that nominal exchange rate is price of one currency determinate by price of other currency (Mankiw 2020). For example, an exchange rate of 20 CZK/USD means that the person needs 20 units of CZK to buy one unit of USD. As already mentioned above, there are two forms of exchange rate quotation, which are (Frait 1996):

- direct quotation – the exchange rate expresses the number of units of domestic currency per unit of foreign currency (typical for the Czech Republic),
- indirect quotation – the exchange rate expresses the number of units of foreign currency per unit of domestic currency (typical for the USA).

2.1.2 Real Exchange Rate

The real exchange rate expresses the purchasing power of the domestic currency against foreign goods. As Mankiw (2020) mentions in his famous textbook, it is the rate at which the goods of one country are exchanged for the goods of another country. Like the nominal exchange rate, the real exchange rate can be written in two forms (Frait 1996; Mankiw 2020):

direct quotation:

$$Real\ Exchange\ Rate = \frac{Nominal\ Exchange\ Rate\ \cdot Foreign\ Price}{Domestic\ Price}, \tag{2.1}$$

indirect quotation:

$$Real\ Exchange\ Rate = \frac{Nominal\ Exchange\ Rate\ \cdot Domestic\ Price}{Foreign\ Price}. \tag{2.2}$$

2.2 Exchange Rate Regimes

In this section we come to the exchange rate regimes. The term exchange rate regime refers to how a country's exchange rate is managed. In general, exchange rate regimes can be divided into floating and fixed regimes. As mentioned by Jílek (2013), a fixed exchange rate regime is an exchange rate regime where the central bank or other central government institution maintains the exchange rate against a reference currency through foreign exchange interventions, while a floating exchange rate regime is a market-dependent exchange rate regime. When the central bank or other institution does not intervene in the exchange rate by foreign exchange interventions, we can speak of a clean floating exchange rate regime. If a central bank or other institution influences the exchange rate, then it is a managed or independent floating exchange rate. Managed means that the exchange rate is influenced by foreign exchange interventions to achieve a target exchange rate, while independent means that the exchange rate is influenced by foreign exchange interventions without achieving a certain target exchange rate (Jílek 2013). This is the general division of the exchange rate regimes.

In the thesis, for the sake of clarity, the current breakdown of the exchange rate regimes according to the International Monetary Fund (IMF) is presented. Figure 2.1 shows three main categories of the exchange rate regimes: Hard pegs, Soft pegs (Intermediate) and Floating. Hard pegs mean no flexibility of the exchange rate. Floating regimes imply free movement of the currency's price relative to other currencies. In between these two variants there is a variety of intermediate exchange rate regimes called soft pegs (IMF 2021a).

Figure 2.1: Exchange rate regimes, source: (IMF 2021a), own creation

Figure 2.2 shows a more detailed classification of exchange rate regimes by IMF. This classification is effective from February 2, 2009, and reflects an attempt to provide greater consistency and objectivity of exchange rate classifications across countries and to improve the transparency of the IMF's bilateral and multilateral surveillance in this area (IMF 2021b). The IMF's explanation of the different currency regimes in the Figure 2.2 can be found in (IMF 2009).

Type	Categories				
Hard pegs	Exchange arrangement with no separate legal tender	Currency board arrangement			
Soft pegs	Conventional pegged arrangement	Pegged exchange rate within horizontal bands	Stabilized arrangement	Crawling Peg	Crawl-like arrangement
Floating regimes (market determined rates)	Floating	Free floating			
Residual	Other managed arrangement				

Figure 2.2: Classification of exchange rate arrangements, source: (IMF 2021b, p. 1), own creation

2.3 Determination of Exchange Rate

In this part of the chapter, the theoretical concepts of exchange rate determination are presented. Uncovered interest rate parity and covered interest rate parity are presented first. The Fisher effect is presented next. Next, the theory of purchasing power parity with different forms is introduced. The Balassa-Samuelson effect is also introduced. As an aggregate of several theoretical concepts together is presented the model of parity conditions.

2.3.1 Uncovered Interest Rate Parity

For simplicity, uncovered interest parity is based on the domestic interest rate, the foreign interest rate, and the current exchange rate. We use these three variables to determine the future expected exchange rate. According to Frait (1996) the foreign exchange market is in equilibrium when the exchange rate is such that economic subjects want to hold exactly the quantities of foreign and domestic assets that are on offer. The equilibrium condition is that foreign and domestic assets offer the same expected rate of return. This means that the domestic interest rate must balance equal to the foreign interest rate and the expected rate of change of the exchange rate. In the foreign exchange market, the following equation applies (Frait 1996):

$$i_D = i_F + \frac{E^e_{t+1} - E_t}{E_t} = i_F + \%\Delta E^e, \tag{2.3}$$

where i_d is domestic interest rate, i_F is foreign interest rate, E_t is exchange rate in time t, E^e_{t+1} expected exchange rate in time $t+1$, $\%\Delta E^e$ is percentage change in exchange rate. To interpret uncovered interest rate parity, it is useful to modify the equation as follows (Frait 1996):

$$\frac{E_{t+1}^e - E_t}{E_t} = \%\Delta E^e = i_D - i_F. \tag{2.4}$$

According to Frait (1996), if the domestic interest rate is higher than the foreign interest rate ($i_D > i_F$), the domestic currency is expected to depreciate in the future ($E^e_{t+1} > E_t$), because it will compensate the higher interest rate. However, if the domestic interest rate is lower than the foreign interest rate ($i_D < i_F$), the domestic currency is expected to appreciate in the future ($E^e_{t+1} < E_t$), because it will compensate the lower interest rate. From the uncovered interest parity condition, the adjustment can be used to obtain a relationship for the current exchange rate (Frait 1996):

$$E_t = E_{t+1}^e \cdot \frac{1 + i_F}{1 + i_D}. \tag{2.5}$$

Figure 2.3 shows the uncovered interest rate parity relationship. The difference between interest rates corresponds to percentage change of the exchange rate. For example, if the difference between the domestic interest rate and the foreign interest rate is 2%, then according to uncovered interest rate parity this corresponds to a 2% change of the exchange rate.

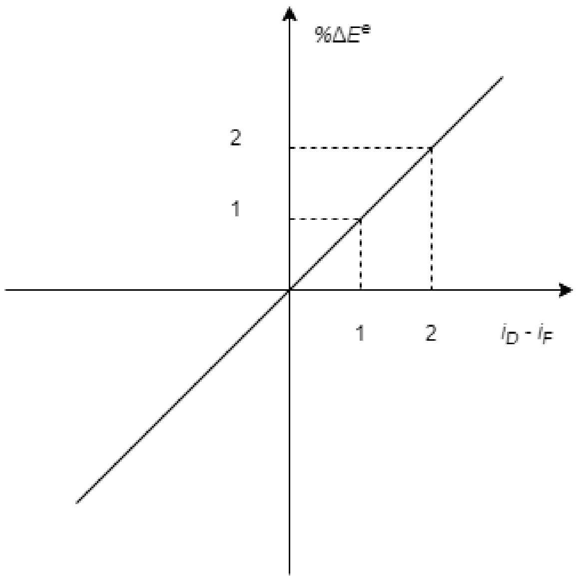

Figure 2.3:Uncovered interest rate parity relationship, source: (Frait 1996, p. 67), own creation

Figure 2.4 shows the uncovered interest rate parity cycle for better interpretation. The initial investment of 100 CZK is exchanged at the rate of 25 CZK/EUR at time t. This corresponds to 4 EUR. Subsequently, this investment bears interest at a rate of 5% per annum. After one year, the investment is worth 4.2 EUR. Subsequently, the investment is exchanged at the expected exchange rate of 26.19 CZK/EUR, which subsequently amounts to 110 CZK.

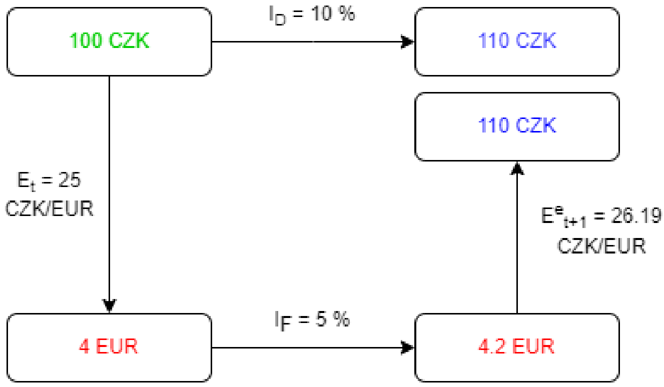

Figure 2.4: Uncovered interest rate parity cycle, source: own creation

The result is therefore the same if the investor had invested 100 CZK in the domestic currency at a domestic annual interest rate of 10%. After one year, the investor would also receive 110 CZK.

2.3.2 Covered Interest Rate Parity

Covered interest parity is very similar to uncovered interest rate parity. The name already implies that something will be covered (agreed in advance). Instead of the expected exchange rate, we use the forward exchange rate. This means that the result of the transaction is a foregone conclusion. Covered interest rate parity ensures equality of returns from domestic and foreign covered investments and is defined as (Frait 1996):

$$i_D - i_F = \frac{F_t - E_t}{E_t}, \tag{2.6}$$

where F_t is forward exchange rate in time t, E_t is exchange rate in time t, i_D is domestic interest rate and i_F is foreign interest rate.

Figure 2.5 shows covered interest rate parity relationship. The difference between interest rates corresponds to the difference in the percentage change of forward exchange rate relative to the current exchange rate. For example, if the difference between the domestic interest rate and the foreign interest rate is 2%, then according to covered interest rate parity this will result in a 2% difference between the forward and current exchange rates relative to the current exchange rate.

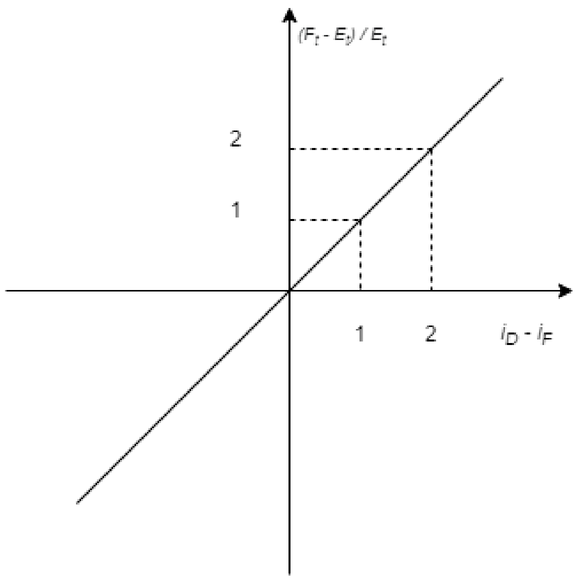

Figure 2.5: Covered interest rate parity relationship, source: (Frait 1996, p. 71), own creation

Figure 2.6 shows the covered interest rate parity cycle for better interpretation. The initial investment of 100 CZK is exchanged at the rate of 25 CZK/EUR at time t. This corresponds to 4 EUR. Subsequently, this investment bears interest at a rate of 5% per annum. After one year, the investment is worth 4.2 EUR. Subsequently, the investment is exchanged at the forward exchange rate of 26.19 CZK/EUR, which subsequently amounts to 110 CZK. The result is therefore the same if the investor had invested 100 CZK in the domestic currency at a domestic annual interest rate of 10%. After one year, the investor would also receive 110 CZK.

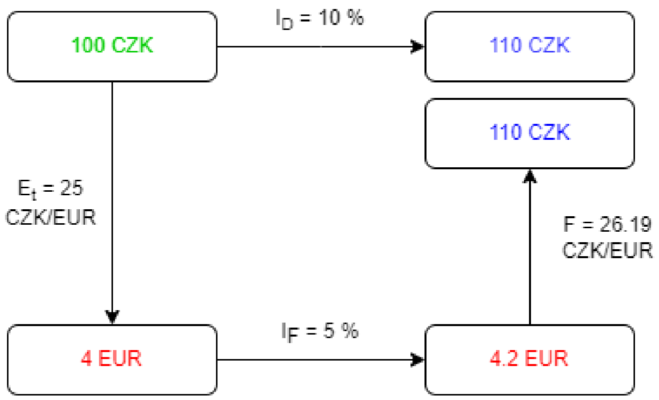

Figure 2.6: Covered interest rate parity cycle, source: own creation

Compared to uncovered interest rate parity, here the future exchange rate is already determined in advance whereas in uncovered interest rate parity the exchange rate is expected to change based on interest rates in the domestic and foreign country.

2.3.3 Fisher effect

The Fisher effect tells us that the nominal interest rate in each country is determined by two factors: the real rate of return and the ex-ante expected inflation rate. The nominal interest rate is then (Frait 1996):

$$i = r + \pi^e + r \cdot \pi^e, \tag{2.7}$$

where i is nominal interest rate, r is real rate of return and π^e is ex-ante expected inflation rate. A generalized version of the Fisher effect argues that if the real interest rate, i.e., the exchange rate between today's goods and future goods, were to vary from one country to another, arbitrage between rewards and foreign markets should occur in the form of capital flows. These flows should equalize the real interest rates of different countries at the same level ($r_D = r_F$) (Frait 1996).

In equilibrium, the difference between domestic and foreign nominal interest rates should correspond to the difference between domestic and foreign expected inflation rates. In other words, a country with a higher inflation rate should have a higher level of nominal interest rates than a country with a lower inflation rate. A generalized version of the Fisher effect can then be written as (Frait 1996):

$$(1 + \pi_D{}^e)/(1 + \pi_F{}^e) = (1 + i_D)/(1 + i_F). \tag{2.8}$$

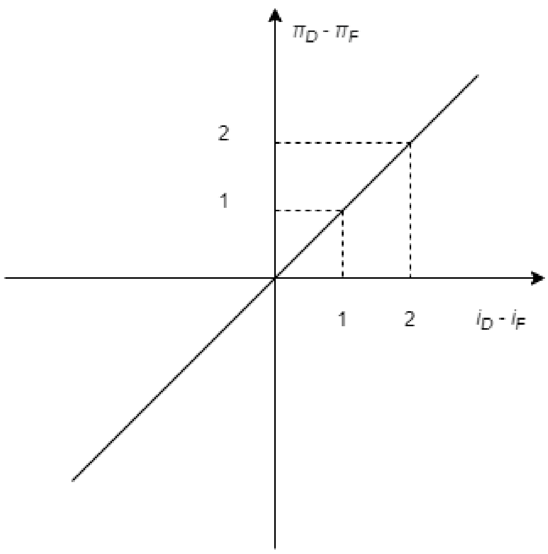

Figure 2.7: Fisher effect relationship, source: (Frait 1996, p. 70), own creation

Figure 2.7 shows Fisher effect relationship. The difference between interest rates corresponds to the difference in inflation rates. For example, if the difference between the domestic interest rate and the foreign interest rate is 2%, then according to the Fisher effect this corresponds to a 2% difference between the domestic inflation rate and the foreign inflation rate.

2.3.4 Theory of Purchasing Power Parity

Purchasing power parity theory is used to determine the exchange rate in the long term. The main determinants of the exchange rate are the price levels or inflation rates of the respective countries.

2.3.4.1 Absolute Version of the Theory of Purchasing Power Parity and ERDI Coefficient

The absolute version of the purchasing power parity theory is based on the law of one price (Krugman *et al*. 2015). The law of one price states that the prices of identical internationally traded goods must be the same in all countries. Purchasing power parity theory argues that exchange rates change to maintain the purchasing power parity of the currencies being compared. According to this theory, commodity prices are relatively fixed and the restoration of the equilibrium relationship between the domestic price level P_D and the foreign price level P_F takes place through a change in the exchange rate E and not through a change in domestic and foreign prices (Mandel & Durčáková 2020). The equilibrium exchange rate according to the absolute version of the parity theory E_{PPP} can therefore be expressed by the relation (Mandel & Durčáková 2020):

$$E_{PPP} = \frac{P_D}{P_F}. \tag{2.9}$$

The domestic and foreign price levels are calculated using commodity basket (sum of weighted prices of individual goods, weights w and price p) as (Mandel & Durčáková 2020):

$$P_D = \sum_{i=1}^{n} w_{D_i} \cdot p_{D_i}, \tag{2.10}$$

$$P_F = \sum_{i=1}^{n} w_{F_i} \cdot p_{F_i}. \tag{2.11}$$

The parameter by which we can determine the ratio between the market exchange rate E and the calculated value of the purchasing power parity of the E_{PPP} is the ERDI (Exchange Rate Deviation Index) parameter which is defined as (Mandel & Durčáková 2020):

$$ERDI = \frac{E}{E_{PPP}}. \quad (2.12)$$

The ERDI parameter is significantly higher than one when comparing emerging economies with advanced economies (Mandel & Durčáková 2020).

2.3.4.2 Relative Version of the Theory of Purchasing Power Parity

The relative version of purchasing power parity does not focus on the level of price levels, but on the relative (percentage) changes in price levels over the chosen period. According to the relative version of the PPP theory, the equilibrium exchange rate adjusts to the inflation differential (Krugman *et al*. 2015):

$$(E_t - E_{t-1})/E_{t-1} = \pi_D - \pi_F. \quad (2.13)$$

2.3.4.3 Generalized Version of the Theory of Purchasing Power Parity

One of the problems with the simple version of PPP theory is the assumption that it applies to all goods. If we divide goods into tradable and non-tradable, we can get a more realistic version of the PPP theory. By tradable goods we can think of goods and services that can be exported and imported, thus getting goods from one country to another. On the other hand, by non-tradable goods we can imagine goods and services that cannot be exported and imported and are therefore different in each country, e.g., hairdresser, restaurant. Then we can write (Frait 1996):

$$P_{T_D} = E \cdot P_{T_F}, \quad (2.14)$$

where P_{TD} is domestic price level of tradable goods, E is an exchange rate and P_{TF} is foreign price level of tradable goods. The aggregate price level in the domestic and foreign economy is the weighted average of the price levels of tradable and non-tradable goods and is defined as (Frait 1996):

$$P_{A_D} = w_D \cdot P_{N_D} + (1 - w_D) \cdot P_{T_D}, \quad (2.15)$$

$$P_{A_F} = w_F \cdot P_{N_F} + (1 - w_F) \cdot P_{T_F}, \quad (2.16)$$

where P_{AD} is the aggregate price level in the domestic economy, w_D is the share of domestic tradable goods in the aggregate price level and P_{ND} is the price level of domestic non-tradable goods. Variables with the $_F$ attribute are valid for foreign country. If we divide the two equations, we then get (Frait 1996):

$$P_{A_D}/P_{A_F} = [w_D \cdot P_{N_D} + (1 - w_D) \cdot P_{T_D}]/[w_F \cdot P_{N_F} + (1 - w_F) \cdot P_{T_F}]. \tag{2.17}$$

If we further divide the numerator by the expression P_{TD} and the denominator by $E.P_{TF}$, which are equivalent expressions, we then get (Frait 1996):

$$P_{A_D}/P_{A_F} = [w_D \cdot P_{N_D}/P_{T_D} + (1 - w_D)]/[w_F \cdot P_{N_F}/P_{T_F} + (1 - w_F)]. \tag{2.18}$$

If we rearrange this equation, we get a generalized version of the PPP theory (Frait 1996):

$$E = [w_F \cdot P_{N_F}/P_{T_F} + (1 - w_F)]/[w_D \cdot P_{N_D}/P_{T_D} + (1 - w_D)] \cdot P_{A_D}/P_{A_F}. \tag{2.19}$$

2.3.5 Balassa-Samuelson Effect

The Balassa-Samuelson effect was developed by Balassa and Samuelson in 1964 in their seminal papers and what is called the Balassa-Samuelson effect (Dumitru & Jiuanu 2009). The Balassa-Samuelson effect explains the differences in prices and incomes between countries due to differences in productivity (ČNB 2002). According to (Dumitru & Jiuanu 2009), increase in productivity which will have the effect of appreciating the real exchange rate can be explained as follows. Growth in productivity in the tradable sector will lead to wage growth in the tradable sector. This will lead to wage growth in the non-tradable sector. Consequently, relative prices in the non-tradable sector will increase. If productivity increases in the tradable sector in the domestic country faster than in their trading partners, this will lead to higher inflation than in their trading partners and hence an appreciation of the real exchange rate (Dumiru & Jiuanu 2009).

2.3.6 Model of Parity Conditions

The parity conditions model is a model that, based on international arbitrage in the goods and capital markets, constructs a set of equations - equilibrium conditions that apply to product prices (goods and services), capital prices (interest rates) and money prices (spot and forward exchange rates) (Frait 1996).

Figure 2.8 shows the model of parity conditions. The model is based on three differences (Frait 1996, p. 83-84):

- the difference between the domestic inflation rate and the foreign inflation rate,
- the difference between the domestic nominal interest rate and the foreign nominal interest rate,
- the difference between the spot and forward exchange rate (forward premium or discount).

The future exchange rate is determined by the three differences and a total of five parity conditions, which are (Frait 1996, p. 83-84):

1. FE (Fisher Effect) - according to the fisher effect, the difference between the domestic nominal interest rate and the foreign nominal interest rate is determined by the difference between the domestic expected inflation rate and the foreign expected inflation rate,
2. CIRP (Covered Interest Rate Parity) - term premium or discount (F_t/E_t) is determined by the difference between the domestic nominal interest rate and the foreign nominal interest rate,
3. Relative PPP (Relative Version of The Theory of Purchasing Power Parity) - The relative version of PPP theory states that the expected future exchange rate is determined by the difference between the domestic expected inflation rate and the foreign expected inflation rate,
4. UIRP (Uncovered Interest Rate Parity) - This condition states that the expected future exchange rate is determined by the difference between the domestic nominal interest rate and the foreign nominal interest rate,
5. UFR (Forward Rate as Unbiased Predictor of Future Spot Rate) - This condition states that if the foreign exchange market is efficient, the forward exchange rate must reflect prevailing expectations about the future exchange rate.

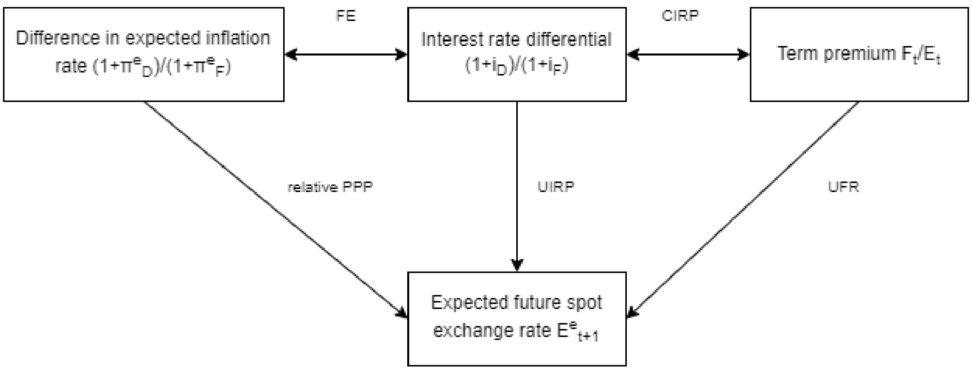

Figure 2.8:Model of parity conditions, source: (Frait 1996, p. 83), own creation

2.4 Theoretical Concepts of Relationship Between Exchange Rate and Stock Market and Its Empirical Evidence

This part of the chapter introduces two main theoretical concepts of the relationship between the exchange rate and the stock market. Next, empirical evidence on the relationship between the exchange rate and the stock market is presented.

2.4.1 Theoretical concepts

The first theoretical concept is the flow-oriented model also called as the goods market approach or balance trade of model developed by Dornbusch and Fischer (1980) (Dahir *et al*. 2018; Tian *et al.* 2023). The flow-oriented model is based on the current account. It tells us that the exchange rate will have an impact on international competitiveness and the balance of trade, thereby affecting countries outputs and thus affecting stock prices (Sui & Sun 2016). If the domestic currency appreciates, this will affect the profits of domestic pro-exporting companies as they become less competitive and hence their stock prices are expected to decline. However, if the domestic currency depreciates, the competitiveness of domestic pro-exporting companies will increase, thus increasing profitability and the stock prices are expected to rise (Dahir *et al*. 2018).

On the other hand, for companies that are pro-importing based, the polarity is reversed. If the domestic currency appreciates, imports become cheaper, which will lead to an increase in the profitability of pro-importing companies, which in turn will lead to an increase in their stock prices. If the domestic currency depreciates, the situation is reversed (Tian *et al.* 2023).

The second theoretical concept is the stock-oriented model. The stock-oriented model tells us that the direction goes from stock prices towards the exchange rate. The stock-oriented model is divided into two mechanisms (Tian *et al*. 2023). The first mechanism is the portfolio balance model proposed by Branson (1983) and Frankel (1983) (Dahir *et al*. 2018). This theory assumes that the exchange rate is affected by stock prices movements via the capital account (Sui & Sun 2016). The portfolio balance model is based on that stock prices movements lead money to flow into or out of the country, which affects the demand for money, the change in interest rates and the change in the exchange rate (Sui & Sun 2016). In simple terms, it can be said that increase in the domestic stock prices will cause an appreciation of the domestic currency and, conversely, a decrease in the domestic stock prices will cause a depreciation of the domestic currency. In this case, there is a negative relationship between the exchange rate and the stock market (Dahir *et al*. 2018).

The second mechanism is the monetary model (Gavin 1989). This mechanism is based on the fact, that an increase in the stock market will lead to a higher rate of return and the wealth of domestic investors, which in turn will cause a decline in the demand for money and a subsequent increase in the domestic price level, which will cause an increase in the exchange rate through PPP. In this case, there is a positive relationship between the exchange rate and the stock market (Xie *et al*. 2020; Tian *et al*. 2023).

2.4.2 Empirical evidence

Several studies have examined the relationship between the exchange rate and the stock market. Although theories suggest causal relationship between those variables, the empirical evidence of the relationship between exchange rate and stock prices is mixed (Wong 2017).

Liu and Wan (2012) focused on studying the relationship between the CNY/USD exchange rate and the Shanghai stock market. They used daily data from July 22, 2005, to July 15, 2011. Using a nonparametric causal test, they find that there are short-run co-movements between the exchange rate and the stock market. In the long period, they did not find a causal relationship.

Tsai (2012) studied the relationship between exchange rate and stock price in six Asian countries (Singapore, Thailand, Malaysia, the Philippines, South Korea, and Taiwan). In the study was used monthly data from January 1992 to December 2009. The method used was a quantile regression model. Based on the empirical results, it was found that a stock-oriented model exists in all countries.

Caporale *et al*. (2014) studied linkages between stock market prices and exchange rates in the US, the UK, Canada, Japan, the Euro area and Switzerland using weekly data from August 2003 to December 2011. They found that the estimation of bivariate UEDCC-GARCH models provides evidence of unidirectional short-run Granger causality from stock returns to exchange rate changes in the US and the UK, in the opposite direction in Canada, and of bidirectional feedback in the euro area and Switzerland during the banking crisis between 2007 and 2010.

Bashir *et al*. (2016) studied dynamics of the relationship between foreign exchange markets and stock markets in four Latin American countries, namely, Brazil, Mexico, Chile, and Argentina. They used monthly data for Brazil from April 1993 to February

2015, for Mexico from November 1991 to February 2015, for Chile from October 1996 to February 2015, and for Argentina from October 1993 to February 2015. They used a DCCA method. For Brazil, Chile, and Argentina they found weak positive cross-correlation. For Mexico they found strong positive cross-correlation for longer time scale.

Wong (2017) studied the relationship of the real exchange rate and real stock price returns in Malaysia, the Philippines, Singapore, South Korea, Japan, the United Kingdom, and Germany. Based on CCC/DCC-MGARCH models, it was found that the exchange rate and the stock market are strongly correlated during the period of the financial crises. However, the study did not find a correlation in the long period. Based on the Granger causality test, it was found that the flow-oriented model holds for Malaysia and South Korea. On the other hand, the stock-oriented model holds for the Philippines and Singapore.

Dahir *et al*. (2018) studied dynamic links between exchange rates and stock returns in Brazil, Russia, India, China, and South Africa (BRICS countries). The study was based on wavelet analysis. They used daily data from January 1, 2006, to December 31, 2016. The study found that relationship between exchange rates and stock returns are negative in the medium and long-term, indicating that exchange rates lead stock returns in Brazil and Russia. In India, however, they found positive relation, where stock returns lead exchange rate in 64-128-day scales over the periods 2008, 2010-2012 and 2012-2015. South Africa seems to have a more bidirectional lead/lag relationship and the Chinese index pair did not show any correlation.

Xie *et al*. (2020) focused on studying the relationship between exchange rate and stock market in 20 advanced economies and 6 emerging economies. They used daily data from January 1, 1998, to May 20, 2019. Based on symmetric and asymmetric bootstrap panel Granger non-causality tests, they found as a main result that the stock prices can predict the exchange rates.

Tian *et al*. (2023) studied the relationship between exchange rate and stock market in Brazil, Chile, Hungary, India, Mexico, Philippines, Poland, Russia, South Africa, and Thailand. Using daily data from 3 January 2003 to 30 December 2021 they found a negative relationship between the exchange rate and the stock market.

2.5 Chapter Summary

The chapter discusses the theoretical background of the exchange rate and its determinants. In subsection 2.1, the difference between the nominal and real exchange rates is presented. In addition, this subsection outlined the difference between direct and indirect forms of exchange rate quotation. It is important to distinguish the difference between an increase of a country's exchange rate and the appreciation of a country's currency. In the thesis, a direct exchange rate quotation is used for the analyzed countries, so it is important to keep in mind the inverse relationship an increase of a country's exchange rate and the appreciation of that country's currency.

Exchange rate regimes are discussed in subsection 2.2. The basic difference between fixed and floating exchange rate regimes is presented. It is also mentioned the current IMF classification of exchange rate regimes.

In subsection 2.3 the basic theoretical concepts on exchange rate determination are introduced. Uncovered interest rate parity, covered interest rate parity and the Fisher effect are presented. The theory of purchasing power parity in absolute, relative, and generalized form is also presented. Next, the Balassa-Samuelson effect is presented.

In subsection 2.4 the theoretical concepts of the relationship between the exchange rate and the stock market are presented. In standard textbooks dealing with exchange rate issues, mention of the theoretical background of the relationship between the exchange rate and the stock market is often absent, and the reader becomes acquainted with this theoretical issue probably only through academic journal articles. Further, in this part of the chapter, empirical evidence is presented from high quality impacted journals and their findings on this issue.

3 Development of Variables and Explanation of Methods Used in the Analysis

This chapter discusses the data and methods used in the analysis between the exchange rate and the stock market. Monthly data from January 2000 to January 2023 are used in the thesis. In this chapter, the exchange rates and the stock indices are presented for the four analyzed countries, namely Brazil, Canada, Norway, and Russia. The currencies of each country are referenced against the US dollar. The exchange rates have currency designations according to the ISO 4217 codes. A list of the ISO 4217 codes for individual currencies can be found in (ISO 2023).

Subsection 3.1 introduces the stock indices used in the analysis. The MSCI Brazil Index, the MSCI Canada Index and the MSCI Norway Index are selected as representative for Brazil, Canada, and Norway respectively. Due to the exclusion of the Russian stock index from the published indices within MSCI, the MOEX Russia Index is used as representative for the Russian stock market.

Subsection 3.2 presents the time paths of stock indices. All stock indices are in local currencies and start with a value of 100 from January 2000.

Subsection 3.3 presents the time paths of the individual exchange rates used in the analysis. Specifically, the exchange rates are BRL/USD, CAD/USD, NOK/USD, and RUB/USD.

Within Subsection 3.4, the time series are transformed using logarithmic differencing. Subsequently, the time paths of the transformed time series are presented.

Subsection 3.5 presents general descriptive statistics of the original and transformed time series. The Jarque-Bera test is also included in the descriptive statistics to assess whether the time series have a normal distribution.

Subsection 3.6 presents methodology. Wavelet analysis is chosen as the main method for the analysis, because of its ability to analyze in the time-frequency domain.

3.1 Stock Indices

MSCI indices are used for the analysis as representatives of stock markets in Brazil, Canada, and Norway. MSCI indices are published by MSCI company. The MSCI company is a global provider of critical decision support tools and services for the global investment community (MSCI 2023a). In short, they publish various economic and financial analyses, indicators etc. for global investment community and one of the key indicators they publish are the MSCI indices that are used in the thesis. Why MSCI indices? One of the main reasons is that MSCI indices are market-capitalization-weighted, so a change in the stock price of the companies in the index will affect the resulting index value depending on the market capitalization. The larger the company by market capitalization, the greater the weight of the company in the index and therefore the greater the impact on the resulting index value. This is an advantage compared to a price-weighted index, where a small company can have a significant impact on the index, while its share of the total market capitalization of the stock market is negligible.

Another reason why MSCI indices are used is that the MSCI indices sufficiently represent stock market in each country. Used MSCI indices cover 85% of the free float-adjusted market capitalization in each analyzed country. Free float means that the shares are freely available for trading on the stock market. For example, state-owned shares in companies are not included in the index as they do not fall into the free float category because they are not traded on the stock market.

MSCI also publishes the MSCI ALL CAP indices, which represent 99% of the free float-adjusted market capitalization in each country, but the data is only available since 2007. Moreover, MSCI publishes MSCI ALL CAP indices for only a few developed countries. For this reason, the standard MSCI indices are used with 85% of the free float-adjusted market capitalization, which is sufficiently representative of the stock market size of each country. To better capture stock market movements, the MSCI indices are used without dividends.

Following the Russian invasion of Ukraine in early 2022, Russia was removed from the MSCI indices. For this reason, the MOEX Russia Index is used as a representative of the Russian stock market. Like the MSCI indices used, the MOEX Russia Index is used without dividends.

3.1.1 MSCI Brazil Index

One of the indices that is used in the analysis is the MSCI Brazil Index. The MSCI Brazil Index is designed to measure the performance of the large and mid-cap segments of the Brazilian market. As of February 28, 2023, the index includes 48 constituents, cover approximately 85% of the free float-adjusted market capitalization in Brazil and represents a market capitalization of approximately 321 USD Billions (MSCI 2023c).

Figure 3.1 shows the top 10 constituents in the index. The largest constituent is Vale ON from materials sector, followed by Itau Unibanco PN from financials sector and Petrobras PN from energy sector.

TOP 10 CONSTITUENTS	Float Adj. Mkt. Cap (USD Billions)	Index Wt. (%)	Sector
VALE ON	62.48	19.43	Materials
ITAU UNIBANCO PN	23.60	7.34	Financials
PETROBRAS PN	23.02	7.16	Energy
PETROBRAS ON	20.49	6.37	Energy
BANCO BRADESCO PN	13.36	4.16	Financials
WEG ON	12.59	3.92	Industrials
B3	12.32	3.83	Financials
AMBEV ON (NEW)	12.12	3.77	Cons Staples
ITAUSA PN	8.04	2.50	Financials
ELETROBRAS ON	7.97	2.48	Utilities
Total	196.01	60.97	

Figure 3.1: Top 10 constituents of MSCI Brazil Index, source: (MSCI 2023c, p. 2), own creation

Figure 3.2 shows sector weights of the MSCI Brazil index. We can notice that the largest share of companies in the index is from materials sector, followed by financials sector and energy sector.

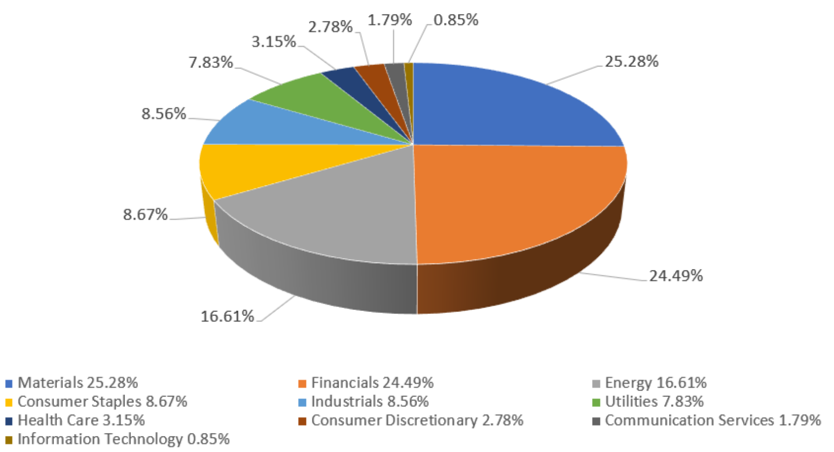

Figure 3.2: Sector weights of MSCI Brazil Index, source: (MSCI 2023c, p. 2), own creation

3.1.2 MSCI Canada Index

Another index that is used in the analysis is the MSCI Canada Index. The MSCI Canada Index is designed to measure the performance of the large and mid-cap segments of the Canadian market. As of February 28, 2023, the index includes 89 constituents, cover approximately 85% of the free float-adjusted market capitalization in Canada and represents a market capitalization of approximately 1.79 USD Trillions (MSCI 2023d).

Figure 3.3 shows the top 10 constituents in the index. The largest constituent is Royal Bank of Canada from financials sector, followed by Toronto-Dominion Bank from financials sector and Enbridge from energy sector.

TOP 10 CONSTITUENTS	Float Adj. Mkt. Cap (USD Billions)	Index Wt. (%)	Sector
ROYAL BANK OF CANADA	141.62	7.92	Financials
TORONTO-DOMINION BANK	121.37	6.79	Financials
ENBRIDGE	76.13	4.26	Energy
CP RAILWAY	70.78	3.96	Industrials
CANADIAN NATL RAILWAY	67.07	3.75	Industrials
BANK MONTREAL	63.78	3.57	Financials
CANADIAN NAT RESOURCES	63.52	3.55	Energy
BANK NOVA SCOTIA	59.26	3.32	Financials
SHOPIFY A	48.96	2.74	Info Tech
BROOKFIELD CORP A	46.87	2.62	Financials
Total	759.36	42.48	

Figure 3.3: Top 10 constituents of MSCI Canada Index, source: (MSCI 2023d, p. 2), own creation

Figure 3.4 shows sector weights of the MSCI Canada Index. We can notice that the largest share of companies in the index is from financials sector, followed by energy sector and industrials sector.

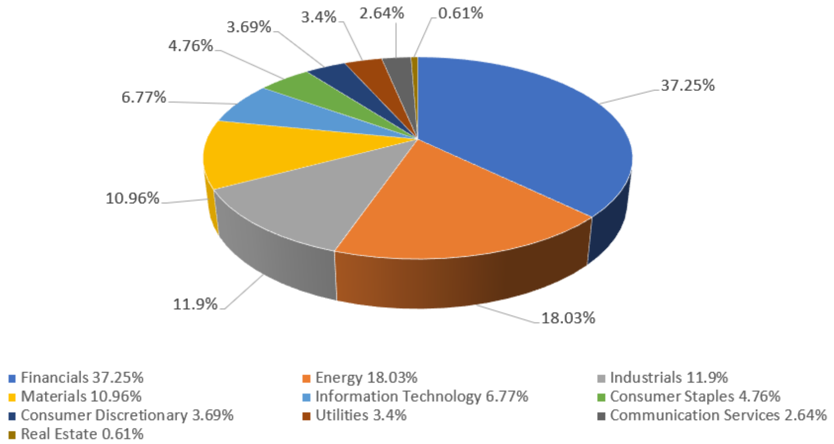

Figure 3.4: Sector weights of MSCI Canada Index, source: (MSCI 2023d, p. 2), own creation

3.1.3 MSCI Norway Index

Another index that is used in the analysis is the MSCI Norway Index. The MSCI Norway index is designed to measure the performance of the large and mid-cap segments of the Norwegian market. As of February 28, 2023, the index includes 12 constituents, cover approximately 85% of the free float-adjusted market capitalization in Norway and represents a market capitalization of approximately 107 USD Billions (MSCI 2023e).

Figure 3.5 shows the top 10 constituents in the index. The largest constituent is Equinor from energy sector, followed by DNB Bank from financials sector and Norsk Hydro from materials sector.

TOP 10 CONSTITUENTS	Float Adj. Mkt. Cap (USD Billions)	Index Wt. (%)	Sector
EQUINOR	29.48	27.61	Energy
DNB BANK	18.66	17.48	Financials
NORSK HYDRO	9.83	9.21	Materials
AKER BP	8.56	8.02	Energy
YARA INTERNATIONAL	7.91	7.41	Materials
TELENOR	7.88	7.38	Comm Srvcs
MOWI	7.18	6.73	Cons Staples
ORKLA	5.08	4.75	Cons Staples
KONGSBERG GRUPPEN	3.70	3.47	Industrials
GJENSIDIGE FORSIKRING	3.56	3.34	Financials
Total	101.85	95.40	

Figure 3.5: Top 10 constituents of MSCI Norway Index, source: (MSCI 2023e, p. 2), own creation

Figure 3.6 shows sector weights of the MSCI Norway Index. We can notice that the largest share of companies in the index is from energy sector, followed by financials sector and materials sector.

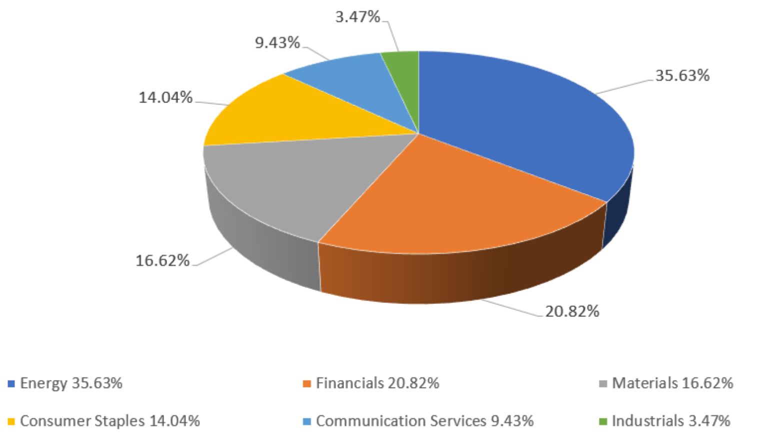

Figure 3.6: Sector weights of MSCI Norway Index, source: (MSCI 2023e, p. 2), own creation

3.1.4 MOEX Russia Index

Another index that is used in the analysis is the MOEX Russia Index. The MOEX Russia Index is designed to measure the performance of the largest and most liquid stocks of the Russian market. The most up-to-date factsheet on the official Moscow Exchange website is the factsheet from March 2021 (MOEX 2021). As of March 2021, the index includes 44 constituents, cover approximately 89,8% of the free float-adjusted market capitalization in Russia and represents a market capitalization of approximately 238 USD Billions (MOEX 2021).

Figure 3.7 shows the top 10 constituents in the index. The largest constituent is Sberbank from financials sector, followed by Gazprom from energy sector and Lukoil from energy sector.

TOP 10 CONSTITUENTS	Float Adj. Mkt. Cap (USD Billions)	Index Wt. (%)	Sector
SBERBANK	33.3	14.0	Financials
GAZPROM	31.9	13.4	Energy
LUKOIL	27.5	11.6	Energy
YANDEX N.V.	18.0	7.6	Info Tech
NORILSK NICKEL	16.9	7.1	Materials
NOVATEK	12.6	5.3	Energy
ROSNEFT	8.8	3.7	Energy
TCS GROUP HOLDING PLC	6.7	2.8	Financials
POLYMETAL	6.6	2.8	Materials
TATNEFT	5.5	2.3	Energy
Total	167.8	70.6	

Figure 3.7: Top 10 constituents of MOEX Russia Index, source: (MOEX 2021, p. 1), own creation

Figure 3.8 shows sector weights of the MOEX Russia Index. We can notice that the largest share of companies in the index is from energy sector, followed by financials sector and materials sector.

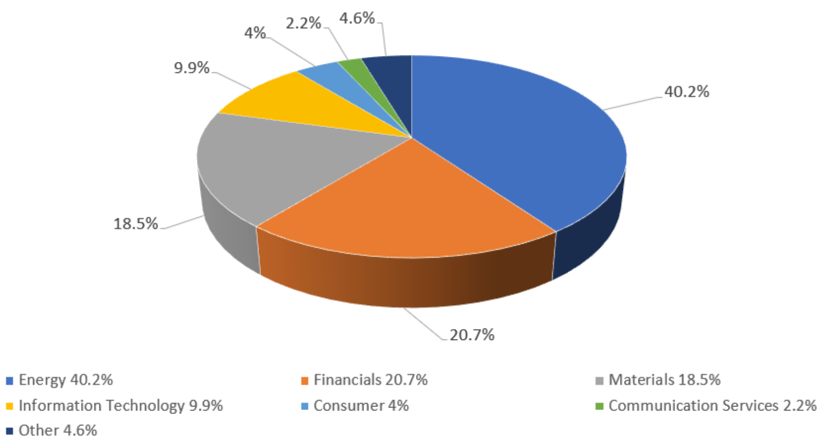

Figure 3.8: Sector weights of MOEX Russia Index, source: (MOEX 2021, p. 1), own creation

3.2 Stock Index Time Paths

In this subsection, the time paths of the individual indices are presented. Figure 3.9 shows stock index time paths of analyzed countries. All indices are in local currencies and do not include dividends.

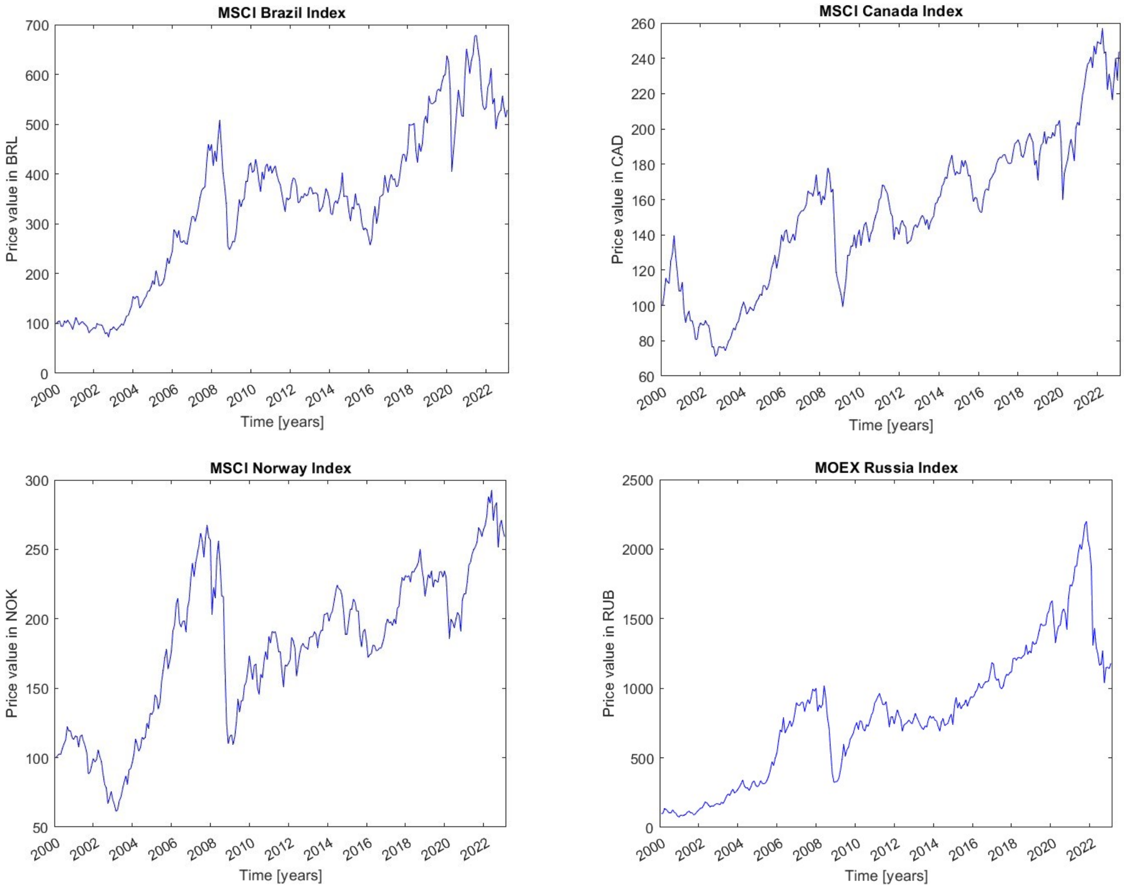

Figure 3.9: Stock index time paths of analyzed countries, source: (MSCI 2023b), own creation

3.2.1 Brazil

From the early 2000s, when the dot-com bubble burst, the MSCI Brazil Index stagnated until 2003. From 2003 onwards, the index started to rise significantly until the global financial crisis in 2008. In the second half of the year, the stock index recorded a sharp decline, as did other stock indices, around the world (MSCI 2023b). At the time, Federal Reserve Chairman Ben Bernanke after the crisis said: *"September and October of 2008 was the worst financial crisis in global history, including the Great Depression,"* (The Wall Street Journal 2014). Brazil's only economic decline during the global financial crisis was in 2009, when real GDP fell by 0.1% (The World Bank 2023a). Since the global financial crisis, the MSCI Brazil Index has stagnated and trended downwards until 2016. In 2015 and 2016, Brazil recorded an economic crisis, with real GDP falling by 3.5% in 2015 and 3.3% in 2016 (The World Bank 2023a). From 2016 onwards, the stock index started to rise until the covid crisis in 2020. During early 2020, the MSCI Brazil Index recorded sharp decline, as did stock indices around the world. On March 16, 2020, stock indices marked sharp declines around the world (MSCI 2023b). The U.S. saw a daily record drop, *"The Dow recorded its worst one-day point drop in history and its worst performance on a percentage basis since October of 1987, also known as "Black Monday,"* (CNN 2020). In the following months, however, stock indices began to rise, including the MSCI Brazil Index. Towards the end of 2021, the MSCI Brazil Index started to decline gradually until the beginning of 2023.

3.2.2 Canada

From 2000 to 2003, the MSCI Canada Index gradually declined. From 2003 to 2008, the index increased. During the global financial crisis, the index recorded a deep decline and then began a gradual increase in the value of the index. In 2009, real GDP declined by 2.9%, so Canada recorded a larger decline in GDP than Brazil (The World Bank 2023a). Towards the end of 2011, the index declined, and one possible reason could be investors' fear of another global economic crisis as the debt crisis was starting in Europe. Eurozone GDP fell by 0.8% in 2012 and 0.2% in 2013 (The World Bank 2023a). As for Canada, it did not record an economic downturn after all. The next index downturn came around the turn of 2015/2016. Canada's real GDP growth declined from 2.9% in 2014 to 0.7% growth in 2015. By 2016, GDP was already growing at 1% (The World Bank 2023a). Next, a covid shock came in 2020, when the index first declined and then began to rise significantly.

3.2.3 Norway

The dot-com bubble peaked in the early 2000s and, as in other countries, the stock index in Norway began a gradual decline until 2003. Real GDP growth gradually slowed, with 3.2% in 2000, 2.1% in 2001, 1.4% in 2002 and 0.9% in 2003. Growth accelerated in 2004, when real GDP growth was 4% (The World Bank 2023a). The MSCI Norway Index grew gradually until 2008, when the global financial crisis hit, and the stock index plummeted. In 2009, Norway recorded an economic downturn of 1.7% and compared to Canada, this was a smaller economic downturn. On the other hand, however, the stock index in Norway recorded a larger decline than in Canada. A possible reason for this could be the different composition of the stock index, with Norway having its stock index more dependent on the energy and materials sectors and the profits of companies in these sectors hanging heavily on the price of commodities. During 2008, there was a dramatic fall in commodity prices, with Brent crude oil, for example, falling significantly from its peak of 134 USD per barrel in July 2008 to only 41 USD per barrel in December 2008

(FRED 2023e). Since 2009, the index has gradually increased. It recorded a deeper decline at the turn of 2015/2016, although annual real GDP growth in those years was still positive. Subsequently, there was a significant fall during the 2020 covid crisis, when there was first a significant fall and then a significant rise in the index.

3.2.4 Russia

The MOEX Russia Index stagnated in the early 2000s. The stock index in Russia started to rise from the end of 2001, instead of from about mid-2003 as in the previous countries. A significant rise in the index occurred at the turn of 2005/2006. The index continued to rise until 2008, when the global financial crisis hit. From the second half of 2008, the stock index weakened significantly until 2009. From 1999 to 2008, real GDP growth was very high, growing at more than 5% in all years except 2002 when GDP grew by 4.7%. In 2009, however, real GDP fell by a significant 7.8% (The World Bank 2023a). From 2009 onwards, the index started to grow, but between 2011 and 2014 the index stagnated. The debt crisis in Europe and investors' fears about future developments may have played a role in this situation. The Russian economy was relatively prosperous during this period, with economic growth being positive throughout.

Since 2014, however, Russia has occupied Ukrainian Crimea and a wave of sanctions has followed. Moreover, with commodities falling since 2014, what has happened is that Russia's real GDP fell by 2% in 2015. However, in 2016, Russia was already showing moderate GDP growth, with growth reaching 0.2% (The World Bank 2023a). Although Russia recorded an economic decline in 2015, this decline was not reflected in the stock index. A possible explanation for this could be higher inflation rates and higher corporate profitability in nominal terms, with inflation in Russia hitting 15.5% in 2015 (OECD 2023). In the following years, inflation gradually declined while real GDP growth gradually increased (OECD 2023; The World Bank 2023a).

The stock index has had an upward trajectory since 2015. However, the index did not decline much during the covid crisis and continued to grow strongly from the second half of 2020. Rising commodity prices may have contributed to this growth. In particular, the price of natural gas for Europe has been rising, with the price of natural gas traded in the Netherlands reaching over 100 EUR/MWh by the end of 2021, whereas around the covid crisis in 2020 the price was even below 4 EUR/MWh (Trading Economics 2023). However, from the beginning of 2022, the index began to decline as reports began to emerge about a possible Russian attack on Ukraine and the subsequent possible derivative economic sanctions by the West. Fears were confirmed and Russia attacked Ukraine on February 24, 2022 (ČT24 2022a). In retaliation, the West imposed several sanctions on Russia. Joe Biden's speech of 24 February 2022 included these words: "*I just spoke with the G7 leaders this morning and we're in full and total agreement. We will limit Russia's ability to do business in dollars, euros, pounds, and yen, to be part of the global economy*", the full recording of Joe Biden's February 24, 2022, speech can be found in (ABC News 2022). In the days following the Russian invasion of Ukraine, the stock index recorded a deep decline that continued until the end of 2022. From the beginning of 2023, the index began to rise (Yahoo Finance 2023a).

3.3 Time Paths of Exchange Rates

In this part of the chapter, the time paths of the nominal exchange rates of the analyzed countries are presented. The nominal exchange rates of all the analyzed countries are given against the USD.

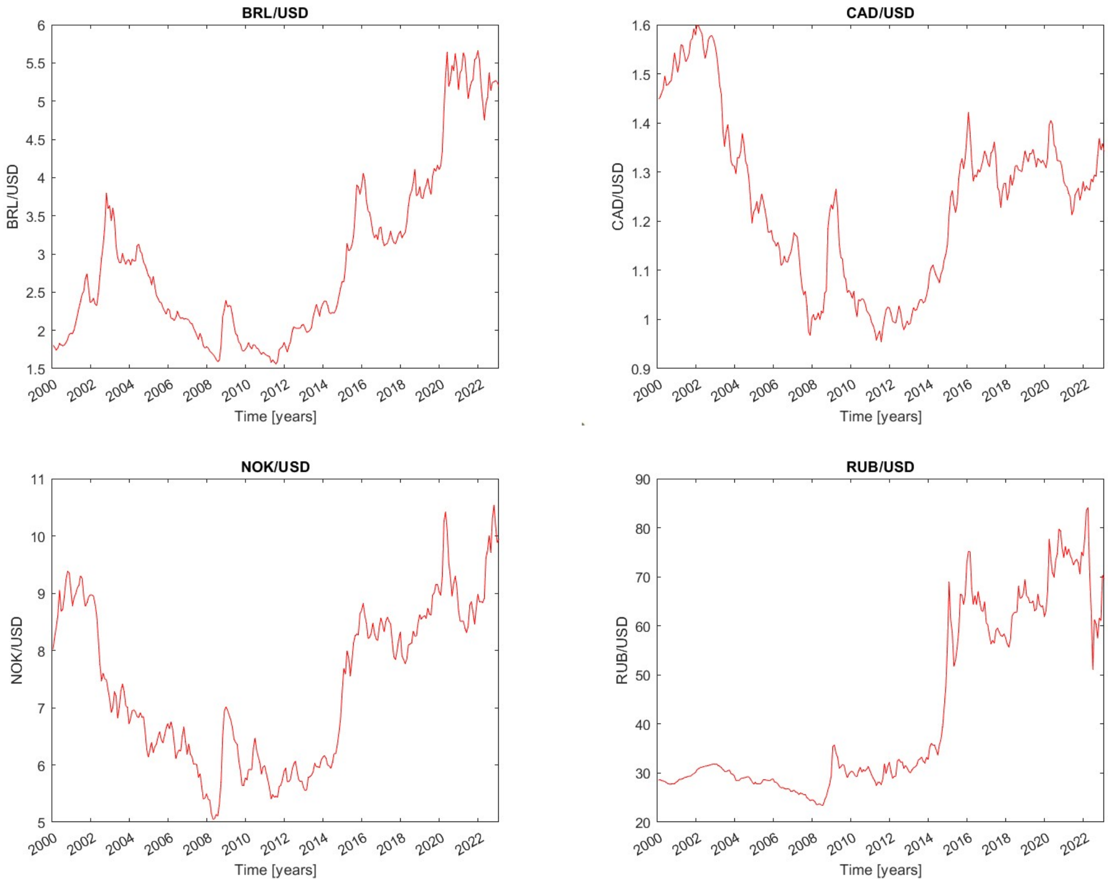

Figure 3.10: Time paths of exchange rates of analyzed countries, source: (FRED 2023a; FRED 2023b; FRED 2023c; FRED 2023d), own creation

3.3.1 Brazil

The base currency of Brazil is the Brazilian real (ISO 4217 code: BRL). From the early 2000s, the Brazilian real began to depreciate against the USD until 2003. From 2003 onwards, the BRL began to appreciate against the USD, a trend that continued until mid-2008, when the global financial crisis was underway. From the first half of 2009, the BRL started to appreciate against the USD until 2011. Subsequently, the BRL started to depreciate. The turn of 2015/2016 is interesting, when the BRL first weakened significantly and then started to appreciate. During this period, there was a decline in GDP and subsequent growth as Brazil went through an economic crisis. As mentioned in the stock index time series section, Brazil recorded a decline of 3.5% and 3.3% in 2015 and 2016, respectively. Then in 2017, Brazil's GDP showed a growth of 1.3% (The World Bank 2023a). Subsequently, the Brazilian real began to depreciate. It depreciated sharply from the start of the covid shock in 2020. Subsequently, it stabilized against the USD and the exchange rate fluctuated between around 5 and 5.5 BRL/USD.

3.3.2 Canada

The base currency of Canada is the Canadian dollar (ISO 4217 code: CAD). From the early 2000s, the Canadian dollar began to depreciate against the USD until 2003. Since 2003, there has been a significant appreciation of the Canadian dollar against the US dollar, a trend that continued until 2008, when the global financial crisis hit. In the second half of 2008, the Canadian dollar began to depreciate significantly and since 2009 the trend has reversed. Like the Brazilian real, the appreciation of the Canadian dollar continued until around the end of 2011. Subsequently, the CAD began to depreciate against the USD until the end of 2015. Compared to Brazil, Canada showed positive economic growth during 2015 and 2016 and did not record an economic crisis (The World Bank 2023a). There has not been a significant exchange rate trend since 2016. Significant is the shock around 2020, when the CAD first depreciated and then started to appreciate significantly. In 2021, however, it began to depreciate again and by early 2023 the exchange rate was above 1.3 CAD/USD.

3.3.3 Norway

The base currency of Norway is the Norwegian krone (ISO 4217 code: NOK). From the beginning of 2000, the Norwegian krone began to depreciate until 2001. Next, from 2001 to 2003 there was a significant appreciation, this trend continued until 2008, when the global financial crisis hit. Subsequently, the Norwegian krone depreciated sharply. From 2009 onwards, the Norwegian krone tended to appreciate until the end of 2011. Subsequently, it started to depreciate. It started to depreciate most significantly during 2014 and 2015. During this period, commodity prices fell. Norway is largely dependent on crude oil and the stock market in Norway is also dependent on crude oil. From mid-2014 to early 2016, the price of Brent crude oil fell significantly. In June 2014, a barrel of Brent crude oil cost 112 USD. In January 2016, Brent crude oil was trading at 32 USD per barrel (FRED 2023e). Since 2016, the Norwegian krone has appreciated slightly until 2018. Thereafter, there was a gradual depreciation, with a significant depreciation during early 2020. Subsequently, there was a significant appreciation. By the first half of 2021. From the second half of 2021, the Norwegian krone started to depreciate against the USD again.

3.3.4 Russia

The base currency of Russia is the Russian ruble (ISO 4217 code: RUB). A significant event that occurred before 2000 was the Russian financial crisis in 1998, when real GDP fell by 5.3% (The World Bank 2023a). During this period, Russia went through a currency crisis when the Russian ruble depreciated significantly. In November 1997, the Russian central bank lost 6 USD Billions in liquid reserves when the central bank intervened to strengthen the Russian ruble, which was equivalent to two-thirds of total reserves at the time. After the Russian financial crisis, the Russian central bank focused on exchange rate stability (Esanov *et al*. 2005).

From the early of 2000s, the Russian ruble began to depreciate until 2003. Like the exchange rates of previous countries, the Russian ruble began to appreciate against the US dollar in 2003 and this trend continued until the global financial crisis hit in mid-2008. In the second half of 2008, the Russian ruble started to depreciate until the beginning of 2009. From the beginning of 2009 until the end of 2011, the Russian ruble had a slight appreciation trend. From 2012 onwards, the Russian ruble started to depreciate gradually. Like previous exchange rates of other countries, the Russian ruble started to depreciate significantly during 2014 and 2015 in the case of the RUB/USD exchange rate. This may be due to the significant decline in the price of Brent crude oil (FRED, 2023e). Another reason may be the sanctions imposed on Russia in retaliation for the West's seizure of the Ukrainian Crimea. Another reason may be the significant inflation, with inflation exceeding 15% in 2015 (OECD 2023). Due to the significant depreciation of the Russian ruble and the strong inflation, the Russian central bank started to raise interest rates. The short-term interest rate was at 5.5% at the beginning of the year and reached 17% in January 2015. From January 2015 to August 2015, the Russian central bank gradually reduced the interest rate to 11%. The interest rate was maintained at 11% until June 2016. Then, it gradually started to lower the interest rate as inflation in Russia started to decline (Bank of Russia 2023; OECD 2022). Since 2016, the Russian ruble has depreciated slightly against the USD with occasional fluctuations.

Since the thesis uses monthly data, we cannot see the depreciation of the Russian ruble in Figure 3.10 after the Russian invasion of Ukraine, which began on February 24, 2022. The Russian ruble began to depreciate gradually after the invasion. The Russian central bank has tried to combat the depreciating Russian ruble through foreign exchange interventions and interest rate hikes (ČT24 2022b). For the Russian central bank, the freezing of their foreign exchange reserves by the West in the struggle to defend the Russian ruble was a huge problem. Prior to the invasion of Ukraine, Russia held foreign exchange reserves as follows: 32% in Euros, 16% in US dollars, 22% in gold, 13% in Chinese yuan, and smaller holdings in British pounds and other freely convertible currencies (Seznam Zprávy 2022). Thus, the Russian central bank could not use foreign exchange reserves in Euros and US dollars. To combat the weakening ruble, the central bank increased the short-term interest rate from 8.5% to 20%. The peak of the RUB/USD exchange rate occurred on March 10, 2022, when the exchange rate was over 135 RUB/USD (Xe 2023). From the second half of March, the Russian ruble gradually began to appreciate, and the strengthening of the Russian ruble stopped in June 2022. During this period, the exchange rate reached its low on 30 June 2022, when the exchange rate was approximately 52.5 RUB/USD (Xe 2023). This is an interesting finding as economic sanctions have been imposed on Russia and foreign exchange reserves frozen by the West and yet the Russian ruble has appreciated. As Jeffrey Frankel, professor of capital formation and growth at the Harvard Kennedy School, said: *"It's an unusual situation,"* (CBS News 2022). Tatiana Orlova, lead emerging markets economist at Oxford Economics explained the situation in July 2022 as follows: *"Commodity prices are currently sky-high, and even though there is a drop in the volume of Russian exports due to embargoes and sanctioning, the increase in commodity prices more than compensates for these drops,"* (CBS News 2022). From the second half of 2022, the Russian ruble started to depreciate against the USD. At the end of the first half of April 2023 (15 April

2023), the Russian ruble was trading at an exchange rate of about 82 RUB/USD (Xe 2023).

3.4 Transformed Time Series

For less non-stationarity of the time series, it is advisable to transform the time series. Time series for subsequent analysis are transformed using logarithmic differencing. The exchange rate and stock market returns have the equation (Dahir *et al*. 2018):

$$R_t = (\log P_t - \log P_{t-1}) \cdot 100, \tag{3.1}$$

where R_t represents the return, P_t represents the value of the variable at time t and P_{t-1} represents the value of the variable at time t-1. Figure 3.11 shows the logarithmic differences of the original variables. For clarity, the logarithmic differences of exchange rates are shown in red, whereas the logarithmic differences of the stock indices are shown in blue. From Figure 3.11, it appears that the time series have better stationarity after logarithmic differencing. During the dot-com bubble of the early 2000s, there was a slightly larger fluctuation in the BRL/USD exchange rate around 2003. Other exchange rates appear to have had smaller fluctuations. The RUB/USD exchange rate was very stable in the early 2000s until mid-2008. This may be due to the fact, that the Russian central bank tried to keep the exchange rate stable after the Russian financial crisis in 1998. In terms of stock indices, the stock index in Russia recorded a more significant fluctuation in the early 2000s.

A significant spike occurs around the global financial crisis, with the logarithmic differences of all observed exchange rates reaching high positive values in the second half of 2008. As for the logarithmic differences of stock indices, they also reach significant fluctuations in the second half of 2008, but in this case the logarithmic differences show a negative value. Thus, around the global financial crisis in the second half of 2008, there seems to be a strong negative co-movement between exchange rates and stock indices.

Another significant event was the second half of 2011, when concerns about another global crisis arose and indices around the world fell (MSCI 2023b). We do not see very significant fluctuations during this period. Monthly data was used in the analysis and the fall in indices was mainly in August 2011. Investors' fears were not confirmed, and the global economy did not record a downturn, the economic downturn was more of a local one in the case of Europe (The World Bank 2023a).

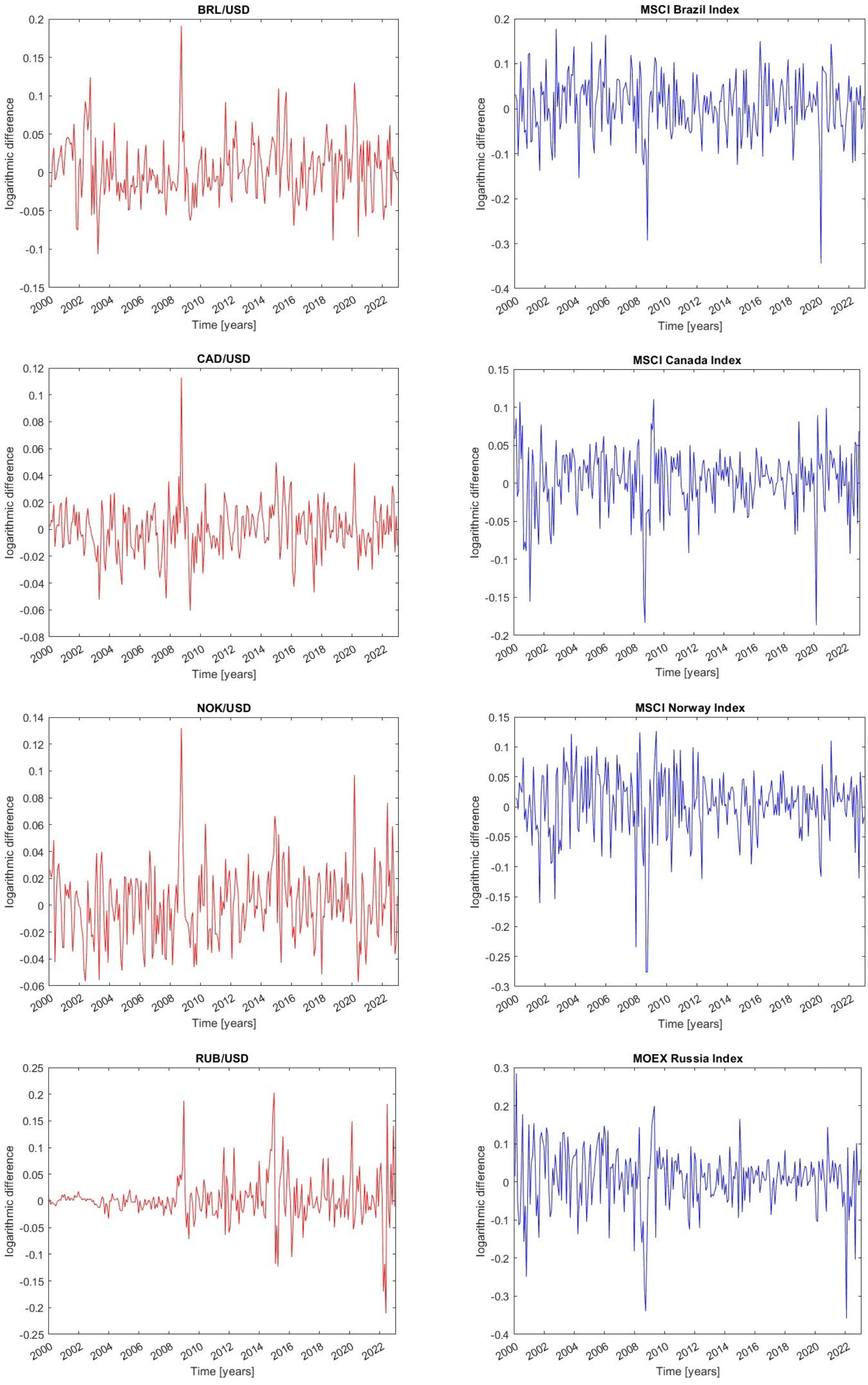

Figure 3.11: Logarithmic differences of variables used in analysis, own creation

Another important point is the decline in commodity prices from mid-2014 to early 2016. In this case, there is more fluctuation in all exchange rates than in the case of investor concerns from the second half of 2011. The RUB/USD exchange rate recorded the largest fluctuation during the commodity downturn. As for stock indices, they did not record much fluctuation during this period. Only the Russian stock index has seen a slight fluctuation towards positive logarithmic differences values.

The other significant event was the covid shock in 2020. During this period, all exchange rates recorded significant fluctuations. The logarithmic differences are positive for all exchange rates at the beginning of 2020. In contrast, all stock indices showed a significant negative logarithmic difference. However, Brazil and Canada recorded more significant fluctuations than Norway and Russia.

Another major event is the Russian invasion of Ukraine, which began on 24 February 2022, and is still ongoing these days (second half of April 2023). During the period after the start of the Russian invasion, only NOK/USD and RUB/USD recorded significant exchange rate fluctuations. Understandably, the most significant fluctuation was in the Russian ruble, as the currency of the country involved in the conflict. In a similar vein, the stock index fluctuated, with Russia registering the most significant fluctuation of all countries during this period.

3.5 Descriptive Statistics

In this section, descriptive statistics of the variables used are presented. Table 3.1 shows the descriptive statistics of the original variables as well as the variables after transformation (logarithmic differences). The basic descriptive statistics in the form of mean, minimum (min), maximum (max), standard deviation (Std. Dev.), skewness, and kurtosis are presented. In addition, the Jarque-Bera test (JB) is used to assess whether the data are normally distributed.

Based on the standard deviation of the logarithmic differences, it can be noticed that the RUB/USD exchange rate has the highest fluctuation between the exchange rates. On the other hand, the CAD/USD exchange rate has the lowest fluctuation. Within the stock indices, the situation is similar, with the Russian stock index having the highest fluctuation and the Canadian stock index having the lowest fluctuation.

Table 3.1: Descriptive statistics, own creation

	BRL/USD	CAD/USD	NOK/USD	RUB/USD	MSCI Brazil Index	MSCI Canada Index	MSCI Norway Index	MOEX Russia Index
Mean	2.910	1.240	7.366	42.515	338.658	152.524	179.976	807.478
Min	1.563	0.955	5.054	23.446	73.456	71.223	61.349	76.474
Max	5.655	1.600	10.541	84.085	678.488	256.709	292.381	2197.977
Std. Dev.	1.144	0.172	1.377	18.051	156.466	42.890	55.012	479.795
Skewness	0.971	0.203	0.188	0.732	-0.051	0.123	0.286	0.475
Kurtosis	-0.080	-0.791	-1.217	-1.152	-0.779	-0.454	0.764	0.010
JB	43.211***	9.245*	18.710**	39.801***	7.267*	3.210	10.623*	10.304*
	log. dif. BRL/USD	log. dif. CAD/USD	log. dif. NOK/USD	log. dif. RUB/USD	log. dif. MSCI Brazil Index	log. dif. MSCI Canada Index	log. dif. MSCI Norway Index	log. dif. MOEX Russia Index
Mean	0.004	0.000	0.001	0.003	0.006	0.003	0.003	0.009
Min	-0.106	-0.060	-0.057	-0.210	-0.343	-0.187	-0.276	-0.357
Max	0.190	0.113	0.132	0.203	0.177	0.110	0.125	0.285
Std. Dev.	0.039	0.019	0.027	0.044	0.067	0.042	0.057	0.081
Skewness	0.687	0.562	0.611	0.601	-0.768	-1.066	-1.271	-0.817
Kurtosis	4.907	7.366	4.808	9.435	6.033	6.164	7.268	6.040
JB	63.536***	233.661***	54.765***	492.756***	132.906***	167.336***	283.778***	136.989***

Statistical significance at $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

Based on the JB test, it can be noticed that not all the original variables are normally distributed. The lowest JB statistic comes out for the MSCI Canada Index, specifically with a value of 3.210 and the p-value in this case is above 5%, so the data are not normally distributed at this significance level. The other stock indices are normally distributed, but not at the 1% significance level. The situation is better within the exchange rates and all exchange rates are normally distributed at the 5% significance level. However, the CAD/USD exchange rate is not normally distributed at the 1% significance level and the NOK/USD exchange rate is not normally distributed at the 0.1% significance level. After transformation under logarithmic differences, all variables, both exchange rates and stock indices are already normally distributed at the 0.1% significance level. For the sake of better stationarity, transformed variables are used in the analytical part of the thesis.

3.6 Methodology

3.6.1 Wavelet Analysis

Wavelet analysis is a time-frequency analysis. It is a very powerful analysis, because it gives us information not only in the time domain but also in the frequency domain. The wavelet function ψ is defined as (Dahir *et al*. 2018):

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{|s|}}\psi\left(\frac{t-\tau}{s}\right); s,\tau \in R; s \neq 0, \tag{3.2}$$

where s represents the scale parameter, which adjust for wavelet length, τ stands for the location parameter showing whether the wavelet is centered, $\sqrt{|s|}$ represents a factor of normalization that conserves unit variance of the wavelet, and $|\psi_{\tau,s}| = 1$ denotes a scaling factor that controls the breadth of the wavelet, as scale and frequency have an inverse relationship. The Morlet wavelet is used in the thesis as it is frequently used in finance and economics to study amplitude and phase (Reboredo *et al*. 2017). The Morlet wavelet is defined as (Dahir *et al*., 2018; Reboredo *et al*. 2017):

$$\psi(t) = \frac{1}{4\pi^{1/4}} e^{i\varpi_0 t} e^{-t^2/2}, \quad (3.3)$$

where $4\pi^{1/4}$ conserves the energy of wavelet as a unit, ω_0 represents frequency without a unit and points as the central frequency, $e^{i\omega_0 t}$ represents a complex sinusoid and $e^{-t^2/2}$ is a Gaussian envelope with a unit standard deviation. In the thesis $\varpi_0 = 6$ is set same as in (Reboredo *et al*., 2017) as representing a suitable trade-off between time and frequency localization. A typical Morlet wavelet is shown in Figure 3.12 for better clarity.

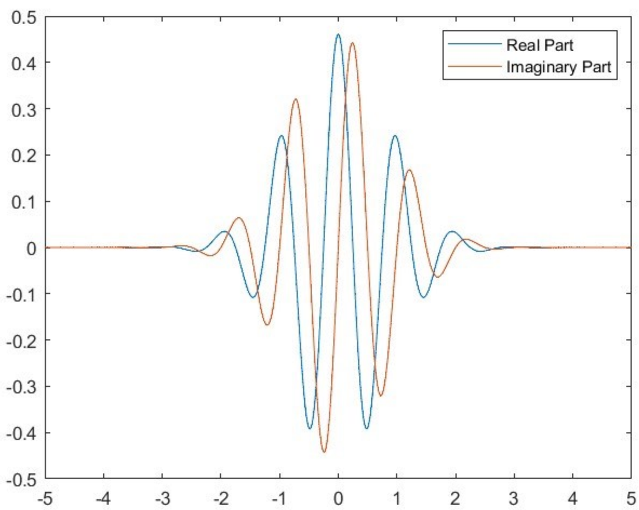

Figure 3.12: Morlet wavelet, own creation

There are two types of wavelet transform. Discrete wavelet transform and continuous wavelet transform. Continuous wavelet transform is according to Dahir *et al*. (2018) better than discrete wavelet transform, because it offers an easy way to select wavelets that depend on the length of data. In the thesis, continuous wavelet transform is used.

3.6.1.1 Continuous Wavelet Transform (CWT)

Continuous wavelet transform (CWT) can be characterized as a band pass filter to the time series (Andrieș *et al*. 2014). Continuous wavelet transform is defined as (Dahir *et al*. 2018):

$$W_X(s) = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{s}} \psi^* \left(\frac{t}{s}\right), \tag{3.4}$$

where * symbolizes the complex conjugate, the scale parameter *s* determines whether the wavelet can detect higher or lower constituents of the series *x(t)*.

3.6.1.2 Cross Wavelet Transform (XWT)

To characterize dependence between the two-time series, wavelet power spectrum, cross-wavelet power, and cross-wavelet transform (XWT) are used. The wavelet power spectrum measure contribution to the variance of the series at each time scale, while cross-wavelet power measure covariance contribution in the time-frequency domain (Reboredo *et al*. 2017). The cross wavelet transform between two time series *x(t)* and *y(t)* with continuous wavelet transforms $W^X(n,s)$ and $W^Y(n,s)$ is defined as (Reboredo *et al*. 2017; Tian *et al*. 2016):

$$W^{XY}(n,s) = W^X(n,s) W^{Y^*}(n,s). \tag{3.5}$$

where * denotes the complex conjugate.

3.6.1.3 Wavelet Coherence (WTC)

Interdependence of two time series over time and across frequencies can be measured by using wavelet coherence (WTC) (Reboredo *et al*. 2017). The squared cross-wavelet coherence $R^2(n,s)$ is defined as (Reboredo *et al*. 2017):

$$R^2(n,s) = \frac{|[S^{-1}W^{XY}(n,s)]|^2}{[S^{-1}|W^X(n,s)|^2] \cdot [S^{-1}|W^Y(n,s)|^2]}, \tag{3.6}$$

where S is a smoothing operator for both time and scale, $R^2(n,s)$ closely resembles the correlation coefficient and ranges between 0 and 1. A value of 0 indicates a low coherence, while a value of 1 indicates a high coherence.

3.6.1.4 Phase Difference

Phase difference is proposed to detect negative and positive correlation and lead-lag relationship between two time series (Reboredo *et al*. 2017). The wavelet coherence phase difference is defined as (Reboredo *et al*. 2017):

$$\varphi_{xy}(n,s) = \tan^{-1}\left(\frac{Im\{(S^{-1}W^{XY}(n,s))\}}{Re\{(S^{-1}W^{XY}(n,s))\}}\right), \tag{3.7}$$

where *Im* is the imaginary and *Re* is the real part of the smooth power spectrum. In the wavelet coherence plot, the phase difference is represented by arrows. The interpretation is as follows: if the arrow points to the right (left), it means that the two-time series are in-phase (out-of-phase), and the correlation coefficient is positive (negative). If the arrow points up (down), the first (second) variable leads the second (first) variable by π/2. If the phase difference is zero, it means that the time series are moving simultaneously (Dahir *et al*. 2018). In the literature, it is also possible to find that the term anti-phase is used instead of the term out-of-phase. For example, the term anti-phase is used in Andrieș *et al*. (2014). Within the thesis, the term out-of-phase is used, as in Dahir *et al.* (2018). Figure 3.13 is presented for better clarity and understanding of phase differences. It shows phase difference states in four different quadrants. In the first quadrant (0;π/2), the first variable x is leading and the second variable y is lagging.

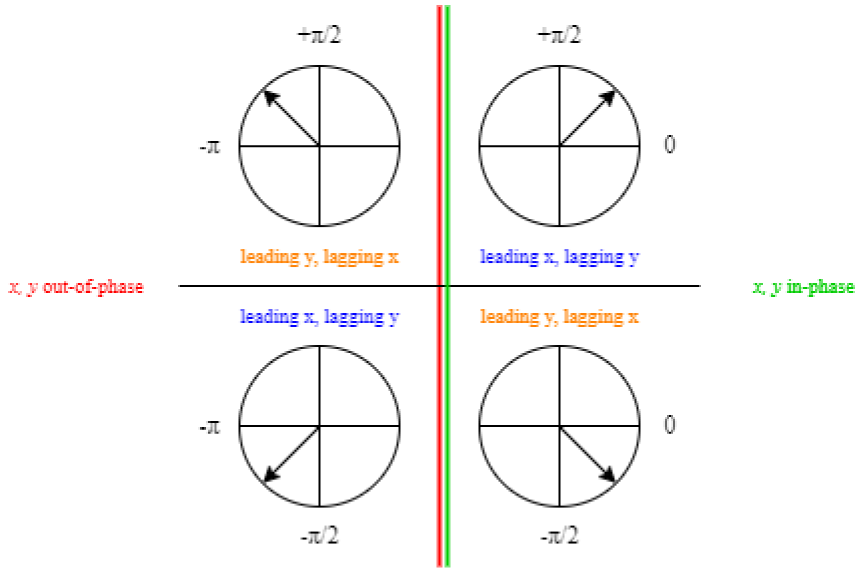

Figure 3.13: Phase difference states, source: (Schmidbauer & Roesch 2018, p. 7), own creation

The variables x and y are in-phase, which means that there is a positive coherence between them. In the second quadrant (π/2;π), the second variable y is leading and the first variable x is lagging. The variables x and y are out-of-phase, which means that there is a negative coherence between them. In the third quadrant (-π;-π/2), the first variable x is leading and the second variable y is lagging. The variables x and y are out-of-phase and there is a negative coherence between them. In the fourth quadrant (-π/2;0), the second variable y is leading, and the first variable x is lagging. The variables x and y are in-phase and there is a positive coherence between them. Within the thesis the notion of coherence and the notion of co-movement are taken as synonyms.

3.6.1.5 Cone of Influence

Cone of influence appears in the wavelet transform. This is a region that is affected by the edge effect, where at the beginning and end of the time series the values of the transformation are miscalculated. There is a direct proportionality between the edge effect and the period. In other words, a smaller edge effect is produced at smaller periods, whereas a larger edge effect is produced at larger periods (Aguiar & Soares 2011).

3.7 Chapter Summary

Subsection 3.1 introduces the stock indices used in the analysis. MSCI indices for Brazil, Canada, and Norway are presented. Due to the exclusion of Russia from MSCI published indices after the Russian invasion of Ukraine, the MOEX Russia Index is presented as a representative of the Russian stock market.

Subsection 3.2 presents the time paths of stock indices. It can be noticed that stock indices show similar paths during major events such as the dot-com bubble, the global financial crisis, or the covid shock in 2020. In the current global situation of the Russian invasion of Ukraine, the Russian stock index has seen a sharp decline during 2022.

Subsection 3.3 presents the time paths of the individual currencies used in the analysis against the US dollar. Specifically, the exchange rates are BRL/USD, CAD/USD, NOK/USD, and RUB/USD. The time paths of exchange rates for individual countries had similar trends, seemingly most notably around the global financial crisis of 2007-2010, more specifically in the second half of 2008, when all currencies of the analyzed countries depreciated against the USD.

Within Subsection 3.4, the time series are transformed using logarithmic differencing. The time difference for the RUB/USD exchange rate shows a very stable RUB/USD exchange rate in the early 2000s until mid-2008. As discussed in subsection 3.4, this may be due to the Russian central bank's pursuit of a stable exchange rate after the Russian financial crisis in 1998, and from the time paths of the logarithmic differences, it appears that the Russian central bank was successful in its goal of stabilizing the Russian ruble during this time. The logarithmic differences show a large fluctuation around 2008, when individual country currencies depreciated against the USD. Next, the Russian ruble shows high fluctuations during the first months after the start of the Russian invasion of Ukraine.

Subsection 3.5 presents descriptive statistics of the original and transformed time series. The Jarque-Bera test is also included in the descriptive statistics to assess whether the time series have a normal distribution. Based on the Jarque-Bera test, all-time series show a normal distribution after logarithmic differencing. For this reason, logarithmic differences are used in the evaluation of the relationship between the exchange rates and the stock indices.

Subsection 3.6 presents the wavelet analysis. It is an advanced method for finding the mutual co-movement of two time series in both the time and the frequency domain. Continuous wavelet transform is used to observe the fluctuation of a given variable in time-frequency domain, whereas according to Andrieș *et al*. (2014) the wavelet coherence can be viewed as localized correlation coefficients in time-frequency domain.

4 Evaluation of the Relationship Between Exchange Rate and Financial Markets

This chapter presents results from a wavelet analysis to assess the relationship between the exchange rate and the stock market in the analyzed countries. The outputs of the analyses are performed using MATLAB software.

In subsection 4.1, continuous wavelet transform is performed to see how a given variables fluctuate over time at different frequencies.

In subsection 4.2, wavelet coherence is performed to assess the relationship between the exchange rate and the stock market in the analyzed countries.

In subsection 4.3, a robustness analysis using cross wavelet transforms is performed.

4.1 Continuous Wavelet Transform (CWT)

This subsection presents continuous wavelet transform of exchange rates and stock indices of the analyzed countries. Continuous wavelet transform is defined in subsection 3.6.1.1.

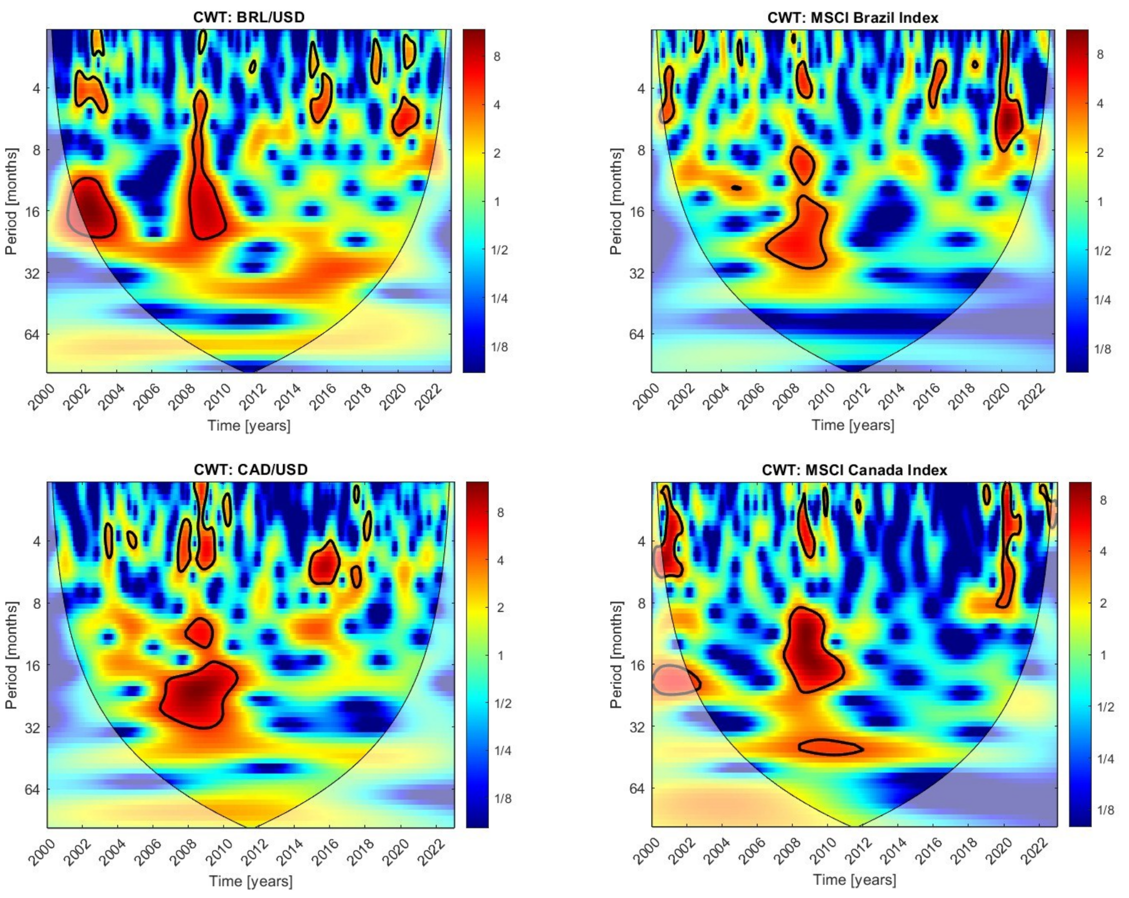

Figure 4.1: Continuous wavelet transform of analyzed variables, own estimation

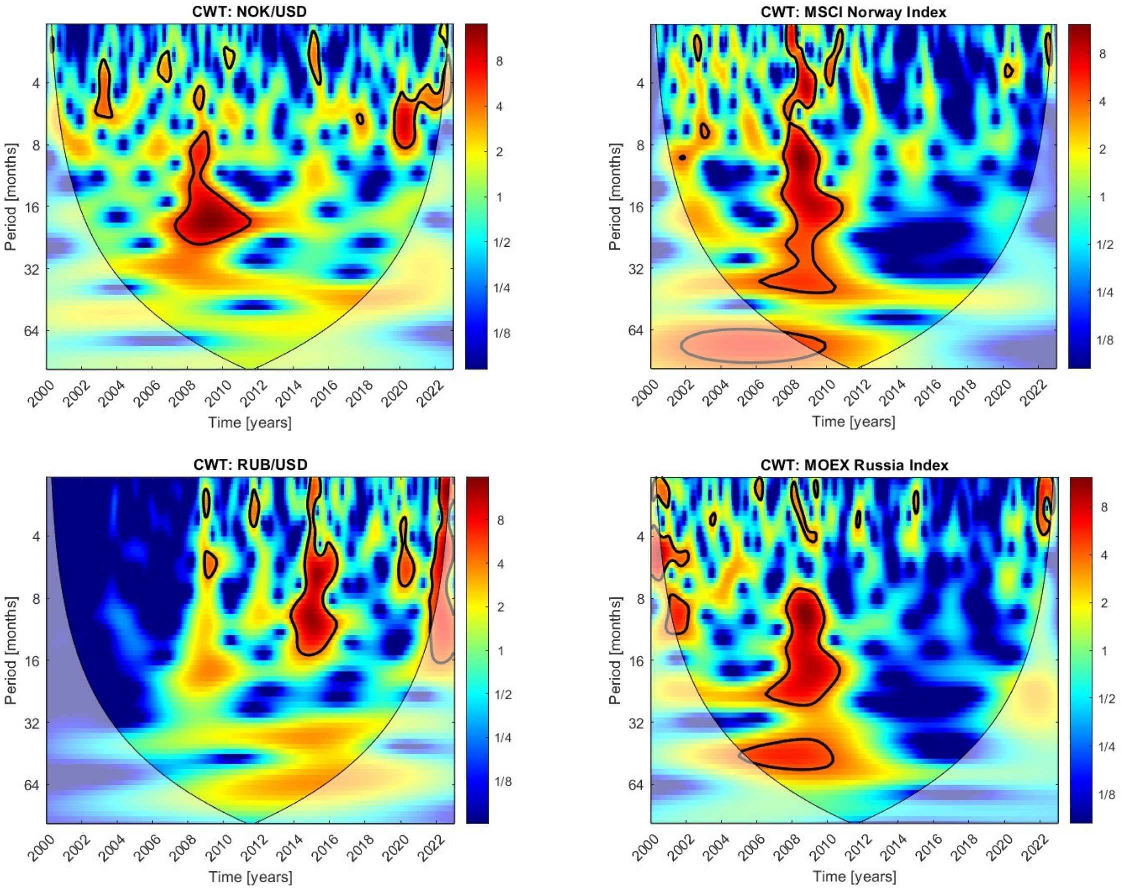

Figure 4.1 (continued)

Note: The horizontal axis represents the time component. The vertical axis represents the frequency component. The thick black contour shows the area that is significant at the 5% significance level. The color code for wavelet power ranges from blue (low power) to red (high power). The cone of influence represents the region that is affected by the edge effect, source: (Andrieș *et al*. 2014; Dahir *et al*. 2018).

4.1.1 Brazil

Continuous wavelet transform within the exchange rate and stock index show significant fluctuation from the early 2000s when the dot-com bubble peaked. The exchange rate was volatile over a short period of around 2 months during this time. Subsequently at a period of around 4 months. Significantly strong fluctuation occurred during this time at a period of around 16 months. Within the stock index, it fluctuated at the turn of 2000/2001, when fluctuations occurred around period of 4 months. At the end of 2002, the index fluctuated at a very short period of about 2 months. Subsequently, fluctuations in both variables emerged around the global financial crisis at the turn of 2007-2010. As regards the exchange rate, fluctuations were particularly pronounced in 2008 at period of 4 months to 16 months. With fluctuations continuing at the period of about 16 months until 2010. A miniature fluctuation occurred in 2008 at around the period of about 2 months. Within the stock index, the fluctuation occurred earlier in 2007 at a period of about 25-30 months. Subsequently, in 2008, fluctuations in the stock index also occurred at other periods. Specifically, at period of about 4 months, 10 months, and 16-30 months. Furthermore, slight fluctuations occurred at the turn of 2015 and 2016 at a short period of around 4 months in both variables. More significant fluctuations occurred during the covid shock in 2020. Within the exchange rate, fluctuations occurred at around period of 3 month and period of 7 month. Within the stock index, fluctuations occurred at a range of 2 months to about 8 months.

4.1.2 Canada

As in the case of Brazil, Canada recorded fluctuations in its exchange rate and stock index during the early 2000s. However, the stock index fluctuates more significantly than the exchange rate during this time. Which may be due to the bursting of the dot-com bubble. Already during 2000, the stock index fluctuates at low periods of around 4 months. Further, it can be stated that fluctuation also occurred at a period of around 16 months, but due to the edge effect, only a part around 2002 is statistically significant.

Another important point was the global financial crisis at the turn of 2007-2010. Both variables fluctuated during this period, but the exchange rate fluctuated a little earlier at a period of about 16 to 30 months. This fluctuation was throughout the global financial crisis. In addition, in 2008 there were fluctuations at a period of around 4 months and around 10 months. Within the stock index, fluctuations occurred in 2008. Similarly, to the exchange rate, fluctuations also occurred around the period of 4 months. There was also fluctuation at a period of around 8 to 20 months. This lasted until 2010. There was also fluctuation at a longer period, namely around a period of 40 months, which continued from 2008 until the end of 2011.

Another important point was the fall in commodity prices from mid-2014 to early 2016. The stock index recorded no fluctuation during this time. The exchange rate did. During 2015 and 2016, there was fluctuation at a period of around 4 to 7 months. Subsequently, very small fluctuations also occurred around 2017. During covid shock in 2020, in the case of the exchange rate, there was no significant fluctuation this time around; on the other hand, the stock index shows a very short band of fluctuation over period of about 2 months to a period of about 8 months. Furthermore, a smaller fluctuation occurs at the turn of 2021 and 2022, but due to the edge effect only a bit of this fluctuation is statistically significant.

4.1.3 Norway

Also, in the case of Norway, fluctuations in variables occurred around the dot-com bubble in the early 2000s, but they were very mild. The exchange rate only fluctuated in the second half of 2003 around the period of 4 months, when economic growth gradually started to pick up after the dot-com bubble (The World Bank, 2023a). Interestingly, the Norwegian stock index almost did not record significant fluctuations around this period, only very brief ones at period of about 3 and 7 months. Both variables recorded significant fluctuations around the global financial crisis of 2007-2010. Compared to Canada, in the case of Norway, the stock index recorded fluctuations first than the exchange rate, with fluctuations already occurring from the beginning of 2006 at a period of around 40 months. Subsequently, fluctuations in both variables occurred during 2008. Significant fluctuations occurred in the exchange rate at a period of 8 months to about 25 months. Fluctuations continued at around 20 months until 2011. Within the stock index, a larger fluctuation can be seen during the global financial crisis, when fluctuations took place at several time periods and ran from 2 months to about 40 months. Interestingly, the fluctuation also occurred over a longer period of around 64 months.

Between 2014 and 2016, fluctuations occurred only in the exchange rate, but the fluctuations were very small. During the covid shock in 2020, the Norwegian stock index did not have much fluctuation, compared to, say, Brazil or Canada. On the other hand, the NOK/USD exchange rate fluctuated much more during this time, for example, CAD/USD, with fluctuations occurring at a period of about 6 to 8 months. The exchange rate had fluctuations even after the covid shock. It is also interesting to note that the Norwegian stock index started to fluctuate slightly at a short period during the time of the Russian invasion of Ukraine, while the exchange rate also continued to fluctuate on a short-time period during this time.

4.1.4 Russia

During the dot-com bubble, the stock index in Russia fluctuated at several monthly periods, but the exchange rate showed almost no fluctuation over this time. As mentioned in the subsection 3.4, the RUB/USD exchange rate showed high stability from the beginning of 2000s to mid-2008. During this time, the Russian central bank tried to keep the exchange rate stable after the financial crisis that occurred in Russia in 1998. From the CWT results for the RUB/USD exchange rate, it seems that the Russian central bank succeeded in exchange rate stability from the beginning of 2000s to mid-2008. The stock index fluctuated over this time at a period of about 2 months, then between about 4 and 6 months, and finally around 8 to 12 months. In the context of the global financial crisis, both variables had already fluctuated, but the stock index has fluctuated more significantly. As in the case of Norway, the stock index started to fluctuate earlier than the exchange rate. The index had already fluctuated significantly in 2005 over a period of about 40 to 50 months. Towards the end of 2007 and the beginning of 2008, this fluctuation was joined by a fluctuation at a period of 8 months to about 25 months. There was also a statistically significant but very small and short fluctuation at a period of about 3 to 4 months. The exchange rate fluctuated briefly around the period of 3 months and 7 months.

Between 2014, 2015 and 2016, the exchange rate fluctuated significantly, whereas the stock index fluctuated only at a short period of about 3 months at the turn of 2015/2016. The exchange rate fluctuated from a period of 2 months to about 15 months. The next significant event is the covid shock in 2020. There was no statistically significant fluctuation in the stock index during this time. Within the exchange rate, the fluctuation occured at a period of about 4 to 7 months. The exchange rate then recorded a significant fluctuation from the end of 2021 when the exchange rate fluctuated at period about 2 to 12 months. Due to the edge effect, the fluctuation in 2022 at the higher period cannot be considered statistically significant, but the lower period can be considered. It can be noted that in 2022 when Russia invaded Ukraine the exchange rate fluctuated significantly at a short period from about 2 months. Within the stock index, it also fluctuated significantly from the beginning of 2022 at low period from about 2 months to 4 months.

4.2 Wavelet Coherence (WTC)

This subsection presents the wavelet coherence, defined in subsection 3.6.1.3, between the exchange rate and the stock index of the analyzed countries. In the output of the wavelet coherence plots, phase differences are used to assess the mutual co-movement. An explanation of the interpretation of the phase differences is given in the subsection 3.6.1.4. To reiterate the relationship between the exchange rate and the stock market, it is useful to review subsection 2.4.1. We give a brief recap. If the exchange rate is the leading variable, this is the flow-oriented model. If the leading variable is the stock index, it is the stock-oriented model. The stock-oriented model is further divided into whether there is a positive or negative relationship between the exchange rate and the stock index. If there is a positive one, it means that it is the monetary model. If there is a negative relationship, it means that it is the portfolio balance model.

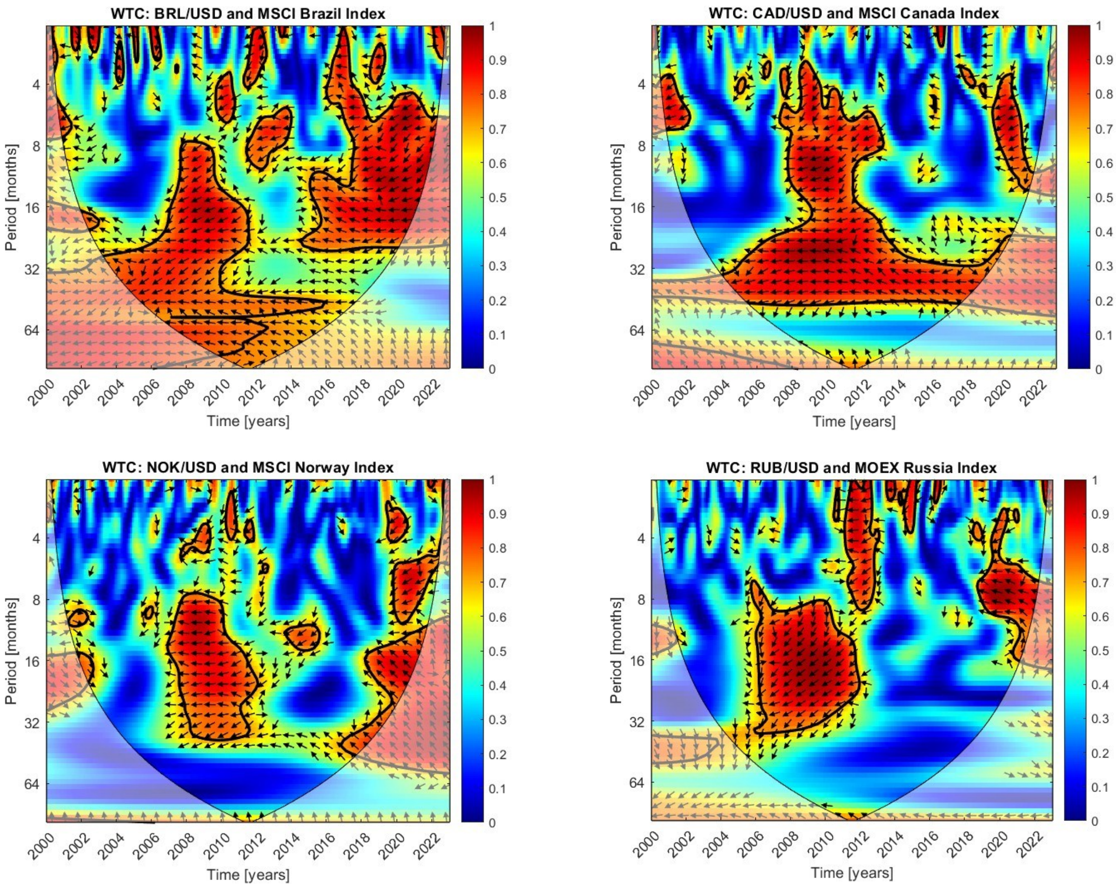

Figure 4.2: Wavelet coherence of analyzed variables, own estimation

Note: The horizontal axis represents the time component. The vertical axis represents the frequency component. The thick black contour shows the area that is significant at the 5% significance level. Arrows pointing right up and down represent in-phase condition, while arrows pointing left up and down represent out-of-phase. The color code for wavelet coherence ranges from blue (low coherence) to red (high coherence). The cone of influence represents the region that is affected by the edge effect, source: (Andrieș *et al*. 2014; Dahir *et al*. 2018).

4.2.1 Brazil

In the time from January 2000 to January 2023, co-movement occurs at many periods. In the early 2000s, during the dot-com bubble, there are several small co-movements at low period of up to 4 months. During 2001, there was a negative co-movement at a period of 4 to 8 months when the exchange rate was the leading variable. This indicates the flow-oriented model. At a period of about 16 months during 2002 there was also a negative co-movement, but in this case the leading variable was the stock index. This indicates the portfolio balance model. Because of the edge effect, longer periods cannot be analyzed during the dot-com bubble. From 2004 until the global financial crisis, there is a statistically significant negative co-movement at period from 32 months onwards. In most cases, the leading variable is the exchange rate. This indicates the flow-oriented model. During the global financial crisis, there is also a significant negative co-movement at lower period from 8 to 32 months. In this case, the exchange rate is also the leading variable. This indicates the flow-oriented model here as well. However, there is also a negative co-movement at a period of about 50 months when the leading variable is the stock index, indicating the portfolio balance model. The global financial crisis was followed by negative co-movements at lower periods. For example, at the turn of 2011/2012, there was a negative co-movement at a period of about 8 months when the exchange rate led the stock index, indicating the flow-oriented model. A significant negative co-movement between the variables appeared from the end of 2015 at about period from 10 to 20 months and subsequently at other lower periods. This co-movement continued through the covid shock in 2020 until the beginning of 2023. Between 2016 and 2018, the leading variable was the stock index indicating the portfolio balance model, but from 2018 onwards, the leading variable was the exchange rate indicating the flow-oriented model. A small co-movement at a period of about 2 months occurred in early 2022 when the war conflict between Russia and Ukraine broke out. Interestingly, in this case the co-movement is positive, and it is problematic to determine which variable is the leading one.

4.2.2 Canada

Canada, like Brazil, shows co-movement in negative polarity in most statistically significant places. During the dot-com bubble in the early 2000s, there is a statistically significant negative co-movement over a period of about 4 to 7 months. The leading variable in this case is the exchange rate, indicating the flow-oriented model. Like the case of Brazil, there is a statistically significant negative co-movement between the exchange rate and the stock index for Canada since 2004 at a period of about 32 months. In this case, however, the co-movement does not exist at larger periods and the maximum period where the co-movement occurs is about 45 months. It cannot be determined which variable is leading. During the global financial crisis since 2008, negative co-movement also appears at lower periods. In the lower periods from about 4 months to 15 months, the exchange rate is the leading variable in this case, indicating the flow-oriented model. The co-movement at lower periods ends around 2011. As for the co-movement at periods of 32 to 45 months, it also continues in the years following the global financial crisis. Compared to Brazil, the co-movement does not appear at a period of 4 to 30 months since 2014/2015. The negative co-movement appears during the covid shock around 2020 at periods of 4 to 16 months. The leading variable in this case is the exchange rate, indicating the flow-oriented model.

4.2.3 Norway

During the dot-com bubble in the early 2000s, the change from Brazil is that there is a positive co-movement around 2002 at period of 10 months and then around period of 16 to 20 months. In this case, the leading variable is the stock index, indicating the monetary model. Subsequently, a strong negative co-movement appears during the global financial crisis between 2008 and 2010. At periods of about 8 to 30 months there is no lag between the variables, at around the period of 32 months the leading variable is the exchange rate, indicating the flow-oriented model. Furthermore, a short negative co-movement appears around 2014 at a period of about 10 months, where the leading variable is the exchange rate, indicating the flow-oriented model. A larger area of spliced negative co-movement is the time from 2017 onwards, where the negative co-movement first appears at a period of about 40 months. Subsequently, it also appears at lower periods, in this case the leading variable is the stock index, indicating the portfolio balance model. However, at shorter periods around 2020 the situation reverses, and the leading variable is the exchange rate, indicating the flow-oriented model. Because of the edge effect, the co-movement in 2022, when Russia attacked Ukraine, cannot be observed much.

4.2.4 Russia

No statistically significant co-movement can be observed during the dot-com bubble of the early 2000s. However, during 2006, there is a significant negative co-movement at periods of about 8 to 32 months. The co-movement persists throughout the time of the global financial crisis and the leading variable is the exchange rate, indicating the flow-oriented model. At the turn of 2011/2012, there is a statistically significant band of negative co-movement over periods of about 2 months to 8 months. At lower periods between the variables, the leading variable cannot be identified, but from about 5 to 8 months, the leading variable is the exchange rate, indicating the flow-oriented model.

During 2014 to 2016, there is a short negative co-movement between exchange rate and stock market at lower periods from about 2 months to 4 months. A significant negative co-movement appears from the end of 2018 at a period of about 6 to 9 months. The leading variable in this case is the stock index, indicating the portfolio balance model. The co-movement continues until the covid crisis around 2020. During early 2020, it also appears at a lower period of about 3 to 6 months, but it is very short. A significant event for Russia is the invasion of Ukraine in early 2022. In this case, a short co-movement appears statistically significant at a period of about 2 months. In this case, it is problematic to determine whether this is a positive or negative relationship.

4.3 Robustness Analysis

4.3.1 Cross Wavelet Transform (XWT)

In this subsection, a robustness analysis is performed. Cross wavelet transform is used, for example, in Dahir *et al*. (2018) or Andrieș *et al*. (2014) and is used as a robustness analysis in the thesis. Cross Wavelet Transform is defined in subsection 3.6.1.2.

Figure 4.3 shows cross wavelet transform of the analyzed variables in Brazil, Canada, Norway, and Russia. Compared to wavelet coherence, there is less co-movement in the cross wavelet transform. During the dot-com bubble of the early 2000s, all countries except Russia recorded co-movement. In Brazil, the negative co-movement occurred around a period of about 12 months in 2002, where the leading variable is the exchange rate, indicating the flow-oriented model. In Canada, the negative co-movement is around a period of 3 to 5 months at the turn of 2001/2002, the leading variable is the exchange rate, indicating the flow-oriented model. Within Norway at the turn of 2001/2002 the positive co-movement is only around a period of 8 months, and it is problematic to determine the leading variable. In 2002 the co-movement is then around 4 to 7 months. During this time, the Russian central bank tried to maintain a stable exchange rate, and this probably factored into why there is no co-movement in the case of Russia.

The most significant negative co-movement occurred during the global financial crisis between 2007 and 2010. Within Brazil, it occurred over a period of 8 to about 30 months. In this case, the leading variable is the exchange rate, indicating the flow-oriented model. Within Canada, the co-movement occurred over a period of about 8 to 40 months. In this case, in most co-movement locations, it is not possible to determine which variable is the leading and which is the lagging. Within Norway, the co-movement occurred over a period of about 8 to 40 months. At lower periods it is difficult to identify the leading variable. However, at a period of 32 to 40 months, the leading variable is the exchange rate, indicating the flow-oriented model. Within Russia, the co-movement occurred at a period of about 8 to 25 months. In this case, the exchange rate is the leading variable, indicating the flow-oriented model. Furthermore, very short co-movements at lower periods occurred during the global financial crisis.

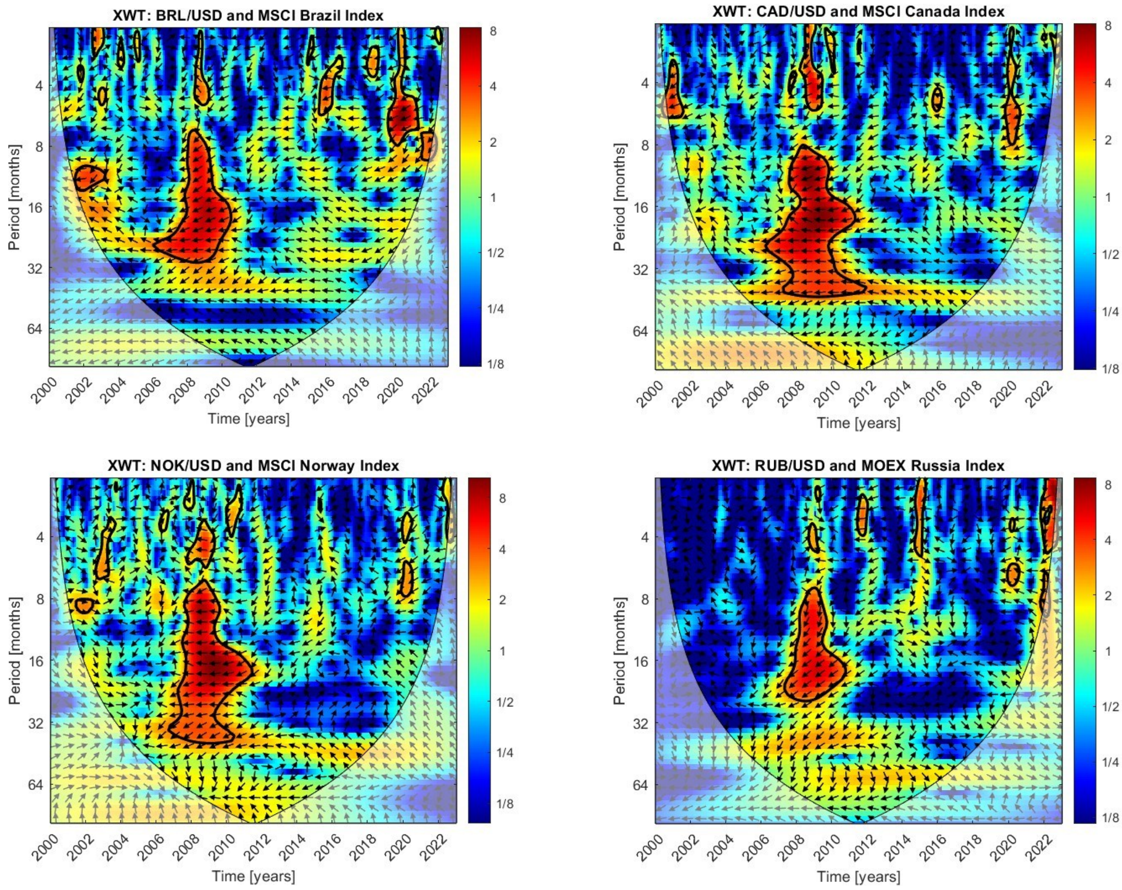

Figure 4.3: Cross wavelet transform of analyzed variables, own estimation

Note: The horizontal axis represents the time component. The vertical axis represents the frequency component. The thick black contour shows the area that is significant at the 5% significance level. Arrows pointing right up and down represent in-phase condition, while arrows pointing left up and down represent out-of-phase. The color code for wavelet coherence ranges from blue (low coherence) to red (high coherence). The cone of influence represents the region that is affected by the edge effect, source: (Andrieș *et al*. 2014; Dahir *et al*. 2018).

From mid-2014 to early 2016, when commodity prices were falling, very short co-movements occurred at this time. During 2014, the co-movement appeared in Brazil at a period of about 3 to 6 months. Within Canada, a co-movement appeared at the end of 2015 at a period of about 5 months. No significant co-movement occurred within Norway.

Towards the end of 2014, a short co-movement occurred in Russia for a period of approximately 2 to 5 months.

The next significant event was the covid shock around 2020. The statistically significant negative co-movement in the case of Brazil occurred at a period of 2 to 8 months. The leading variable is the exchange rate, indicating the flow-oriented model. Within Canada, there is a short co-movement at a period of about 2 months to 8 months. At lower periods, it is problematic to identify the leading variable. However, at a period of about 6 to 8 months, the leading variable is the exchange rate, indicating the flow-oriented model. Within Norway, the co-movement occurred around the period of 4 months and then around the period of 7 months. In both cases the leading variable is the exchange rate, indicating the flow-oriented model. Within Russia, the negative co-movement occurred at period of 3 months and 7 months. In the case of the first co-movement, it is difficult to identify the leading variable. However, in the case of the second co-movement, the leading variable is the stock index, indicating the portfolio balance model.

As for the beginning of 2022, when Russia invaded Ukraine. So, in the case of Brazil, there was very small, but statistically significant co-movement at a period of about 2 months, and before the invasion at the end of 2021 a negative co-movement with a period of about 8 months appeared, the leading variable is the exchange rate, indicating the flow-oriented model. In the case of Canada, there was also a very small but statistically significant co-movement around at period 3 months. In the case of Norway, there was a statistically significant co-movement between periods of about 2 and 4 months. As for the co-movement within Russia, there was a co-movement at about 2 to 5 months. A statistically significant but very short co-movement also occurred before the invasion in late 2021 at a period of about 7 to 9 months.

4.4 Chapter Summary

This chapter analyses the relationship between the exchange rate and the financial market, in this case the stock market.

In subsection 4.1, a continuous wavelet transform is performed for the exchange rate and stock index of the analyzed countries. It can be said that all countries exhibited fluctuations in certain periods associated with closed-world events. Except for the RUB/USD exchange rate, all the variables of the analyzed countries showed fluctuations around the dot-com bubble in the early 2000s. As already mentioned, since the financial crisis in Russia in 1998, the Russian central bank had focused on exchange rate stability and the results of the continuous wavelet transform show that the Russian central bank had been successful, as the RUB/USD exchange rate does not exhibit fluctuation from the beginning of 2000 to mid-2008.

During the global financial crisis from 2007-2010, all exchange rates and stock indices of the analyzed countries showed significant fluctuation. During the commodity price downturn from mid-2014 to early 2016, Brazil showed fluctuation for both variables, Canada only for the exchange rate, and Norway also only for the exchange rate. Russia showed a strong fluctuation within its exchange rate, as for the stock index, there was a very short volatility around a period of 3 months. During the covid shock around 2020, Brazil showed fluctuation within both variables, Canada only in the case of the stock index, Norway in the case of both variables, but there was very little fluctuation within the stock index. As for Russia, it showed fluctuation only within the exchange rate. As for the most recent world event, namely Russia's invasion of Ukraine, in this case Brazil showed no fluctuation within any variable. Within Canada, there was fluctuation only within the stock index. In the case of Norway, both variables showed fluctuations, as did Russia.

Subsection 4.2 analyses the relationship between the exchange rate and the stock index using wavelet coherence. During the dot-com bubble, all countries except for Russia showed co-movement. Brazil and Canada showed negative co-movement, whereas Norway showed positive co-movement and the leading variable is stock index, indicating the monetary model. Across all empirical results, the case of Norway during the dot-com bubble is the only case where the monetary model occurs. During the global financial crisis from 2007 to 2010, all countries showed negative co-movement. Within Brazil, the exchange rate was the leading variable in most cases, indicating the flow-oriented model. Within Canada, at lower periods the exchange rate was the leading variable, indicating the flow-oriented model, but at higher periods it is difficult to determine which is the leading variable. Within Norway, it is also difficult to identify the leading variable in most cases. Around the 32-month period, however, the exchange rate is the leading variable, indicating the flow-oriented model. Within Russia, the exchange rate is the leading variable throughout, indicating the flow-oriented model. It seems that in most periods during the global financial crisis the flow-oriented model holds. During the commodity price downturn from mid-2014 to early 2016, Brazil's co-movement was negative for a period of about 12 to 25 months and for a longer period of about 45 months.

However, Brazil has recorded significant negative co-movement at several periods since 2016. As for Canada, it exhibited a long-run negative co-movement around a period of about 30 to 40 months when commodity prices fell. Within Norway, there was a short co-movement of around 12 months. In the case of Russia, there were very short co-movements at low periods of about 3-4 months. In the covid shock period around 2020, co-movement occurred in all countries and was negatively oriented. Around the Russian invasion of Ukraine, short co-movement at low periods occurred for Brazil, Norway, and Russia.

Overall, therefore, the analysis shows a negative relationship between the exchange rate and the stock index in most places. In a few cases the stock index is leading, indicating the stock-oriented model. In most cases the exchange rate is leading, indicating the flow-oriented model.

In subsection 4.3, a robustness analysis using the cross-wavelet transform is performed. Compared to the wavelet coherence, the cross wavelet transform shows less co-movement. During the dot-com bubble, a short co-movement appeared in Brazil, Canada, and Norway. Significant negative co-movement emerged during the global financial crisis, when all analyzed countries showed co-movement at several periods and the leading variable is the exchange rate, indicating the flow-oriented model. Thus, a robustness analysis confirms the wavelet coherence results in this time. In the time from mid-2014 to early 2016, when commodity prices were falling, short co-movement appeared in the case of Brazil, Canada, and Russia. During the covid shock around 2020, short co-movement appeared at lower periods for all analyzed countries. In the time of the Russian invasion of Ukraine, co-movement appeared for all analyzed countries. However, it was most pronounced for Russia.

5 Conclusion

The research objective of this thesis is to empirically investigate the relationship between the exchange rate and the stock market.

The second chapter of the thesis presents the theoretical background of the exchange rate. The theoretical concepts of the relationship between the exchange rate and the stock market are also presented in this chapter. Finally, the chapter also provides empirical evidence from high quality impacted journals of studies on the relationship between the exchange rate and the stock market.

The third chapter presents the data and methodology used. The thesis uses the data as logarithmic differences, which, based on the Jarque-Bera test, all logarithmic differences have normal distributions at the 0.1% significance level. The main method in the thesis is wavelet analysis.

The fourth chapter of the thesis presents empirical results from wavelet analysis. First, a continuous wavelet transform is performed, which tells us how a variable fluctuates at a given time and frequency. From the results obtained, we can conclude that both the exchange rate and the stock index achieve high fluctuations during economic crises. For the time from January 2000 to January 2023, in most cases the largest fluctuations occurred during the global financial crisis of 2007 to 2010. Another interesting finding is that continuous wavelet transform showed that the RUB/USD exchange rate was very stable from January 2000 to mid-2008, and the Russian central bank had been successful in its goal of stabilizing the Russian ruble since the Russian financial crisis in 1998.

Next, wavelet coherence is performed to assess the relationship between the exchange rate and the stock market. For all analyzed countries, there is a co-movement between the exchange rate and the stock index. In most cases there is a negative co-movement. As for the leading and lagging relationship, in some cases the leading variable is the stock index, indicating the stock-oriented model, but in most cases the leading variable is the exchange rate, indicating the flow-oriented model. Based on the theory, if the leading variable is the exchange rate and there is a negative relationship between the exchange rate and the stock market, it indicates that the stock market in the country is pro-importing oriented. However, the analyzed countries are major exporters and from chapter 3, when the structures of the indices are presented, it appears that the stock market in the analyzed countries is more pro-exporting based. According to the most recent data by The World

Bank for 2021 (The World Bank 2023b), analyzed countries have a positive net trade in goods and services, specifically for Brazil the net trade is 19.25 USD Billions, for Canada 1.89 USD Billions, for Norway 58.63 USD Billions and, for Russia 170.09 USD Billions. It is an interesting finding that in most cases the flow-oriented model with negative relationship is applied in the analyzed countries.

Co-movements occur most often around economic crises, which may be caused by investors fleeing to so-called "safe havens". In this case, it is possible that investors who are invested in bonds, for example, flee first, which means that the currency of risky countries depreciates first, as bond investors flee when they demand USD and try to sell the currency in risky countries, and then stock investors flee from risky countries when they sell stocks. This could explain why the leading variable in most cases during the economic crisis is the exchange rate and the stock index is a lagged variable. In other words, bond investors might react earlier than stock investors. For example, during the sharp decline in stock prices from the second half of 2008 to early 2009, the 10-year treasury yield in the US hit its low on 31 December 2008. The stock index (S&P 500) reached its low on 9 March 2009. In the next sharp fall in stock prices at the beginning of 2020, the 10-year US treasury yield hit its low on 9 March 2020, while the S&P 500 hit its low on 23 March 2020 (Finance Yahoo 2023b; Finance Yahoo 2023c). It is therefore possible that the bond market reacts earlier than the stock market during economic crises.

The results of the thesis in the time of the global financial crisis are consistent with the results contained in Dahir *et al.* (2018), where they also use wavelet analysis when they analyze the relationship between the exchange rate and the stock market within the BRICS countries. They also find that there is a negative relationship between the exchange rate and the stock index in Brazil and Russia during the global financial crisis. The leading variable is the exchange rate in both Brazil and Russia. The results of that study are consistent with the results of this thesis. Due to the small number of studies that use wavelet analysis, it is necessary to refer to studies that do not use wavelet analysis.

In the recent study by Xie *et al.* (2020), using a Granger causality test, they find that there is bidirectional causality between the exchange rate and the stock market in the case of Norway. In the context of this thesis around 2020 at a period of 8 months, the leading variable is the exchange rate, whereas at a period of 16 months the leading variable is the stock index. There is no clear leading variable in the case of Norway. So, the findings of this thesis can be considered similar to those of the presentred study in the case of Norway.

Within Canada, a study by Xie *et al*. (2020) finds, based on a Granger causality test, that there is unidirectional Granger causality running from stock prices to exchange rate. In this thesis, in the case of Canada, the leading variable is the stock index only at a period of about 32 to 40 months from mid-2013 to 2018. At lower periods the exchange rate is the leading variable.

Next, the results of this thesis find similar findings as Wong (2017), that there is a strong correlation between the exchange rate and the stock market during financial crises. A recent study by Tian *et al.* (2023) analyzes the relationship between exchange rate and stock market in several countries and includes Brazil and Russia among the countries. The study concludes that there is a negative relationship between the exchange rate and the stock market in analyzed countries and thus confirms the empirical results obtained in this thesis.

The contribution of the thesis is in several aspects. The first contribution of the thesis is to perform a wavelet analysis of whether there is a co-movement between the exchange rate and the stock index, what polarity it has and whether the leading variable is the exchange rate or the stock index within Brazil, Canada, Norway, and Russia. The second contribution of the thesis is that, because the thesis is written in English, foreign readers can also access it and broaden their knowledge on a very interesting topic, which the relationship between the exchange rate and the stock market is undoubtedly.

Overall recommendation, investors investing in the financial markets may be enriched by the interesting finding that in most cases a negative co-movement between the exchange rate and the stock index holds in Brazil, Canada, Norway, and Russia. This is a very useful piece of information because if investors believe that the stock index will rise, the exchange rate will most likely fall (the currency of the that countries will appreciate). Therefore, if the investor expects the value of the stock index to increase, it is advisable not to hedge against currency risk, as this way the investor will not lose the potential return in the form of exchange rate appreciation of his/her investment. The second recommendation is that for all analyzed countries, the exchange rate was the leading variable and the stock index lagged at a period of about 8 to about 32 months during the global financial crisis from 2007 to 2010. Thus, it appears that in the event of a prolonged economic crisis, the stock index tends to lag behind the exchange rate at a period of 8 to 32 months in all analyzed countries. Based on this finding, investors but also speculators who may use various financial derivatives can make better decisions in their favor. However, the empirical results in the thesis should be taken with a grain of salt as every empirical result has its limitations and cannot be taken as dogmatic truth.

For future research in the form of a dissertation or an article in a professional journal, there are several suggestions. Based on the empirical results of the thesis, it would be appropriate to investigate in further research whether the bond market reacts earlier than the stock market in Brazil, Canada, Norway, and Russia. It would be appropriate to make co-movements between the exchange rate – the stock market, the exchange rate – the bond market and the stock market – the bond market. This research would better explain how investor flows work, especially in times of economic crises. For further research, it might be useful to include the domestic currency in the analysis against a larger number of foreign currencies and to compare whether against other currencies the results of the analysis between the exchange rate and the stock market indicate different biases. Next, it would be very interesting to look at the level of openness in different countries and whether a country's export and import rates affect whether a positive or negative relationship between the exchange rate and the stock market prevails in that country. At the same time, an analysis to determine whether a negative or positive relationship between the exchange rate and the stock market prevails in countries with a positive trade balance or a negative trade balance would also be useful. Another suggestion of where the research could move is that it would be interesting research to assess whether the market capitalization of a country's domestic stock market relative to GDP affects the relationship between the exchange rate and the stock market. The larger the size of the stock market relative to GDP, the greater the shift in investor liquidity when buying/selling stocks could have a greater effect on exchange rate changes.

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List of Abbreviations

BRL	Brazilian Real
BRICS	Brazil Russia India China South Africa
BEER	Behavioral Equilibrium Exchange Rate
CAD	Canadian Dollar
CIRP	Covered Interest Rate Parity
CWT	Continuous Wavelet Transform
ČNB	Česká Národní Banka
ERDI	Exchange Rate Deviation Index
FE	Fisher Effect
GDP	Gross Domestic Product
IMF	International Monetary Fund
ISO	International Organization for Standardization
JB	Jarque-Bera Test
NATREX	Natural Real Exchange Rate
NOK	Norwegian Krone
PPP	Purchasing Power Parity
RUB	Russian Ruble
UFR	Forward Rate as Unbiased Predictor of Future Spot Rate
UIRP	Uncovered Interest Rate Parity
USD	United States Dollar
WTC	Wavelet Coherence
XWT	Cross Wavelet Transform
FEER	Fundamental Equilibrium Exchange Rate
DEER	Desired Equilibrium Exchange Rate