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What causes fluctuations in the exchange rate?

A quantitative study on the underlying variables that affects the Swedish Krona and Euro exchange rate

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January 24, 2020

Bachelor's Thesis – 15 credits

Economics

Autumn 2019

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Abstract

This paper focuses on analysing the SEK/EURO exchange rate and focuses on testing if 5 specific variables chosen based on previous research affect the SEK/EURO rate. The study uses monthly data from January 2000 to September 2019, the five variables tested are Interest Rate differentials, Inflation Rate differentials, Yield Curve differentials, Implied Volatility Index and the difference in Economic Sentiment. We ran both bivariate and multivariate regression analysis and found, in contrary to theory, no significance for inflation in neither of the tests. Our second finding worth noting, were that the variable Economic Sentiment showed no significance when tested separately in a bivariate regression but significant when tested simultaneously in a multivariate regression.

Acknowledgements:

We would like to give our sincerest regards to our supervisor, Charles Nadeau, whom have given us valuable inputs and comments that were vital for the process of our thesis writing. As well a thank you to The Centre of Finance at the University of Gothenburg who provided us with the recourses necessary to complete our analysis. At last, we want to address our gratitude to Monica Jaxelius for her valuable input on our English grammar.

JEL Classification: F21, G15

Key words: Swedish krona and Euro Exchange rate, Interest rate, Inflation, Yield Curves, Implied Volatility, Economic Sentiment

Abbreviations:

UIP – Unconvered Intersest Rate Parity

PPP – Purchasing Power Parity

BEER Model – Behavioral Equilibrium Exchange Rate Model

GOF – Goodness of Fit

MSE – Mean Squared Errors

VIF – Variance Inflation Factor

AEC – All Else Constant

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1.0 Introduction

In a country with floating exchange rate, the rate will be decided by the supply and demand of the country's currency. If the demand of the currency increases, the value of the currency will appreciate and vice versa. Investors have, for many years, tried to pinpoint the underlying variables that are affecting the exchange rates in order to explain the fluctuations and beating the market to earn a profit. This thesis aims to build a model that can explain historical fluctuations and estimate the effect that five different variables have on the long-run exchange rate, Swedish krona/Euro.

The previous research is divided between the old-school, more simple and narrow models which has focused on the basics of macro- and financial theories and the more modern ones which are built on bigger, more complex models. However, it is easy to find similarities between the two since the older models have laid the base for the continuous research in the field. Many scholars are in consensus regarding the importance of a various set of variables and their effect on the exchange rate, like interest rates and inflation rates.

The variables we choose in order to create our model were based on previous research, Interest Rates, Inflation Rates, Yield Curves, Implied Volatility and Economic Sentiment. However, what makes our thesis different from earlier studies is by the usage of the variable Economic Sentiment. The variable is based on the European Commission's Business and Consumers Surveys, and measures investors' confidence in different economic sectors. This gives us valuable insight in how investors forecast the future and in turn the expected demand on the different currencies. To make a comparable model we choose to use the differentials in the variables, meaning that we for example took the difference in the repo-rates between Sweden and the Eurozone, likewise, for the variables; Inflation rate, Yield Curves and Economic Sentiment.

By running both bivariate and multivariate regression analysis we compared the effect of the variables when tested separately and together. The results from the bivariate regression showed significance for three out of five variables, Interest Rate, Yield Curve and Implied Volatility. The results from multivariate, however, showed us a different result. We found significance for all variables but Inflation rate. Previously, in the bivariate regression, we could not draw any conclusions about the effect of Economic Sentiment, but when adding the other variables, we could observe a strong significance for the variable, confirming our theory.

1.1 Background

The exchange rate is affecting everyone that has ever purchased groceries, travelled, bought clothes online or traded internationally. The exchange rate affects us on a daily basis and is an important factor in the wellbeing of a country. The foreign exchange market is a system of Central Banks, foreign exchange dealers and brokers as well as private banks. Through these channels, households, firms and governments can buy and sell foreign exchange i.e. purchase and sell another nation's currency. An exchange rate is the market price for the foreign currency in terms of a domestic currency. For example, SEK/EURO = the cost of 1 Euro in terms of the Swedish Krona (Daniels and Van Hoose, 2014). A lower relative value of the country's currency strengthens and increases the export but weakens the import, the reverse occurs when the currency appreciates. A relatively weak exchange rate tends to lead to an increase in tourism, while a relatively strong exchange rate tends to increase the domestic travels. It's hard to find an optimal value for the exchange rate, a relatively "strong" Swedish Krona will lead to an increase in import but decrease the export and vice versa if the Krona is relatively "weak", over a long period of time, the effects of appreciation and depreciation on an economy tends to counterbalance each other.

Chart 1 shows the exchange rate between the Swedish krona and the Euro. The last couple of years Sweden has observed a depreciation of the Swedish krona in relation to the Euro, which arises the question; What underlying variables affect the currency and in what way? The floating exchange rate is mainly decided by the relationship between supply and demand of the country's currency. If the demand of the currency increases, value of the currency will increase or i.e. appreciate. However, are there variables that will affect the investors' demand on a currency?

1.1 Purpose and contributions

By examining the underlying variables that affect the exchange rate, are we aiming to build a model that can explain and follow the realized exchange rate for SEK/EUR. By building a model will we also be able to observe the effect the different variables have and why we have experienced a lower value of the Swedish krona in relation to the Euro. This thesis will contribute to the field by adding the variable Economic Sentiment to the equation. We have found theoretical evidence that it should affect the exchange rate but have not found a research paper that is testing for its significance.

1.2 Delimitations

Due to the complexity of exchange rates, it's hard to grasp and cover all variables that may affect the exchange rate. Therefore, a huge delimitation of our analysis is the choice of variables. We chose variables that we believe has a significant effect on the exchange rates and has in the past been proved to play an important role in the explanation of the exchange rates.

Because we are analyzing the relation between the Swedish Krona and the Euro we will be limited in the amount of observations. When running a regression analysis, the more observations the more trustworthy results. However, the Euro was introduced in the late nineties and used as a currency in the beginning of 2002. This makes our time interval limited to 19 years of observations.

2.0 Literature and theory

2.1 Literature overview

The question of what really affects the exchange rates divides the world of scholars, the question is complex, and plenty of papers have been written in this field. We will focus on papers discussing different exchange rate models as well as on papers discussing the predictability of different models. This paper is not focused on predicting exchange rates. However, if older studies find variables or models that are useful for prediction, they will most likely be useful for explaining what determines exchange rates.

The earlier studies in the field of exchange rates have focused on a narrow set of models. The main factors of these models were money supply, real income, short-term interest rate, long run expected inflation and trade balances. Common for all the variables are that the domestic-foreign differentials were used, except for the trade balances where they used separate values, one for domestic and one for foreign (Meese and Rogoff, 1983).

In more recent research, the older models have been amplified by factors as price levels, productivity growth and a composite specification incorporating several different variables where debt, productivity and interest rates matter. They mainly described the models which augmented productivity-based models and behavioral equilibrium exchange rate models. They further expand on the sets of these models by adding Taylor rule fundamentals, yield curve factors as well as incorporating shadow rates, risk and liquidity factors. The forecasting performance of the models will be compared to a random-walk benchmark. None of the models consistently outperforms a random walk, however the purchasing power parity model does quite well (Cheung et al 2005).

Molodtsova et al (2008) discusses how Taylor rule fundamentals can be used to predict the Deutsche Mark/US Dollar (DM/USD) exchange rate. One of the purposes of their paper is to investigate how the use of real-time data affects the “out of sample” predictability of the exchange rate. This is done by looking at a model for the USD/DM exchange rate (nominal) with Taylor rule fundamentals. They find strong evidence for exchange rate predictability when the real DM/USD enters the Bundesbank’s Taylor rule. However, no evidence is found when only using the inflation and output gap. One thing to note is that increases in both countries’ inflation generate forecast of the exchange rate to appreciate, this is an important determinant of exchange rate predictability. Clarida and Waldman (2008) report that bad news about the inflation will result in good news for the exchange rate.

In a later paper Molodtsova and Papell, (2009) show strong evidence of exchange rate predictability while using Taylor fundamentals. They get the strongest predictability when using the symmetric Taylor rule model with heterogeneous coefficients, smoothing and a constant.

In a later published paper Cheung et al (2017) promoted an expand upon the earlier models (2005) by incorporating factors that the central banks are believed to pay attention to. They further incorporate some factors that, de facto, it’s hard to set interest rates below zero and the increase of the importance of risk and liquidity in financial markets. To take into account for the former, they use shadow interest rates which are short term interest rates consistent with longer term interest rates, by using VIX and TED spreads. The conclusion of the paper was that none of the models consistently outperform a no-change or random walk prediction by a mean squared error measure. But the purchasing power parity model does quite well in outperforming the random walk. By further analyzing the results the authors assert that models that include long run relationships in levels, tend to outperform those that involve growth rates. Thus, the newer models that have become more popular during the past 15 years have not proved to be much better than the older ones.

Furthermore, in an earlier study by Engel, Mark and West (2007) it’s argued that the “Older methods” used in previous research, where they try to outperform a random walk is a too strong criterion for accepting an exchange rate model. Instead, they are examining a “in sample fit” as an alternative to evaluate the models. The basic argument is that the “standard models” all imply random walk behavior and thus their power to beat the random walk out of sample is very low. They also argue for that exchange rates are primarily driven by expectations, so changes in current economic fundamentals might impact the exchange rate indirectly through the changes in monetary policy rather than directly affecting the exchange rate. The example of Taylor rule fundamentals is used where the argument is that in the New Taylor rule models, a higher inflation will lead to appreciation in inflation targeting countries, but it’s because a higher inflation induces expectations of tighter future monetary policy. Furthermore, they try to measure inflation expectations by using data that surveys professional forecasters namely the Money Market Survey.

Because the exchange rate is decided by the supply and the demand of the currency, the importance of the yield curve as a variable in predicting the exchange rate has increased during recent years. Research shows that the difference between two countries yield curves can be used to predict the relative value of the currencies as well as the risk premiums. It has also been proved that changes in the shape of the slope have a significant effect on investors' expectations of the future exchange rate. These results are supported by the uncovered interest rate parity condition. If the slope is flattening or if it's even negative, i.e. if the expected rate of return on long-term bonds is equal or even lower than the interest rate on short-term bonds, it's considered that the country is facing a slower economic growth or even a recession in the future. A flat domestic slope will increase the risk premium and so appreciate the value of the domestic currency in the long run (Cheng and Tsang 2013).

2.2 Theory Review

Based on the paper by Cheung et.al from 2017, we discuss some exchange rate models that are prominent in the economic and policy literature as well as replicable and implementable.

2.2.1 Uncovered Interest Rate Parity Condition

The theory of Uncovered Interest Rate Parity Condition (UIP) is stating that the exchange rate is affected by the interest rate in the home country as well as in the foreign country. Hence, if an investor is looking for where to invest and his only goal is to invest where he will receive the highest rate of return, the decision he makes to invest, is decided not only by the two interest rates but also the current exchange rate and the expected exchange rate of the future. The equation is simple, but it gives an indication of how the exchange rates can differ and Feenstra and Taylor (2017) argues that UIP "is one of the most important conditions in the international macroeconomics" due to its simplicity.

$$F_t = S_t \frac{1 + i_c}{1 + i_b} \tag{1}$$

F_t – Forward rate at time t

S_t – Spot rate at time t

i_c – Interest rate in country c

i_b – Interest rate in country b

2.2.2 Purchasing Power Parity Condition

According to Purchasing Power Parity (PPP) is the exchange rate, dependent of the ratio of price levels of a basket of goods between two countries and that there is no difference in the relative price of the baskets. To the theory of PPP has many supplements been added and many argues, that the Relative Purchasing Power Parity (RPPP) is one of the most important factors for understanding the fluctuations of exchange rates. RPPP is derived from the absolute PPP but adds the rate of changes in prices, in other words the inflation rate. Why is this important? If Relative Purchasing Power Parity holds, the rate of depreciation of the nominal exchange rate equals inflation differentials which is showed in equation below (Feenstra och Taylor, 2017).

$$\frac{E(S_t) - S_0}{S_0} = [\pi_{FC} - \pi_{DC}]^t \quad (2)$$

$E(S_t)$ – Expected spot exchange rate in time t.

S_0 – Current spot exchange rate

π_{FC} – Inflation rate of the foreign country

π_{DC} – Inflation rate of the domestic country

2.2.3 Sticky Price Monetary Model

The Overshooting Model or also called Sticky Price Monetary Model, was presented by Rudiger Dornbusch in 1976 but is still implementable. The model argues that the foreign exchange rate will overreact temporary in response to changes in monetary policy, this is to compensate for sticky prices of goods in the economy, i.e. prices of goods do not instantly respond to changes in monetary policy and tend to stay at the same price level for a period of time. In the short run this means equilibrium will be meet by changes in financial markets such as the foreign exchange, money, derivatives and bond markets. Thus, equilibrium is not met by shifts of the goods themselves. However gradually the prices of goods will "unstick" and thus, adjust for the changes in the financial markets. Summarizing the model; foreign exchange markets initially overreact to changes in monetary policy which creates the short run equilibrium. As the prices of goods slowly adjust to the financial market prices, the foreign exchange market weakens their reaction and thus, create a long run equilibrium.

$$s_t = \beta_0 + \beta_1 m + \beta_2 y + \beta_3 i + \beta_4 \pi + u \quad (3)$$

s_t – log exchange rate

m – log money

y – log real GDP

i – Interest rate

π – Inflation rate

2.2.4 Behavioural Equilibrium Exchange Rate Model

The BEER model was first introduced by Clarke and MacDonald in 1994 and is a very simple model. The (generalized) model tries to explain the behaviour of the exchange rate in terms of different economic variables. It is a simple econometric model which uses a real or nominal exchange rate as the explained variable and a set of economic fundamentals as the explanatory variables. The economic fundamental variables are a set of variables that are chosen based on relevant economic theory and relevant studies. This in turn means that BEER models across different studies look very different, furthermore, this also means that this model is constantly evolving and adapting (Zhang and Zhibai 2010).

$$E = \beta_0 + \beta_1\gamma_1 + \beta_2\gamma_2 + \ldots + \beta_n\gamma_n \tag{4}$$

E – Nominal or real exchange rate

β_0 – Determines the intercept for the regression and is a constant.

β_x – Determines the change in exchange rates if we add one more unit of the independent variable, ceteris paribus.

γ – A economic variable

2.2.5 Taylor Rule Fundamentals

The Taylor Rule or the Taylor Principle is a proposed guideline for how central banks such as the Swedish Riksbank or Bundesbank should tweak and change the interest rate in response to changes in the economy such as the degree of slack in the economy, inflation rate, difference between short- and long-term interest rates which is known as the slope of the yield curve is taken in account. The main purpose of the principle is short term stabilisation while ensuring long term growth. The rule is based on three factors; the target inflation level vs the actual inflation level, full employment vs actual employment levels and short-term interest rate consistent with full employment (Taylor 1993).

$$i = r^* + \pi + 0.5(\pi - \pi^*) + 0.5(y - y^*) \quad (5)$$

i – nominal interest rate

$r*$ - real federal funds rate

π – inflation

$\pi*$ - target inflation

y – log (real output)

$y*$ - log (potential output)

2.3 Econometric Theory

In statistics and econometrics, when scholars are trying to predict a relationship between a dependent variable and a various number of independent variables, they traditionally use a method called Goodness of Fit (GOF). By creating models based on historical data GOF will help to decide which model is best for testing "out of sample" (Jung et al. 2017). What defines as "the best fit" is decided by how much the different independent variables can be explained by the dependent variable and how much is explained by the error term. This is done by analyzing and comparing the value of R_2 for the different variables. Since we are aiming to create a model that can match fluctuations in the realized exchange rate, will we use the statistical method GOF to create different models and try to find the best fitted model given a certain number of independent variables.

Another way to evaluate the models is by using a similar approach to evaluate our models to those used in the studies in the literature overview. One common method is to look at the mean squared errors (MSE). Specifically, the ratio between the structural models and a driftless random walk. But instead of trying to outperform the random walk we are simply trying to see which model is the best at explaining changes in exchange rate. Since we are using Newey-West standard error we will not get any R2 values or MSE. So instead, have we chosen to compare the residuals of each model with the residuals of a "benchmark model" which we specify as;

$$\log(exchange\ rate) = \beta_0 + \beta_1 * time + \varepsilon \quad (6)$$

The model reflects the realized value of the exchange rate over time. From the benchmark model we will be able to calculate the residuals and compare the residuals from the benchmark model with the residuals from our specific models we build. The model which difference is the closest to 0 with the benchmark model will the best fitted model to explain the fluctuations in the exchange rate over time.

3.0 Methodology and Data Description

3.1 Data Description

All data is collected between the years 2000 – 2019 and is measured monthly. To analyze the variables effect on exchange rates we will be using the differentials between Sweden and the Euro-area for the variables; Inflation, interest rates, yield curves and the indexes for the economic sentiment, hence, it gives us an advantage in comparing the two areas. The implied volatility variable is measure by the percentage change in price of the ES3M index.

3.1.1 Inflation

Inflation has been proved to be a very important factor when explaining the fundamentals of the exchange rate. We have chosen to use the Harmonized Index of Consumer Prices (HICP). The index measures the changes in prices of consumer goods and services and is used by the whole European Union. If a country has a high level of inflation it will be less attractive for investors, hence if Sweden has a higher rate of inflation in comparison with the Eurozone, less investors will invest in Sweden and more in the Euro area and therefore will the Swedish krona depreciate in relation to the Euro (Molodtsova et al 2008). The difference is calculated following:

$$\hat{\pi} = \pi - \pi^* \tag{7}$$

Where π defines the inflation rate, the inflation rate for the foreign country is marked with a star. The inflation rates for the Euro-area and Sweden is collected from Eurostat Database.

3.1.2 Interest Rate

According to previous research in the subject of exchange rates, one often mentioned factor is interest rate. As stated earlier, the exchange rate is highly affected by supply and demand of currency. According to the interest rate parity condition, a higher interest rate in domestic country in comparison to the foreign, increases the incentive for the investors to invest in the domestic country, i.e. the demand for the domestic currency increases which will appreciate the value of the currency. The more capital that flows into a country the more the currency will appreciate. We will be comparing the month repo rates in Sweden with the one-month repo rate of the European Central Bank.

$$\widehat{ir} = ir - ir^* \tag{8}$$

The interest rate is defined as *ir* and the rate for the foreign country is marked with a star. The data is collected from the Swedish Central Bank, Riksbanken and Deutsche Bundesbank.

3.1.3 Implied Volatility

If the investors are worried about the future or if the investors are forecasting a more volatile future, they will be more likely take action to hedge for the risk. It is therefore important to understand the difference between the historical volatility and implied volatility. Whereas the first, as the name implies, is collected historical data of a security's price. Implied volatility, however, measures the degree of uncertainty, associated with the excepted future fluctuation of a security's price or a currency's exchange rate. Implied volatility is based on the collection of the historical volatility data. For the sake of this thesis are we going to use the *EUR SEK 3M ATM Implied Volatility (ES3M)* which reflect the currency option traders' uncertainty associated with future changes in the Swedish Krona and Euro exchange rate. The uncertainty is measured in percentage change of the current exchange rate over a three-month period.

If many investors are predicting a recession or a depreciation of the currency in the future, the expectations will be reflected in the ES3M as volatility rate. The opposite occurs if the forecast becomes positive and the country's currency is expected to more stabilize over time. Hence, by using the implied volatility we will be able to measure how the investors are speculating and that gives us a hint of the future exchange rate (Hull 2014).

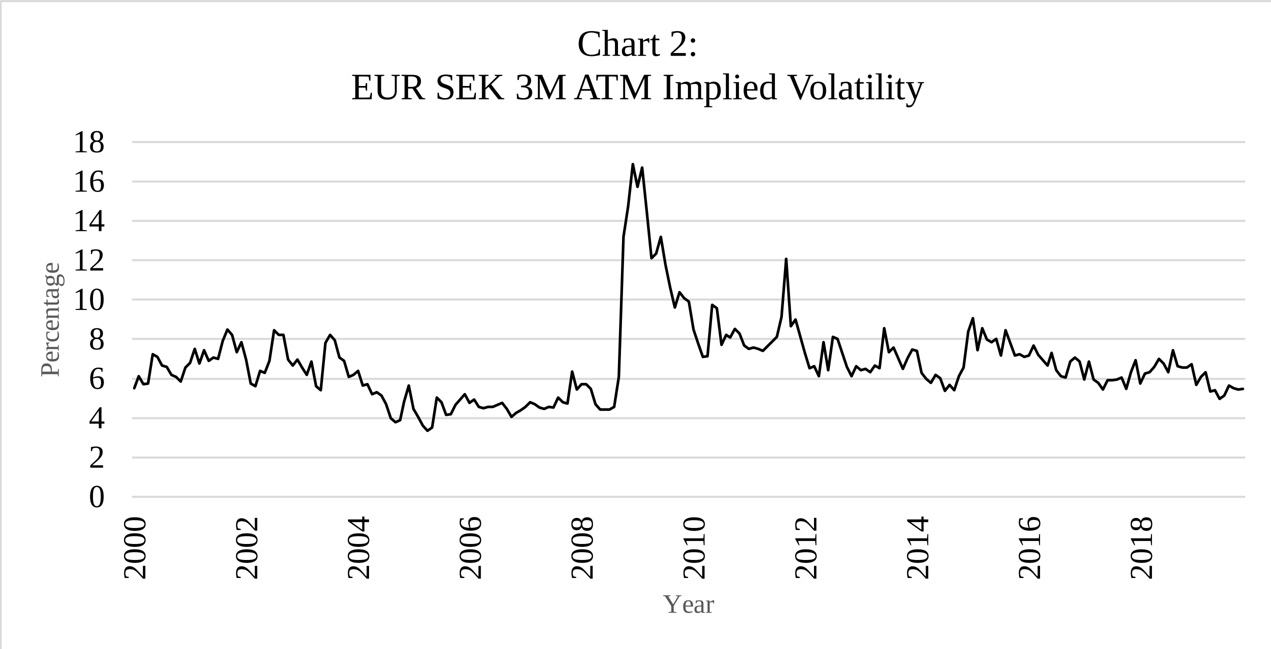

Chart 2 shows how the expected volatility of the exchange rate has changed over time. By comparing the figures with the different financial crisis during the last decade, are we able to observe an increase in expected fluctuations just after every crisis that has led to a recession in the worldwide economy. The first big increase happens just after the great recession in 2008 and the second after the Euro-crisis of 2011. Both crises lead to recessions in the European economies and a depreciation of the exchange rate. So again, by analyzing the implied volatility gives us a relevant indicator of how investors forecast the future and future investments (Hull 2014). The data is collected from Bloomberg.

3.1.4 Yield Curve

When investors, firms or banks invest in bonds they receive an interest rate depending on the maturity of the bond. The longer maturity, i.e. the longer period that they “lock” their money, the higher return they will receive. The maturity could variate from 1-3 months until 10 or even 30 years. The yield curve shows how the interest rate differs over time and is often used as a benchmark in the debt market. Most common is a positive sloping yield curve, meaning that the higher length of maturity, the higher rate of return or interest rate the bond will have. However, if the slope is negative, the short-term bonds will receive a higher rate of return than the long-term bonds. Many investors are, therefore, using the yield curve as an indicator for predicting future growth, negative slope indicates that the country may be facing a recession and decrement growth. We have chosen to compare the yield curve in Sweden with the yield curve in Euro-area. The yield curves show the relationship between 3M bonds with 10Y bonds, i.e. three months maturity bonds with ten years maturity bonds.

$$\gamma = i_{10Y} - i_{3M} \tag{9}$$

$$\gamma^* = i^*_{10Y} - i^*_{3M} \tag{10}$$

Where *i* defines the interest rate for the two different bonds depending on their maturity, the star marks the yield curve for the foreign country.

$$\hat{\gamma} = \gamma - \gamma^* \tag{11}$$

If the yield curve in the home country is flatter relatively to the foreign country, the risk premium in Sweden will be greater than in the Euro-area, which will lead to a higher pressure on the home currency, making its value to appreciate (Cheng and Tsang 2013).
The data is collected from the Swedish Central Bank, Riksbanken.

3.1.5 Economic Sentiment Indicator

The economic sentiment indicator measures the overall business and consumer sentiment. The index is based on monthly surveys in different manufacturing, construction, private sectors and retail trade. There are also surveys going out to consumers, the data is put together into an index which measures how “strong/weak” the current economy is. 100 is the mean value where values between 100-110 shows a stronger than normal economy. Values over 110 show a much stronger than normal economy. 90-100 show a weaker than normal economy and below 90 shows much weaker than normal economy (Bloomberg). We have chosen to look at the difference between the Swedish economic sentiment index (SWETSURV) and the Eurozone (EUSEMU) index (SWETSURV-EUSEMU). Where a positive value indicates that the Swedish economy outperforms the euro area economies, and a negative value indicates the opposite, that the euro area economies are performing better than the Swedish. And 0 means that they should be around the same level. This is interesting to look at since if Sweden's economy is outperforming the Euro area (in the eyes of business and consumers) this should theoretically have an impact on the exchange rate. This is something that we believe, and we haven’t found any research that backs up this statement.

3.2 Methodology

The purpose for many previous researchers has been to predict the future value of the currency using different variables. Since we are aiming to build a model to match the realized exchange rate curve, measure the degree of explanation for our variables and predict the size of the effect that different variables have on the exchange rate will we use historical data of the exchange rate to predict the changes in exchange rate over time. This makes our angle of incidence a little bit different from previous research. To measure the change in exchange rates we have chosen to calculate with the logarithm of exchange rate, this is to simplify the interpretation of the results because we will be able to observe the change in percentage.

Because we are using data that varies over time and all the variables are dependent of its value in previous time, we are expecting to find our variables to be highly auto correlated, the data can either be a random walk, trended or be highly persistent. We will test this by running a Durbin-Watson test, comparing one variable with a lagged version of itself. We believe that our data is highly persistent and that it displays a trend at the same time. If we find high autocorrelation, there are different actions to take into account. One is to add the time variable to the regression, but there is a chance that this will do nothing or very little and one way is to detrend the variables. If we do not take into account for high autocorrelation or serial correlation this might lead to the OLS statistics and standard errors to be misleading. However as stated in the theorem presented in Engel and West (2005), it demonstrates that, under plausible assumptions, models imply that the exchange rate should follow a random walk. Thus, if exchange rate models should follow a random walk there will not be any need for us to alter the data by detrending. What we will do instead is to use Newey-West standard errors or try to add more variables that might be missing, as this also leads to high correlation.

Another risk when dealing with time-series is exposure to multicollinearity, i.e. two or more of our independent variables describing the same phenomenon. This we are not as concerned about because we are using the differentials between the two observed areas but to test if we are dealing with multicollinearity will we use Variance Inflation Factor (VIF). This will measure if the variance of a regression coefficient is inflated due to multicollinearity (Woolridge 2016). If we, in contrary to our predictions, detect multicollinearity we have a problem. There are different ways of dealing with multicollinearity, like erasing the correlated variables or adding more observations to the research. However, these actions will in their turn, create problem for our continuous research. We are dealing with a limited selection of data due to the fact, there is no more data about the Eurozone before 2000 and erasing a variable will weaken the model, we are trying to build which will increase the risk for insignificant results.

3.2.1 Bivariate Regression Analysis

We choose to start our analysis by running simple regressions on exchange rates with all our independent variables. By doing this we will have a chance to observe the relationship between exchange rates and our independent variables. We strongly feel that by adding a bivariate regression to the thesis will give us a greater depth and understanding when discussing the correlation of the independent variables. The more the beta-values changes when we are switching from bivariate- to multivariate regressions the higher correlation between the independent variable there is. The equations for the different variables follow below:

Inflation:

$$\Delta {}^{SEK}/_{€}\% = \beta_0 + \beta_{\hat{\pi}} * Inflation\ difference + \varepsilon \tag{12}$$

Interest rate:

$$\Delta {}^{SEK}/_{€}\% = \beta_0 + \beta_{\hat{ir}} * Interest\ rate\ difference + \varepsilon \tag{13}$$

Yield curve:

$$\Delta {}^{SEK}/_{€}\% = \beta_0 + \beta_{\hat{Y}} * Difference\ in\ slope\ of\ Yield\ curve + \varepsilon \tag{14}$$

Implied Volatility:

$$\Delta {}^{SEK}/_{€}\% = \beta_0 + \beta_{IV} * Implied\ volatility + \varepsilon \tag{15}$$

Economic Sentiment Indicator:

$$\Delta {}^{SEK}/_{€}\% = \beta_0 + \beta_{ES} * Economic\ sentiment\ indicator + \varepsilon \tag{16}$$

β_0 – Determines the intercept for the regression and is a constant.

β_x – Determines the change in exchange rates if we add one more unit of the independent variable, ceteris paribus.

ε – Explains the change that we do not cover in the regression, both known and unknown variables.

Null hypothesis

Before the bivariate regressions we need to set up the null hypothesis for the different variables.

Null hypothesis inflation;

$$H_0: \beta_{\hat{\pi}} = 0$$

$$H_0: Inflation\ difference\ has\ no\ effect\ on\ exchange\ rates$$

Null hypothesis interest rate;

$$H_0: \beta_{\hat{ir}} = 0$$

$$H_0: Interest\ rate\ difference\ has\ no\ effect\ on\ exchange\ rate$$

Null hypothesis yield curve;

$$H_0: \beta_{\hat{Y}} = 0$$

$$H_0: A\ change\ in\ the\ difference\ between\ home\ the\ country's\ and\ the$$
$$foreign\ country\ yield\ curve\ won't\ have\ an\ effect\ on\ exchange\ rates.$$

Null hypothesis implied volatility coefficient;

$$H_0: \beta_{IV} = 0$$

$$H_0: The\ implied\ volatility\ coefficient\ has\ no$$
$$effect\ on\ the\ exhange\ rate$$

Null hypothesis economic sentiment indicator;

$$H_0: \beta_{ES} = 0$$

$$H_0: The\ economic\ sentiment\ indicator\ has\ no$$
$$effect\ on\ the\ exhange\ rate$$

3.2.2 Multivariate Regression Analysis

The reason for using a multiple regression analysis is that a multivariate regression allows us to control if the factors simultaneously affect the exchange rate (Woolridge 2016). By adding more variables that we believe affect the exchange rate, the more of the variability of the exchange rate can be explained (Woolridge 2016). Thus, by using a multiple regression we hope to build a model that better explains changes in exchange rate than the simple bivariate regressions.

$$\Delta {}^{SEK}/_{€}\% = \beta_0 + \beta_{\hat{\pi}} * Inflation\ difference + \beta_{\widehat{ir}} * Interest\ rate\ difference + \beta_{\hat{Y}} * Difference\ in\ slope\ of\ Yield\ curve + \beta_{IV} * Implied\ volatility + \beta_{ES} * Economic\ Sentiment + \varepsilon \quad (17)$$

$\Delta {}^{SEK}/_{€}\%$ – The change in exchange rate in percentage.

β_0 – Determines the intercept for the regression and is a constant.

β_x – Determines the change in exchange rate if we add one more unit of the independent variable, ceteris paribus.

ε – Explains the change that we do not cover in the regression, both known and unknown variables.

Null hypothesis for multivariate regression analysis

We want to test if the variables included as a model has an effect on the exchange rate. Our null hypothesis is the following:

$$H_0: \beta_{\hat{\pi}} = \beta_{\widehat{ir}} = \beta_{\hat{Y}} = \beta_{IV} = 0$$

$$H_0: None\ of\ the\ variables\ have\ an\ effect\ on\ the\ exchange\ rate$$

4.0 Results and Conclusion

In this section will we present and analyse our findings after testing the different variables. We will discuss the work before our regression analysis which will be followed by the results from our regressions. Afterwards follow a discussion and interpretation the different results and we will end by tying them together. However, we cannot emphasize enough, the complexity of studying the exchange rate, especially the exchange rate between the Swedish krona and the Euro. Sweden is a small economy; hence, its currency is a lot more sensitive to the larger economies' well-being. This is important to keep in mind as our results may differ significantly if you choose to analyse a greater exchange rate, for example the US Dollar and Euro exchange rate.

4.1 Results

As discussed in the Methodology section we did run a high risk of auto correlation and this was confirmed after running the Durbin-Watson test which gave us a result of around 0 (where 0 is highly positive autocorrelation and 4 is highly negative). However, based on the research by Engel and West (2005) discussed in the Methodology section, this is something that was expected from the beginning and we will not try to correct for high correlation in this study. When testing for multicollinearity we created a correlation matrix (see Appendix table A.1).

Summarizing the results from the correlation matrix, we can conclude our previous expectations, that we cannot detect multicollinearity in our variables. The highest correlation between two variables is -0.3784 between Economic Sentiment and Yield curve which is not surprising due to the fact that both are based on investors' speculations. The same could be said about Implied Volatility and Yield Curve but since neither test shows a higher correlation than 0.8, we could continue with our analysis without taking any further actions.

4.1.1 Bivariate Regression Analysis Results

After running the bivariate regression analysis, we did receive the following results, shown in Table 1.

Table 1: ***Bivariate regressions***	(1)	(2)	(3)	(4)	(5)
Constant	2.23**	2.23**	2.25**	2.16**	2.23**
	(0.0048)	(0.0054)	(0.0083)	(0.016)	(0.0054)
Interest Rate diff	-0.045**				
	(0.0086)				
Inflation Rate diff		0.025			
		(0.0097)			
Yield Curve diff			-0.0067*		
			(0.0023)		
Implied Volatility				0.01**	
				(0.0022)	
Economic Sentiment diff					-0.0009
					(0.0008)
Number of observations	237	237	237	237	237
Durbin Watson	0.066	0.096	0.055	0.06	0.05

Notes: Newey-West standard errors, * = p < 0.05 ** = p < 0.01

The only two variables that did not give us a significant value were *Inflation* and *Economic Sentiment*, we cannot therefore reject the null hypothesis for the two, that neither of the variables have a significant effect on exchange rate when tested separately (See regression *2* and *5*). For the other variables on the other hand we can observe a significant value and therefore reject the various null hypothesis that the variables have no significant effect when tested separately (see regression *1*, *3* and *4*). Why we did not observe significant result for Inflation could be explained by the error term being too large, meaning that the Inflation itself cannot explain changes in exchange rate. Likewise, the same argument could be said about Economic sentiment. Another explanation is that we do not have enough data to prove that inflation and economic sentiment have a significant effect on exchange rates when separately tested. However, based on theory, the two variables are interesting enough for us to keep them in further analysis.

Because we used the logarithm of the exchange rate, we will not be able to draw any numerical conclusions from our regressions before we have converted the figures. In order to convert different independent variables, we need to calculate the natural exponential of the coefficient of the regression. For example, to examine the effect of interest rate on exchange rate: Where Exp (2.23) = 9.3, is the geometric mean for the exchange rate SEK/EURO, meaning if the interest rate will be held constant the predicted value of 1 Euro is 9.3 SEK. By converting the coefficient, Exp (-0.045) = 0.96, it will tell us that if the interest rate difference increases by 1 percentage unit then the exchange rate decreases by 4%. Table 2 down below contains the converted figures of the regressions we received, which results shown to have a significant effect.

Table 2:

Bivariate regressions with converted figures	(1)	(3)	(4)
Constant	9.3**	9.48**	9.3**
Interest Rate diff	0.96**		
Yield Curve diff		0.99*	
Implied Volatility			1.01**
Number of observations	237	237	237
Durbin Watson	0.066	0.055	0.06

Notes: * = $p < 0.05$ ** = $p < 0.01$

Hence, by looking Table 2, can we conclude that the predicted exchange rate when testing with Yield Curve as independent variable is 9.48 SEK for 1 Euro. Continuously, a 1-percent change in Yield curve difference, when all else constant (AEC), will decrease the exchange rate with 1 %. Likewise, when measuring the Implied Volatility, the predicted value of the exchange rate would be 9.3, and 1 % change in the variable would lead to an increase of the exchange rate with 1 %.

By comparing the regressions 1, 3 and 4 in table 2 can we observe that a change in interest rate differential between the two countries have the “largest effect” on the exchange rate in percentage form. However, important to note is that these tests are only bivariate, basically meaning we assume that this is the only variable we have access to, and all other variables are present in the error term. However, we know that this is not the case and that we have access to more variables.

This brings us to the next step in our analysis, the multivariate tests. By using multivariate testing, we can control several variables at once. This allows us to look at how changing one variable will affect the exchange rate while the other variables are held constant. We can also look at interactions between the variables, meaning for example what will happened if inflation as well as interest rate simultaneously change, however this is something we will not look at. Furthermore, by adding more variables, more of the variation in the exchange rate can be explained, which allows us to build larger and better explaining models. But, some of our variables might "fall out" when we produce a multivariate regression, that one variable may have seemed to have a significant effect in the bivariate analysis, but not in the multivariate. This indicates that two of the explanatory variables explain the same thing in the exchange rate variable, thus, one will fall out.

4.1.2 Multivariate Regression Analysis Results

The results from our multivariate regression on the other hand gave us another, more interesting result, shown in Table 2 down below.

Table 3:

Multivariate regressions	(6)	(7)
Constant	2.19**	2.19**
	(0.0158)	(0.016)
Interest rate diff	-0.06**	-0.06**
	(0.008)	(0.0079)
Inflation diff	0.0086	
	(0.0084)	
Yield curve diff	-0.014**	-0.014**
	(0.0037)	(0.0036)
Implied volatility	0.0098**	0.0099**
	(0.0019)	(0.0019)
Economic sentiment diff	-0.0027**	-0.0028**
	(0.0008)	(0.0008)
Number of observations	237	237
Durbin Watson	0.14	0.13

Notes: * = $p < 0.05$ ** = $p < 0.01$

We wanted to test if the significant variables still were significant in a multivariate regression and also if we could find significant for Inflation and Economic sentiment (see regression *6*). As notice can we now observe significance for *Economic sentiment* but not for *Inflation.* This tells us that economic sentiment in itself cannot predict changes in exchange rate but included with the other variables it can. That fact that we cannot say anything with statistical certainty about inflation may depend on, theoretically it's an effect of changes in the interest rate and therefore cannot contribute anything more than interest rate already has explained. In (regression *7*) have we removed *Inflation* and can still observe significance for the other four variables.

As for the results of the bivariate regressions, we will not be able to conclude any numerical sayings about the multivariate regressions from table 3 without converting the numbers and have therefore complied table 4 down below with the converted figures.

Table 4:

Multivariate regressions with converted figures	(6)	(7)
Constant	8.94**	8.94**
Interest rate diff	0.94**	0.94**
Inflation diff	Not significant	
Yield curve diff	0.986**	0.986**
Implied volatility	1.0098**	1.0099**
Economic sentiment diff	0.997**	0.997**
Number of observations	237	237
Durbin Watson	0.14	0.13

Notes: Newey-West standard errors, * = p < 0.05 ** = p < 0.01

Table 4 shows the figures afterwards we converted them with natural exponential function, which gives us an economic intuition of the results.

Interpreting the sixth regressions gives us the following: The predicted exchange rate if AEC, will be equal to the geometric mean, i.e. the predicted value of 1 Euro, AEC, will be 8.94 SEK. The effect of an increase of 1 percentage unit in interest rate difference, if AEC, equals 6% decrease in exchange rate. Unfortunately, are we not able to draw any statistical conclusions about the variable inflation due to the lack of significance for the variable. The effect of 1 unit increase in yield curve difference, AEC, equals a decrease in exchange rate by 1.4 % The effect of an increase with 1 unit in implied volatility index, AEC, equals an increase in the exchange rate by 0.98%. The effect of 1 unit increase in economic sentiment index difference, AEC, equals 0.3%s decrease in the exchange rate.

For the seventh regression the interpretation would be the following: predicted exchange rate, if all variables are held constant, is 8.94 SEK for 1 Euro. The effect of an increase of 1 percentage unit in interest rate difference, if AEC, equals 6% decrease in exchange rate. A 1-unit increase in the difference between yield curves, AEC, equals a 1.4% decrease in the exchange rate. The effect of an increase in the implied volatility index with 1 unit, AEC equals a 0,99% increase in the exchange rate and finally, a 1-unit increase in the difference in the economic sentiment indexes, AEC equals a 0.3% decrease in the exchange rate.

So basically, if the difference in interest rate increases the SEK/EURO rate will appreciate. And depreciates if the interest rate difference increases. If the difference between the yield curves increases, this will lead to a depreciation, and a depreciation if the difference between the yield curves increases. If the implied volatility index increases, this will lead to an appreciation of the Swedish krona. If the difference between the two Economic Sentiment indexes increases, then the Swedish krona will appreciate, a depreciation occurs when the difference between the indexes decreases.

This is all very intuitive when thinking from an economic point of view. The Swedish krona depreciates when an increase occurs in either Interest Rate differentials, Yield Curve differentials or Economic Sentiment. Why? For example, if the difference between the two Yield Curves increases, if the Yield Curve in the Eurozone flattens out in comparison with the Swedish, it means that the long-term bonds are less attractive in relation to the short-time bonds in Eurozone, which we argued earlier may be interpreted as Eurozone is facing a recession that will not affect the Sweden to the same extent. Or if the Implied Volatility increase, i.e. if ES3M increases, which means that the uncertainty in the predictions of the exchange rate increases. This may be interpreted as the investors are more worried about the future and therefore wants to hedge the risk of potential future fluctuations. This scenario increases the risk-premium of the investment which would make it more attractive to invest in Sweden. As stated earlier, a higher demand for a currency increases the value and the Swedish krona appreciates.

4.1.3 Evaluation of the Models

In equation 6 we observe that all our variables except for inflation are statistically significant. By looking at the values for all the variables we can see that a change in interest rate difference will yield the largest change in the exchange rate. This is in line with our findings from the bivariate regressions where the difference in interest rate also yielded the biggest percentage change. One thing worth noting is that the difference in Economic Sentiment Index has become significant. In model 7 we chose to remove Inflation Rates difference as a variable. This is because we did not get any significance in either the bivariate or the multivariate regression. Based on theory, the Inflation Rate should show significant effect on the exchange rate. However, because the interest rate is set based on an inflation target, this might lead to, Inflation rate not contributing with any new information to the model. By removing the inflation difference from the model, we can see that the other variables basically do not change, they still are significant, and the variables are the same or very close to the same. This further supports the fact that we should remove Inflation Rate difference from the model.

As expected, our Durbin-Watson values are close to 0 which indicates autocorrelation. But as discussed in the Methodology section this is not something, we will pay much attention to since we are already assuming the exchange rate to follow a random walk and thus have high autocorrelation. However, one way of fixing the problem with high autocorrelation is to add more variables until we have all explanatory variables in a model.

To test how well our model is explaining the exchange rate "in sample" we did check the differentials between the residuals from our models and compared it with a "benchmark model" (the residuals from a regression with logarithm of exchange rate and time)[1]. The closer to zero, the better fit our predictions would be in relative with the benchmark model.

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[1] Benchmark model: $\log(exchange\ rate) = \beta_1 + \beta_2 * time + u$. Then we calculate the residual differences

From Table A.2 (see appendix) can we confirm that the best model according to Goodness of fit, “in sample” is the model which contained all variables but the Inflation rate, model 7. Why? Because we can see that model 7 has the smallest residual difference with the benchmark model over time. But why do we choose to use residuals as an evaluation tool as it would make more sense to just look at how the observed values perform against the benchmark or maybe R_2? Based on previous research where a lot of different methods are used to evaluate the models, a very good one is to compare the mean squared error with a driftless random walk. But since we have certain limitations as discussed in the Methodology section, we have chosen to compare the residuals. A residual is how far a theoretical or predicted value (in our case from the regression) is from the real value. So naturally a lower residual value is better since it’s “closer to the real value”. These predicted or theoretical values come from our regression models. We then compared the difference in the residuals between the benchmark model and our regression models. And if the difference in residuals would be 0 then we have “matched” the benchmark model in terms of disturbance.

The best solution would obviously be to compare our model to the optimal model or try to predict the future exchange rate over time. Firstly, there really isn’t an optimal model that explains exchange rates and is always right, otherwise there wouldn’t be continuous research in the field. Secondly, we do not have the time to predict the exchange rate over time, and the main purpose of this paper isn’t exchange rate prediction. Based on all this, we conclude that model 7 is the best in sample fit out of the models we have compared.

4.2 Conclusion

Exchange rate behaviour has always been important and is a field that’s been continually studied. It’s an important part of the increasing globalization as well as a mean of investments. However, it has proven incredibly hard to understand what determines exchange rate changes and fluctuations as well as basically impossible to consistently predict it over time. In this study we have analysed previous research to pick some of the most prominent variables as well as add some more unconventional variables to see if they affect the exchange rate. Specifically, the SEK/EURO exchange rate.

$(Residuals_{benchmark} - Residuals_{model\ n})$.

Firstly, the study reports a significant negative relationship between interest rate differentials and yield curve differentials. The study also shows a significant positive relationship between implied volatility and exchange rate. The study however fails to find a significant relationship between inflation differentials and economic sentiment differentials with the exchange rate. This is at the bivariate level and we can reject null hypothesises 1,3 and 4, but we fail to reject null hypothesis 2 and 5.

For the multivariate analysis the study shows that interest rate differentials, yield curve differentials as well as economic sentiment differentials all have a significant negative relationship with the exchange rate. Furthermore, the study shows that the implied volatility has a significant positive relationship with exchange rate. However, inflation still has no significant relationship with the exchange rate.

The results in the study are quite interesting as they both agree and disagree with earlier research. Interest rate differentials as well as yield curve differentials has shown significant effects on exchange rates in older research. But so, has inflation as well, whereas we fail to see a significant effect of inflation on the exchange rate. The variables implied volatility and economic sentiment differentials are variables we haven't come across in previous research as much. In some of the previous research other similar measures have been used and have mostly showed significant results, as this study shows as well. Due to the discussion earlier, that the exchange rate is decided by the demand and supply of currencies makes it theoretical reasonable that the Implied Volatility and Economic Sentiment are significant when both variables measure investors' predictions of the future in some way.

One interesting thing to note is the fact that the variable for economic sentiment is not significant during the bivariate test but becomes significant during the multivariate regression. This might show that the true relationship between the economic sentiment variable and exchange rate is not shown until we add more variables to the model. This also highlights the fact that it is quite hard to determine what affects exchange rates when some variables, such as economic sentiment in our case, will not show any significance without adding other variables. Furthermore, this highlights the importance of a good theoretical background before beginning hypothesis testing.

Another important result, worth noting, is the insignificance of Inflation Rate. According to RPPP, The Taylor Rule Fundamentals and other pervious research, Inflation Rate should have a significant negative effect on the exchange rate but we did not found any statistical evidence for this relation, despite the fact that we used monthly data over 19 years, which should give a theoretical "good" amount of observations. The result was surprising, especially because Sweden is a small and open economy and is very sensitive to changes in greater economies (like the Eurozone).

This study contributes to the overall, never-ending, discussion about which variables affect the exchange rate. This study specifies on the SEK/EURO exchange rate which is a specific exchange rate where the barriers of trade and investments between Sweden and the Euro-area are very low. This fact should be kept in mind when analysing the results of this study. Together with previous research this study shows that Interest Rate differentials, Yield Curve differentials, difference in Economic Sentiment and Implied Volatility between the two markets affect the exchange rate, however it fails to show any significant effect of inflation on the exchange rate.

One big obstacle when explaining and predicting the exchange rate is how the variable behaves to begin with, as it is a random walk in nature this makes analysis and prediction even harder. But the main problem in this field and for future research still stands, it is to find exactly what variables affect the exchange rates. There are a lot of factors that are known to affect exchange rates that we do not know of or haven't used in our thesis. And even if some variables are significant in some specific markets, they might be insignificant in other markets. And even if anyone would have found the "ultimate model" which would be able to explain and predict exchange rates over time, there are basically two options. First is to keep it a secret and have access to a money-making machine and become rich. Or, make it public and become famous within the world of economics and finance and probably not become that rich. The first option seems the most likely.

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6.0 Appendix

Annex 1: Correlation matrix for the independent variables.

Table A.1:	*Interest Rate*	*Inflation*	*Yield Curve*	*Implied Volatility*	*Economic Sentiment*
Interest rate	1				
Inflation	-0,0644	1			
Yield Curve	-0,2619	-0,0893	1		
Implied Volatility	0,0595	0,0748	-0,1502	1	
Economic Sentiment	-0,0719	-0,0602	-0,3784	0,0100	1

Annex 2: Difference in residuals

Table A.2:

Bivariate regressions	
Regression 1	$-4{,}52e^{-11}$
Regression 2	$2{,}90e^{-10}$
Regression 3	$1{,}18e^{-10}$
Regression 4	$-1{,}83e^{-10}$
Regression 5	$3{,}93e^{-11}$
Multivariate regressions	
Regression 6	$1{,}67e^{-10}$
Regression 7	$-2{,}06e^{-11}$