Is there any theory that explains the SEK?

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Abstract

This paper investigates if the value of the Swedish krona (SEK) against the US dollar ($) and the Euro (€) can be explained by some standard theories and fundamentals, such as the purchasing power parity, the interest rate parity, the debt-ratio and the trade balance ratio, using monthly data since Feb. 1993. All of them fail to explain why the SEK is so "weak". The lower inflation rate in Sweden over the recent years has not strengthened the currency. Similarly, the theoretically stronger SEK implied by the lower interest rates in Sweden as the uncovered interest rate parity predicts, has not emerged yet. Finally, neither the persistent trade balance surpluses, nor the declining and very low debt ratio in Sweden have had any positive effects on the currency. It seems that the traders and investors ignore the fundamentals, speculate against the currency and keep it undervalued. Moreover, a number of simulated paths, predicted from various ARIMA-processes, based on the historic exchange rates, show that the worse exchange rates have already gone and by the end of 2020 the $ and the € will cost around 8 and 9.8 SEK respectively.

Keywords: exchange rate, interest rate parity, purchasing power parity, forecasting

JEL classification: F31, F33, F34, F41.

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1. Introduction

A large number of fundamental factors have been proposed by various researchers to explain a currency path or various exchange rates. Among them, Patel et al. (2014) have mentioned the following: inflation differentials, interest rate differentials, trade balance, debt, budget deficit, speculation, expectations, GDP, unit labor costs, productivity and political stability. In addition to those factors, they mention various prediction models, such as random walk, artificial neural network, feed forward neural network, standard backpropagation, scaled conjugate gradient, and backpropagation with Bayesian regularization.

Most of the empirical studies have examined the first two factors, i.e. to what extent the absolute and relative Purchasing Power Parity (PPP) and the Uncovered Interest Rate Parity (UIP) can explain various exchange rates (good surveys appear in Cheung et. al. (2005), Husted & Melvin (2013), Feenstra & Taylor, (2016)). The majority of the referred studies reject both theories. Notice also that some studies find opposite effects, i.e. instead of expected currency appreciation that the theories predict, the currency under investigation depreciated.

Some of the explanations that have been provided why the PPP performs badly are the following: PPP fits better in the long-run; not all goods are traded internationally; productivity differentials between traded and non-traded goods exist; often there exist high transport costs; there are various barriers to trade or preferential agreements and imperfect competition; there are different adjustment speeds between capital and goods markets.

With regard to UIP theory, various models attempt to explain its unsatisfactory or contradictory prediction. For instance, in monetary models of exchange rate determination, one relies on the assumption that the PPP holds and prices are flexible. Thus, the effects of expansive monetary will lead to inflation, and consequently to depreciation, despite the fact that the UIP theory would predict appreciation, due to lower interest rates from the expansive monetary policy.

Similarly, in the sticky prices model of Dornbusch (1976), an expansive monetary policy will reduce the interest rate immediately, leading to a much larger depreciation (overshooting), despite the fact that the domestic prices will increase gradually, but later. The violation of PPP in the short run will disappear in the long run when both prices and interest rate will increase, leading to a strengthening of the currency.

In the portfolio balance model, the overshooting will improve the current account considerably, leading to a gradual appreciation of the currency. Moreover, the appreciation of the currency will subsequently eliminate the surplus. In that model various risk preferences for foreign or domestic bonds can be consistent with appreciation (depreciation) of the currency and lower (higher) domestic interest rates.

In fact, some empirical studies show that the flexible-price monetary model, the sticky-price portfolio model and the real interest differential model (or the UIP model) perform even worse compared to the simple random walk model. Other studies attempt to model exchange-rate expectations. Exchange rate forecasting is one of the most demanding predictions central institutions make to plan their monetary policies. It is therefore not surprising that this activity attracts a lot of public attention. Good exchange rate forecasts are not only desirable, but also important for correct policy formulation and future adjustments. Often, exchange rate forecasting is based on advanced time series models. There exist also other approaches to predict the accuracy of the models. For instance the forward rate in UIP assumes that expectations are rational, with perfect foresight and nonexistent risk premium. But expectations are not easily observed, vary over time and might be extrapolative and regressive as well.

In this paper I will test to what extent the relative PPP, the UIP, the trade balance ratio and the debt-ratio can explain the SEK/$ and the SEK/€ exchange rates, over the last 26 years, based on a 312 months period (Feb 1993 - Jan 2019)[1]. The PPP and the UIP hypotheses will be tested with standard least & non-linear least squares, as well as with modern methods, such as Random Forest, Nearest Neighbors, Neural Network and Gaussian. In addition, based on the time series processes of these exchange rates levels and their changes, I will run some simulations to predict the SEK path over the next two years. Section 2 presents a very short history of the SEK; in section 3 and 4 the PPP and UIP are tested for SEK against $ and €; in section 5 both theories as well as the Fisher effect is tested; the trade balance ratio and the debt-ratio is tested in section 6; finally section 7 shows some predictions of both exchange rates.

2. A very short history of SEK

The Swedish krona (SEK) participated in the Bretton Woods system since 1950. The value of $ was fixed at 5.17 SEK, which was equivalent to 5.82 SEK per gram of gold. It kept its fixed rate until the system collapsed. In 1973 it joined the fixed exchange rates system "European band" or "snake". In August 1977 Sweden withdrew its SEK from the system, devalued the currency by 9% against the Deutschmark and pegged

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[1] All data are collected from <u>www.ekonomifakta.se/Fakta/Ekonomi</u>.

it in a new basket of currencies, where the $ had the largest weight. In September 1981 it was devalued by 10% and in October 1982 by additional 16%. These devaluations were mainly due to higher inflation in Sweden.

After the last devaluation it was meant that the Central Bank (Riksbank) should keep the currency stable. In May 1991 the currency was linked to ECU, despite the fact that Sweden was not a member of the EU. The central exchange rate against the ECU was set at 7.49 SEK. In addition to that, Sweden chose the narrow deviation (+/- 2.25%) from the central rate. In September 1992 the speculative attacks against many currencies in ECU, affected also the SEK. The country's inflation was above its competitors and huge capital outflows made it difficult to keep the central rate against the ECU. When the Riksbank failed to support the exchange rate, despite the extensive use of its international reserves, the last weapon in its arsenal was the interest rate and increased it to 500%! The attacks against SEK continued when the interest rate was reduced to about 40%, and two months later (November 1992) the fixed exchange rate regime was abandoned. The date it was announced, the SEK depreciated immediately by about 26%.

The flexible exchange rate regime has been in force over twenty-seven years. The Riksbank has no mandate to stabilize the currency anymore. Its key objective has shifted towards keeping the rate of inflation at 2%, mainly through its key interest rate. As expected, the value of flexible SEK did not remain "stable". It has been very volatile and overall much weaker against the main currencies. For instance, just after the Lehman crash, the € was valued at almost 11.50 SEK and in May 2019 about 10.8, i.e. the SEK depreciated by more than 40% compared to central course 7.49 SEK against its predecessor, ECU. Over the recent years many analysts and observers criticized the Riksbank for its over-aggressive monetary policy (by keeping its key interest rate negative over the recent years) in order to lift the rate of inflation towards its target.

3. SEK & PPP theory

As is known, PPP refers to the idea that the same good should be priced equally in both countries and is often called as the low of one price. If for instance a Volvo costs 400,000 SEK in Sweden and 40,000 € in France, ceteris paribus, it implies that 1 € is worth 10 SEK. If for instance, the nominal exchange rate is 10 SEK/€[2], the real exchange rate is equal to 1, i.e. 40,000 €*10 SEK/€ = 400,000 SEK.

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[2] In this paper the nominal exchange rate is defined as domestic-currency (SEK) per foreign-currency ($, or €), i.e. ($E = P_{Swe}/P_{EU}$, respectively $E = P_{Swe}/P_{US}$), indicating that higher (lower) values in E implying depreciation (appreciation) of the domestic currency when the domestic prices are higher (lower). Similarly, the real exchange rate is defined as $E_R = E\, P_{for}/P$, indicating that, values below (above) 1 imply depreciation (appreciation) of the domestic currency.

If the nominal exchange rate remains at 10SEK/€ but the price of Volvo in France decreases to 39,000€ (=390,000SEK), the real exchange rate deviates from 1 and turns out to be 39,000€*10 SEK/€ / 400,000 = 0.975, indicating that Volvo is cheaper in France by about 2.56 percent. A Swede who plans to buy the car will buy it in France cheaper by 1,000€, if the nominal exchange rate remains at 10SEK/€. In fact, the car will not be cheaper in France because the nominal exchange rate should change to 10.2565 SEK/€, i.e. 39,000€*10.2565 SEK/€ = 400,000 SEK. Similarly, if the SEK depreciates by 5%, and the car is still priced at 400,000 in Sweden, a French citizen needs to pay 38,095 € to buy the car (i.e. it is like if Volvo reduces its price in France to that amount).

3.1 The exchange rates

The following graph shows the monthly exchange rates levels (SEK/€ & SEK/$) over the period Feb 1993 - Jan 2019. It is clear that both series[3], and especially the SEK/$, are volatile.

Monthly exchange rates : 1993 −2019
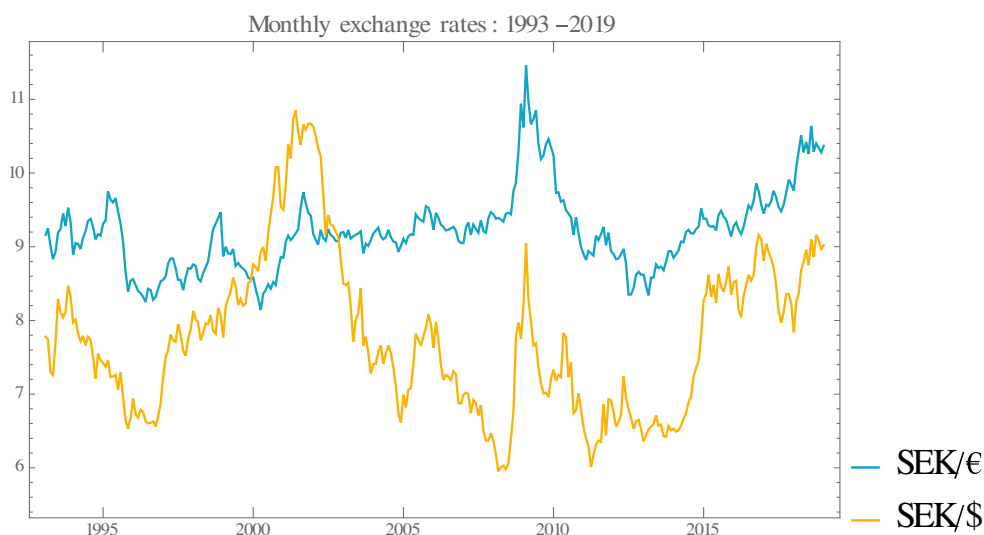
Normality and Stationarity tests

None of the series is normally distributed. The normality hypothesis for both exchange rates is rejected at the 5% level, based on the Cramér-von Mises test. In fact, the three best distributions estimated in Mathematica are various combinations of normal and log-normal, as well as extreme value distributions. For instance the extreme value distribution of SEK/€, has a mean value[4] of 9.23, while the extreme value distribution of SEK/$ has a mean value of 7.78. (In Appendix A, you can see the oscillating mean,

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[3] The Euro was introduced in January 1, 1999. Prior to 1999 the SEK/€ refers to its predecessor, ECU, i.e. it is based on the theoretical weights of the EU countries' currencies.

[4] The mean value of the extreme value distribution is given by: $\alpha + EulerGamma\ \beta$, where α is a location parameter and β is a scale parameter (see Mathematica).

the noisy volatility and the unstable skewness, kurtosis and other measures as well, of both exchange rates levels, their histograms, and the three best Kernel estimated distributions).

Not only are the series non-normal, they are also non-stationary. The stationarity tests below do not reject the existence of unit roots at 5% (or even lower) levels.

Test[5]	SEK/€		SEK/$	
	Statistic	P-Value	Statistic	P-Value
Dickey-Fuller F	0.0915916	0.70765	0.0188754	0.687222
Dickey-Fuller T	0.297102	0.771145	0.0343379	0.692943
Phillips-Perron F	0.0925012	0.707901	0.00932872	0.684483
Phillips-Perron T	0.302985	0.77275	0.016418	0.68715

Due to non-stationarity in exchange rates, the regressions can spuriously show a significant effect of the explanatory variables that might not be true, i.e. yielding incorrect t-statistics in estimates.

A simple method to make the series stationary is to take the differences in logarithms, such as month to month in the same year, quarter to quarter in the same year, or month to month for subsequent years. The three respective processes estimated by Mathematica for the SEK/$ are: *GARCH (1,1), ARMA (1,2)* and *ARMA (1,1)*. Similarly, the three respective processes for SEK/€ are: *GARCH (1,1), ARMA (2,2)* and *AR (1)*.

Also the average of annual differences in logarithms are weakly stationary, as shown in the following graph. Notice that the SEK/€ is two years shorter[6] (1996 - 2018). Positive values show annual rates of depreciation of SEK. It is clear that SEK started to depreciate about seven years ago and its weakening continues until now (May 2019).

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[5] The Dickey-Fuller F, respectively Phillips-Perron F tests, test jointly for both a unit root and a zero intercept; see for instance, Elder & Kennedy (2001).
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.22.7168&rep=rep1&type=pdf
[6] Prior to 1996, there were some countries that did not meet the Maastricht criteria. For instance, not all countries were meeting the inflation limits and the average inflation in EU was very volatile. Since the PPP theory relates inflation differences to exchange rates differences, the SEK/€ starts two years later than the SEK/$.

% Exchange rates
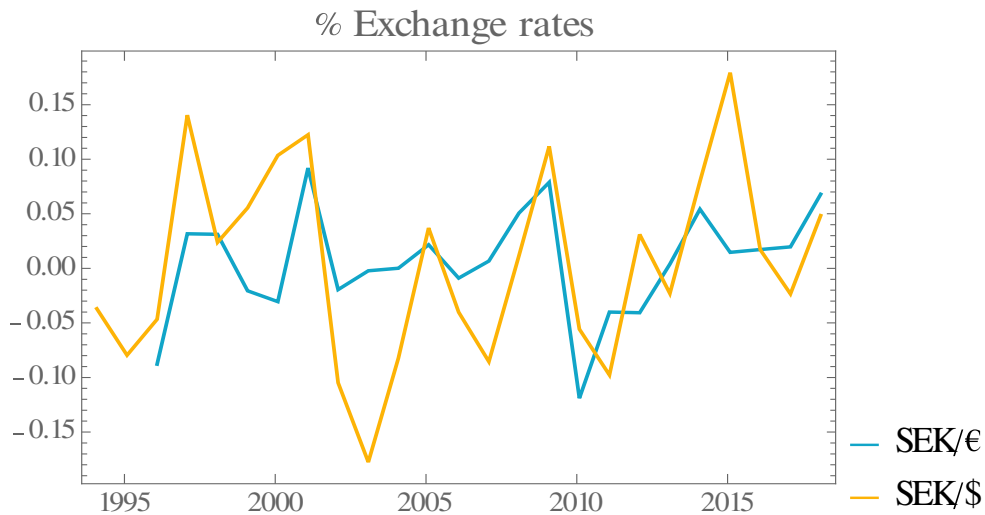
Moreover, despite the fact that the changes of SEK/$ and SEK/€ are stationary, they are not normally distributed (see Appendix B). The non-normality is confirmed at the histogram comparison to fitted smooth kernel normal distribution. The SEK/$ for instance has two peaks, and fatter tails point out at non-normal patterns. In Appendix B, you can also see their means and standard deviations.

3.2 The inflation differentials

The inflation differentials between Sweden & US, respectively Sweden & EU, over the same period are shown below. Both inflation differentials series are weakly stationary, the SWE - EU is *MA (1)* while the SWE - US is *AR (1)*. The average inflation differential over the investigated period was slightly lower in Sweden, by about -0.6 %, compared to the US and EU.

Inflation differences
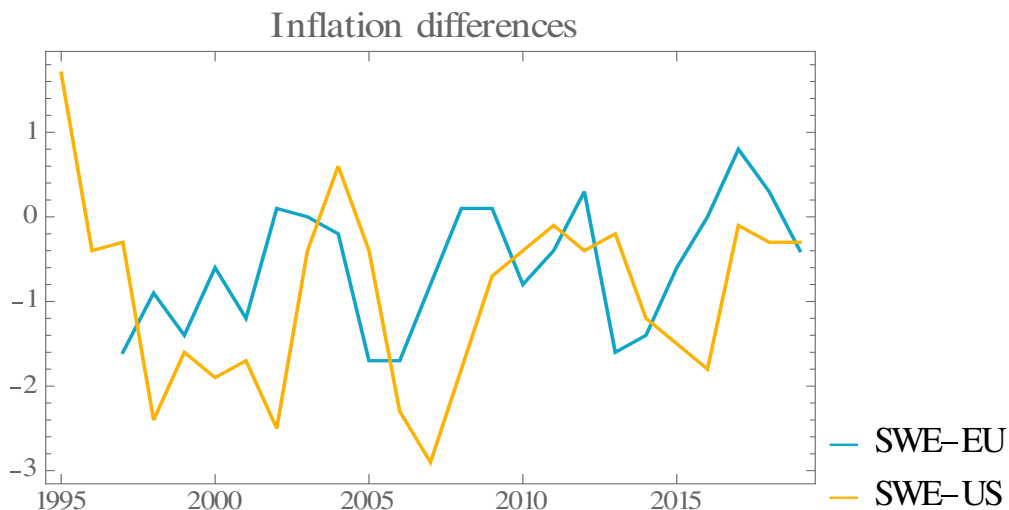
Since both explained (exchange rate changes) and explanatory variables (inflation changes) are stationary, the OLS estimates will be unbiased.

The relative PPP regression to be tested is given by:

$$\Delta \text{Log}[E] = \alpha_1 + \alpha_2(\Delta \text{Log}[P] - \Delta \text{Log}[P^*]) + u_t,$$

where: $\Delta Log[E] = annual\ change\ of\ SEK/\$$, respectively $SEK/€$,
$\Delta Log[P] - \Delta Log[P^*] = annual\ inflation\ changes\ between\ Sweden\ and\ US$, respectively $Euroland$
and $u_t \sim N(0, \sigma^2)$

If PPP holds, $a_1 = 0$ & $a_2 = 1$, i.e. higher inflation in Sweden will increase the exchange rate (i.e. the SEK will depreciate against the respective currency)[7].
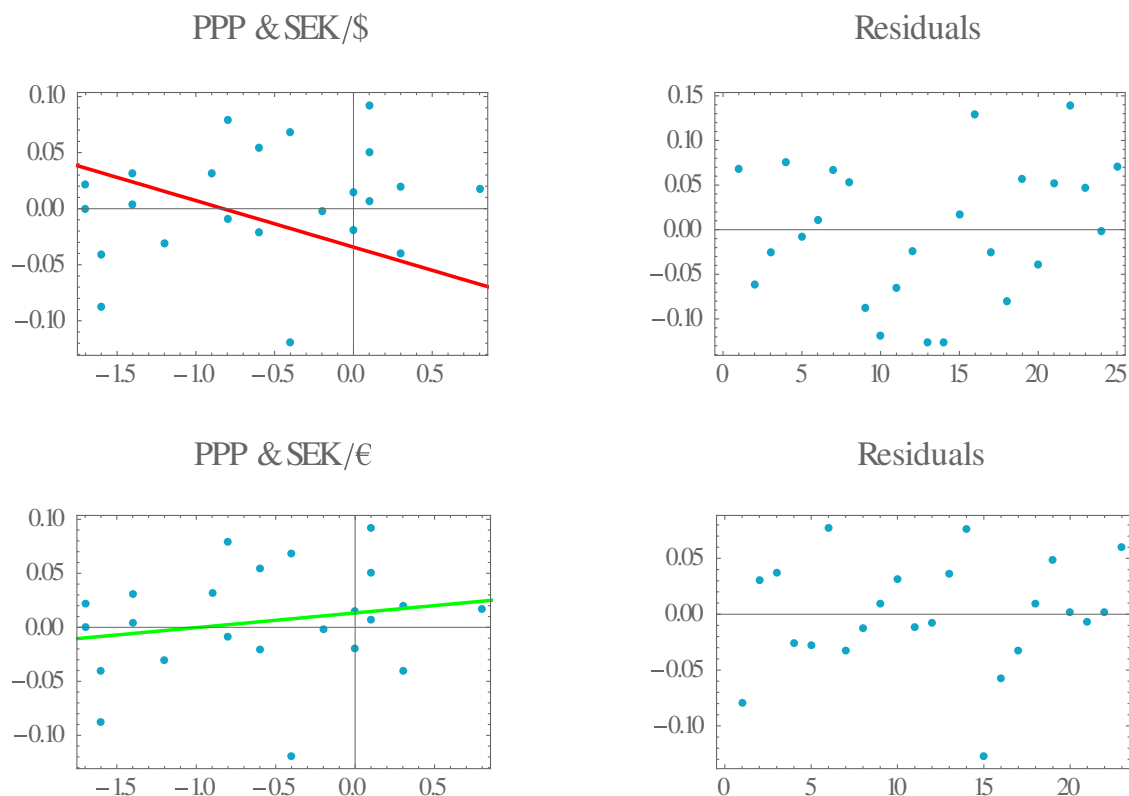
Both Linear (LS) and Non-linear least squares (NLS) were applied. Since LS minimize the sum of squares of correlated errors, the NLS that minimize the sum of non-correlated errors is to be preferred (Hill et. al., 2008). Moreover, both methods yield almost identical estimates.

The NLS estimates are given below. It is clear that the relative PPP hypothesis $\alpha_2 = 1$ is rejected for both exchange rates. In fact, for SEK/$, $\alpha_2 = -1$, i.e. the SEK has depreciated against the $ because of lower inflation in Sweden! According to these estimates it would appreciate by about 7% if the Swedish inflation were 1% higher than the US! Similarly, the Swedish inflation needs to be 1% lower than the EU for the SEK/€ to remain stable.

$\Delta \text{Log}[E]$	a_1	a_2	R^2	DW
SEK/$	−0.0342	-0.0414*	0.26	1.40
	(1.65)	(2.83)		
SEK/€	0.0133	0.0136	0.04	1.95
	(0.99)	(0.95)		
t-stat in parenthesis; (**, *) denote 0.01, respectively 0.05 significance level				

The R^2-values are low, while the Durbin-Watson values indicate no clear autocorrelation for the SEK/$ and absence of autocorrelation for the SEK/€. The regression equations and their residuals are shown on the following graphs. The residuals satisfy the assumption $u_t \sim N(0, \sigma^2)$, because the null hypothesis that they are normally distributed is not rejected at the 5 percent level based on the Kolmogorov-Smirnov test. All pair of points, identified by the respective year, are shown as a buddle charts in Appendix C.

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[7] The hypothesis $a_2 = 1$ is an ideal relationship of the relative PPP and is rather impossible to achieve it at least in the short run. Thus, it is sufficient to show that $a_2 > 0$, if the pairs of exchange rate and inflation differences do not necessarily lie on a 45⁰ line.

From the SEK/€ graphs one can observe that, despite the fact that the Swedish inflation was lower than the EU inflation over 15 out of 23 years, the SEK is not stronger. For instance, the recent negative inflation difference is identical to 2011. Moreover, the recent SEK depreciation (May 2019) is about 7% while in 2011 the SEK appreciated by about 11%.

In addition to NLS, I applied four modern methods from Mathematica; Gaussian Process, Nearest Neighbors, Random Forest and Neural Network. All graphs are found in Appendix D. None of them support the relative PPP. On the contrary, the last three seem to reveal that a lower Swedish inflation leads to a depreciated SEK against the $, precisely as the NLS above. Thus, the SEK is undervalued against the $ according to the relative PPP. Similarly, these methods show that SEK is undervalued against the € too.

4. SEK & IRP theory

While the PPP is a long run equilibrium exchange rate, the Interest Rate Parity (IRP) is based on asset market models and attempts to analyze movements in exchange rates over the short run. According to IRP, the exchange rate between two countries will

reflect the differences in the respective interest rates. There are two variants of IRP, the Uncovered and the Covered.

Assume a US investor who buys SEK (with USA = <u>domestic country</u> and Sweden = foreign country). Assume that the spot exchange rate is S = 0.1\$/SEK in New York (or 10SEK/\$ in Stockholm). Assume also that the annual interest rates are r_{SW} = 0.01, respectively r_{US} = 0.025. If there are no other risk-premia or preferences towards \$ or SEK, one can estimate the arbitrage free future spot of SEK (forward) in terms of \$ (or \$ forward in terms of SEK).

The estimation is based on the following strategy (in \$):
   a) Borrow *SEK 1 M* and pay back next year *SEK 1.01 M*
   b) Exchange *SEK 1 M* to 0.1\$ and save it in the US
                           and simultaneously,
   c) Sell the \$ forward at (F) and buy SEK to pay back your loan in SEK.

The US investor will receive in a year (in US): 0.1*(1.025) = \$ 0.1025 M. Without arbitrage profit, 102,500 \$ = 1,010,000 SEK, i.e. approximately F = 0.1015\$/SEK, or 9.5375SEK/\$. This implies that the \$ in Sweden is expected to fall from 10SEK/\$ to 9.5375SEK/\$, or the SEK in the US to increase from 0.1\$/SEK to 0.1015\$/SEK. Thus, at equilibrium the following relationship must hold, in the domestic country, USA:

$$F = \frac{(1 + r_{US})}{(1 + r_{SW})} S,$$

That is the well-known Covered Interest Rate Parity (CIP).

Therefore, if $r_{SW} < r_{US}$, the SEK will be stronger in the future (F > S). If on the other hand, F < S, (i.e. the SEK is expected to weaken in the future), a stronger SEK now will be consistent only if $r_{SW} > r_{US}$. This equilibrium condition applies to changes in interest rates as well. For instance, if the US increase its interest rate to 0.03 (or if Sweden decreases its own rate to 0.005), the spot exchange rate will change as well (i.e. the SEK will depreciate, perhaps from 10 SEK/\$ to 10.25 SEK/\$) and consequently the forward rate will change too.

Moreover, the UIP cannot be tested, since the market expectations of the future exchange rate are not observed. Some investors expect the forward rate to be at premium, while others to be at discount, and many might disregard c) in the above strategy. In that case the expected exchange rate in the future will be different from *F* = 0.1015\$/SEK, and the interest rate parity will then be Uncovered (UIP), or risky. For instance the US investor who invests in the US will experience losses, if the SEK gets stronger than 0.1015\$/SEK. If the exchange rate in New York is higher than 0.11\$/SEK,

its savings in the US are lower than needed to pay back its loan in Sweden (it will have only 102,500$ that will be worth 931,818SEK, i.e. a loss of 78,182SEK compared to 1,010,000SEK the investor must pay for the loan). Similarly, the US investor will make profits if the $ gets stronger than 0.10$/SEK.

Instead of using forward exchange rates, we can assume that $Log[F] = Log[E_{t+1}]$ and $Log[S] = Log[E_t]$. Thus, the UIP can be formulated as:

$$Log[E_{t+1}] - Log[E_t] = \beta_1 + \beta_2(r_t - r^*_t) + u_t, \text{where:}$$

$Log[E_{t+1}] - Log[E_t] = \%\ of\ SEK/\$, respectively\ SEK/€\ within\ a\ year, (r_t - r^*_t)$
$= annual\ interest\ rates\ between\ Sweden\ and\ US, respectively\ Euroland\ at\ the\ start\ of\ year\ t$
$and\ u_t \sim N(0, \sigma^2)$

Notice that, if $Log[E_{t+1}] - Log[E_t] > 0$, the SEK will depreciate, while if it is negative, it will appreciate.

The UIP holds if the right part side has the same sign as the left part side. For instance, if $\beta_1 = 0$ & $\beta_2 = 1$, the SEK is going to depreciate (appreciate) by the same percentage[8], if the Swedish interest rates are higher (lower). Similarly, if $\beta_2 = -1$, the SEK is also going to depreciate if $(r_t - r^*_t) < 0$ and appreciate if $(r_t - r^*_t) > 0$.

Many empirical studies that test if UIP holds (such as Fama (1984), Froot & Thaler (1990), Sarno (2005), Chinn (2007), Spronk et al (2013), Miller (2014)) reject that the forward rate will be the true spot rate in the future. Some of them (Froot & Thaler (1990)) find a significant opposite effect (-0.88), i.e. the currency of the country that has the highest interest rates appreciates, this leads to a third option.

According to that option, the so-called carry trade strategy, investors make risky (naïve) decisions based only on the interest rate differences, and speculate against SEK that nowadays pays lower interest rates. They simply short the SEK and they do not expect it to appreciate, as the UIP would predict. When sufficiently many traders and investors share the same view in the market, the SEK will depreciate, irrespectively if the theory would predict an appreciation of the SEK.
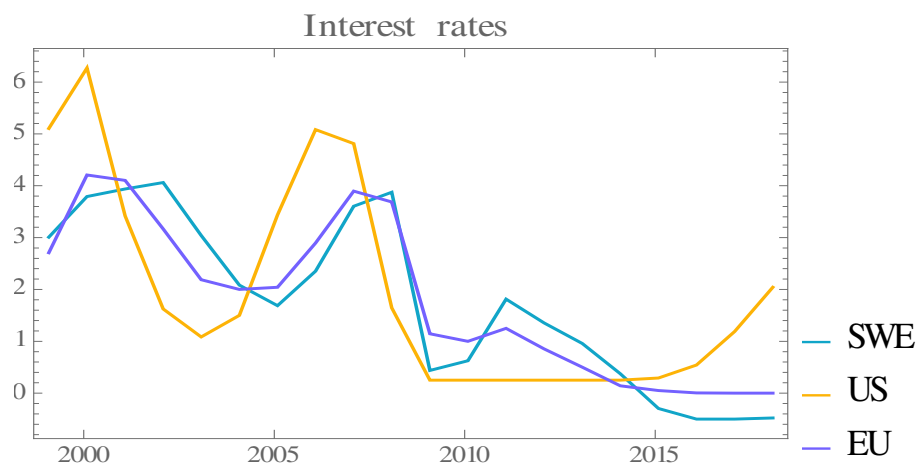
The carry trade strategy will hold if $\beta_1 = 0$ & $\beta_2 = -1$, i.e. the SEK is going to depreciate (appreciate), if the Swedish interest rates are lower (higher).

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[8] Again, there is no need to be "by the same percentage". Moreover, if exchange rates react directly to interest rates differences, it is often argued that the pairs of exchange rate and interest rates differences should lie on a 45^0 line.

Some studies (Frankel & Froot (1990), Galati & Melvin (2004), Burnside et al (2006)) find that this simple (but risky) carry trade strategy is rather profitable.

The graph below shows the key interest rates (Riksbank, FED and ECB) in the three countries, over the period 1999 - 2018. All rates were almost identical around 2014, but thereafter the interest rate in Sweden turned negative, while the US increased and the Euro interest rate remained almost unchanged.
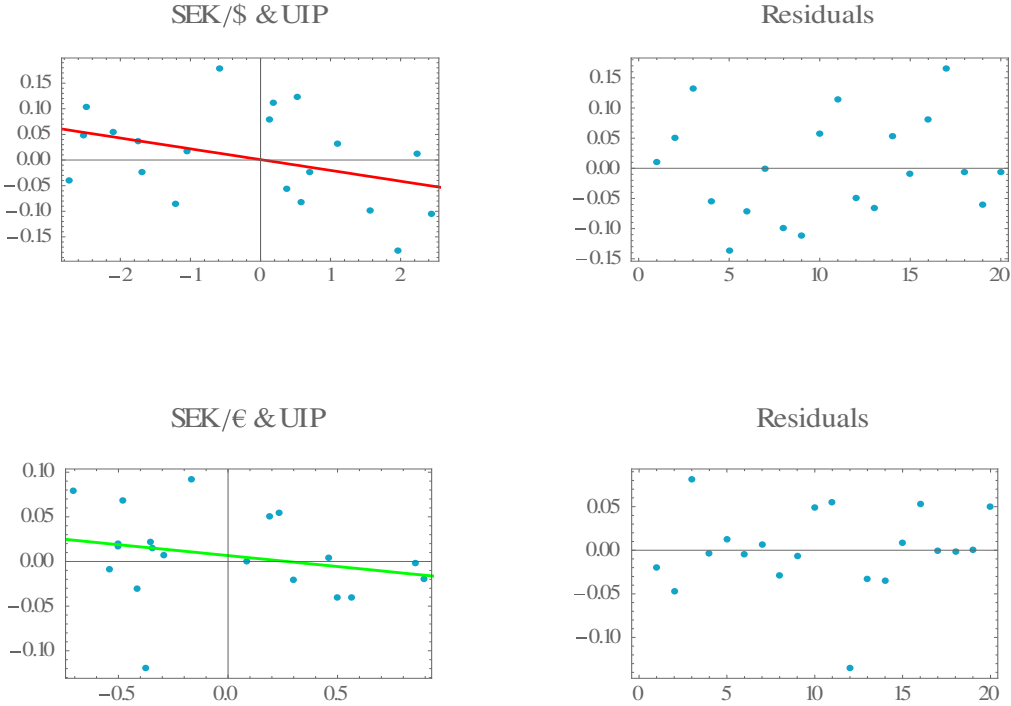

4.1 The estimates

As was mentioned previously, the month-to-month for subsequent years for the SEK/\$ is an *ARMA (1,1)* process while the SEK/€ is an *AR (1)* process. Also, the EU-SWE interest rate differential is an *ARMA (1,1)* process, and the US-SWE interest rate differentials is a *MA (1)* process. Since all processes are stationary[9], the NLS estimates are unbiased.

The NLS estimates for both exchange rates are given below. It is clear that the UIP theory is rejected for both exchange rates (t-stat in parenthesis). R^2-values are low, there is no autocorrelation and the non-normality of residuals is not rejected.

$\text{Log}[E_{t+1}] - \text{Log}[E_t]$	β_1	β_2	R^2	DW
SEK/\$	0.00082	-0.0119	0.15	1.48
	(0.04)	(1.76)		
SEK/€	0.00654	-0.0245	0.06	2.06
	(0.6)	(1.1)		

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[9] Notice that the annual interest rates in Sweden is an *ARIMA (0, 1, 0)* process but non-stationary. On the other hand both the EU and US interest rates are *ARMA (1,1)* and stationary.

Only a very weak negative effect (at about 9% level of significance) is found for the SEK/$, indicating a weak support for the carry trade strategy. For instance if the interest rate differential between Sweden and US is -2.5 (as it is now, May 2019), the product $\beta_2(r_t - r^*_t) = +5.25\%,$ implying a SEK depreciation of about 5.25% (annually). Thus, those who borrowed SEK 1 M and invested their exchanged SEK into $ in the US at 2%, would make high profits when they pay back their SEK-loans, with their appreciated $. Similarly, given the recent interest rate differential between Sweden and EU (-0.5) the product $-0.0245(-0.5)$ predicts less than 2% SEK depreciation, which is much lower than the recent depreciations.

As you can see on the first graph above (SEK/$), out of twenty interest rates differentials (horizontally) and exchange rate changes (vertically), twelve are negatively correlated, and eight are positively correlated, showing a very weak support of the UIP. Notice though that there have been five observations (upper, right) where the SEK depreciated, despite the fact that the interest rates differences were positive. Similarly there have been three observations (lower, left) where the SEK appreciated, even when the interest rates differences were negative.

The additional four methods applied do not seem to clearly support the UIP (see Appendix F). The Random Forest and the Nearest Neighbors show a very weak negative effect, while the Gaussian and Neural Network show unclear effects. In fact,

the non-linearity is apparent in the Neural Network, where interest rates differences of about -1.5 percentage units, or positive, seem to strengthen the SEK against $. Larger percentage units than -1.5 and differences between -1.5 & 0 seem to weaken it.

Finally, in addition to annual interest rates differences, I repeated the regressions with both 240 monthly and 60 quarterly (Feb 1999 - Jan 2019) observations. Neither the intercept, nor the slope were different from zero (see Appendix E).

Thus, the standard argument by many analysts, namely that the Swedish Riksbank is responsible for the weak SEK, by keeping its key interest rate negative (or widening the negative interest rate differential between Sweden and US, respectively EU), does not hold. That argument seems to be valid over the recent three to four years, while similar negative interest rates differences a few years earlier, did not weaken the SEK that time. The support for the alternative carry trade strategy is very weak (for the SEK/$) and is rejected for the SEK/€. Remember though that this strategy is naïve and might have worked over the recent years. Moreover, a sudden strengthening of SEK will force the investors (speculators) to abandon that risky strategy and start covering their positions as implied by the CIP.

5. PPP & IRP combined

So far, I have used nominal interest rates. Investors might be interested in the real interest rate differentials that can affect the exchange rate, either through the IRP, or the curry trade mentioned above. Consequently, if PPP and IRP hold, the real interest rates should be equal across countries.

A variant of real interest rates is credited to Irving Fisher, so that a rise in the expected inflation rate in one country will lead to a rise in its nominal interest rate, i.e. $(r_t - r^*_t) = (P_t - P^*_t)$. Is that true between Sweden and US respectively €?

To test the Fisher effect, the following simple regression was used:

$$(r_t - r^*_t) = \gamma_1 + \gamma_2(P_t - P^*_t) + u_t$$

For instance, if $\gamma_1 = 0$ & $\gamma_2 > 0$, or optimally $\gamma_2 = 1$, the Fisher effect exists.

Simple regressions show that the Fisher effect is not rejected between Sweden and US. The slope $\gamma_2 = 0.87$ and is significant from zero at the 5% level, with an $R^2 = 0.27$. On the other hand there is no Fisher effect between Sweden and EU (the slope is negative but not significant from zero and R^2 almost zero).

An alternative method is to test if the real exchange rates, $E_R = \frac{E\,P^*}{P}$, differ. Instead of testing that , I tested if PPP (inflation differences) and IRP (interest rates differences) simultaneously can explain the changes in SEK/$, respectively SEK/€. The estimates are:

$$\frac{SEK}{\$} = -0.0308 - 0.0333\Delta I - 0.0111\Delta R,$$
$$\frac{SEK}{€} = 0.0050 - 0.00275\Delta I - 0.02483\Delta R,$$

where, ΔI = inflation differences & ΔR = interest rates differences.

Both are very poor and all parameters are insignificant. The three-dimensional graphs below show almost horizontal planes (i.e. no changes in exchange rates are explained by PPP and IRP). About half of the observations are visible while the remaining are below the surface and are invisible.
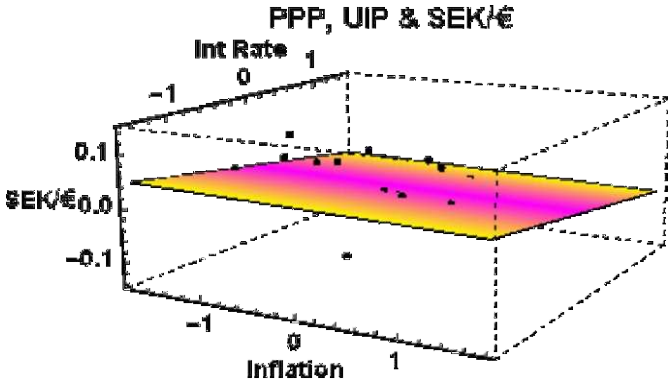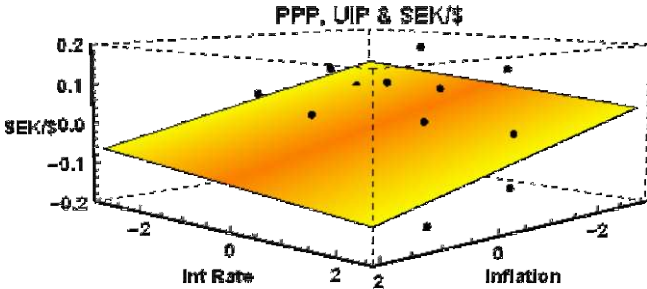
6. Other factors

Neither the inflation differentials, nor the interest rate differentials hypotheses seem to explain why the SEK is so weak against the $ and €. The PPP is clearly rejected (in fact the reverse effect was not rejected against the $). Even the IRP is rejected against the € and almost rejected against the $.

Can other factors, such as trade balance and current account, or budget deficit and debt-ratio explain the weakening of SEK?

6.1 The trade balance

There is a huge empirical literature that investigates if the exchange rate depreciation improves the trade balance, generally over time, i.e. if the J-curve exists. Wang (1993), Marwah and Klein (1996), Shirvani and Wilbratte (1997), Gupta-Kapoor and Ramakrishnan (1999), Bahmani-Oskooee and Goswami (2003), Arora et. al. (2003), Ghosh et al. (2008), show that the real exchange rate depreciation improves trade and confirmed the J-curve. According to Suranjali Tandon (2014), a depreciation of the real exchange rate improves trade balance for some countries, like Italy and France in Europe, as well as for Brazil, Mexico and the Philippines. On the other hand, the trade balance in other European countries, China and Malaysia is not affected, while for the UK, Japan and Singapore an appreciation of the real exchange rate improves their trade balance. Other studies, Rose and Yellen (1989), Rose (1991), Rodrik (1994) and Elbadawi (1998) found no relationship between trade and exchange rate; Bahmani-Oskooee and Brooks (1999), Wilson (2001), Baharumshah (2001), found no evidence for the J-curve. Finally, other studies, Cushman (1983), Thursby and Thursby (1987), Arslan and van Wijnbergen (1993), Chowdhury (1993), Arize et al. (2000) and Mohamad and Nair (2009) found that exchange rate volatility depresses the volume of exports.

Normally, a country with trade surplus like Sweden[10], will accumulate foreign currency. When the holdings of foreign money, relative to domestic money, increase, the foreign currency will depreciate (or the domestic currency appreciate). Sweden has experienced surpluses in both trade balance and current account since early 90ies. For instance the trade surplus has never been below 2% of its GDP and during 1995-2007 it was around 7-8%. Similarly, the current account has never been lower than 2% of its GDP, and over a 12-year period (1999-2011), was above than 5%. The last figures for the current account are from 2017, placing Sweden above China (with +3.2% of its GDP, versus 1.3% for China) and the US with -2.4%.

Since we are interested in explaining the exchange rate in Sweden, contrary to all studies mentioned above that used the exchange rate as a determinant of trade balance, in this study the trade balance ratio to GDP (TB) will be treated as a determinant of exchange rate. Below there are some regression estimates between TB and exchange rates (E), both in levels ($E_t = \beta_1 + \beta_2(TB) + u_t$) and in changes ($Log[E_{t+1}] - Log[E_t] =$

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[10] Since 1982, Sweden has always achieved a trade balance surplus. Against the US and most European countries, Sweden had surplus in 2018. The largest deficit was against Germany (-108 billion SEK), the Netherlands (-54 billion SEK) and the Czech Republic (-10 billion SEK).

$\beta_1 + \beta_2 Log[TB] + u_t$), annually. It is expected that $\beta_2 < 0$, i.e. if the trade balance improves, the exchange rate will decrease (i.e. the SEK is going to appreciate).

	E_t	β_1	β_2	R^2	n
Level	SEK/$	7.43**	0.0605	0.016	26
		(13.2)	(0.64)		
Change	SEK/$	0.0026	-0.055	0.008	25
		(0.14)	(0.42)		
Level	SEK/€	9.79**	-0.1023*	0.19	24
		(36.4)	(2.31)		
Change	SEK/€	0.0022	-0.053	0.013	23
		(.18)	(.53)		
t-stat in parenthesis; (**, *) denote 0.01, respectively 0.05 significance level					

The estimates for SEK/$ are very poor, because the trade balance ratio has no effect on the exchange rate (nether for the level nor for its changes). On the other hand, for the SEK/€ level, β_2= -0.1023 (significant at 0.05), i.e. the SEK would appreciate. For instance, with an actual trade balance ratio of 3%, and given the strongly significant intercept of 9.79, the exchange rate should be about 9.50SEK/€, i.e. at least 1 SEK lower compared to May 2019. For the SEK/€ changes though, the estimates are also poor.

6.2 The debt ratio

The empirical literature between public debt and exchange rates is rather consistent. McMillin and Koray (1990) found that shocks in the US debt lead to a short-lived depreciation of the U.S. dollar; Devereux and Lane (2001) found that exchange rate depreciation increases foreign borrowing through nominal and real interest rate; Fida et. al. (2012) found that increase in external debt depreciates the real exchange rate in Pakistan; also Alam and Taib (2013) found that external debt is related to the exchange rate depreciation, and more significant in debt trap countries (India, Indonesia, Nepal, Pakistan, Sri Lanka and Thailand) than in non-debt trap countries (Bangladesh, Fiji, Korea, Malaysia, Myanmar, Papua New Guinea, Philippines and Singapore). More recently, Bunescu (2014) for Romania and Palić et. al. (2018) for Croatia found that the depreciation of the domestic currencies leads to an increase in external indebtedness. An alternative link between currency risk premia, external debt in $ and depreciation is provided by Wiriadinata (2018). According to her, when the $ strengthens, the real value of dollar debt increases and consequently weakening the currencies of countries with large amounts of dollar debt.

Sweden's debt ratio is among the lowest in the EU. Last figures for 2018 show a debt ratio of about 26% compared to about 74% from its top in 1995, i.e. a steady decline of

at least 4% per year. Sweden has also experienced a budget surplus over the recent years. In 2018 the surplus was (preliminary) around 90 billion SEK, (about 1.5% of its GDP). The large deficit (131 billion SEK) observed in 2013 was motivated by the fact that the Swedish National Debt Office borrowed around 100 billion SEK to strengthen the international reserves of Riksbank that had weakened after the Lehman crash.

Below we present some regression estimates, between debt-ratio (D) and exchange rates (E), both in levels ($E_t = \beta_1 + \beta_2(D) + u_t$) and changes ($Log[E_{t+1}] - Log[E_t] = \beta_1 + \beta_2 Log[D] + u_t$), annually, (t-values in parentheses). It is expected that $\beta_2 > 0$, i.e. if the debt-ratio increases, the exchange rate will increase (i.e. the SEK is going to depreciate).

	E_t	β_1	β_2	R²	n
Level	SEK/$	7.65**	0.0026	0.002	26
		(12.2)	(0.2)		
Change	SEK/$	−0.0009	-0.1377	0.01	25
		(0.04)	(0.5)		
Level	SEK/€	10.04**	-0.0189**	0.29	24
		(34.6)	(3.03)		
Change	SEK/€	0.0083	0.0676	0.008	23
		(.63)	(.40)		
t-stat in parenthesis; (**, *) denote 0.01, respectively 0.05 significance level					

The estimates are very poor, because the debt-ratio does not seem to explain the SEK. Notice though that for the SEK/€ level, $\beta_2 < 0$ (significant at 0.01). This means that the actual debt ratio of 26% reduces the value of € by almost 0.5 SEK and the theoretically correct value of Euro should be 10.04 – 0.5 = 9.55SEK/€, i.e. again about 1 SEK cheaper than the existing one (May 2019). Alternatively, other things being equal, and the debt ratio remained at 41% (as it was in 2006), the € would cost around 9.15 SEK.

7. Forecasting of exchange rates

The falsification of PPP and UIP to explain and predict the exchange rates, led to model it as random-walk processes. Such random-walks forecasts are improved marginally, but not systematically, if they include other macroeconomic and financial fundamentals forecasts (see for instance Rossi (2013), for a broad review). For instance, Cheung *et al*. (2005) showed that the mean-squared errors from PPP models are lower than those of a random walk for longer horizons, while UIP models do not significantly improve on the random walk at any horizon. Carriero *et al*. (2009) and Dal Bianco *et al*. (2012) have improved on the point forecasts of a random walk by relying respectively

on a Bayesian VAR with a large set of exchange rates, and on a mixed frequency dynamic factor model with 4-weekly exchange rates and lower frequency macroeconomic fundamentals. According to Engel and West (2005), the exchange rate unpredictability is due to the typical structural models used. They suggest that all exchange rate determination models should be re-formulated as present discounted values of current and future fundamentals, as well as unobservable shocks. Such a modelling will have a very weak correlation between the exchange rates and the current fundamentals when fundamentals are persistent and agents are patient. On the other hand, future fundamentals will matter more than current fundamentals. Rossi (2006) on the other hand argues that the instability of the relationship between exchange rates and their fundamentals is due to various trading strategies that often put different weights to fundamentals. Bacchetta and Wincoop (2009) support that and show that structural parameters are unknown to economic agents.

Yongmiao *et al*. (2007) and Balke *et al*. (2013) focused on density forecasts and showed that the density forecasts of a random walk can be improved either with non-linear models, or with univariate Taylor rule models with semiparametric confidence intervals. Della Corte *et al*. (2009), found that the time varying volatility is important for the 1-month-ahead predictive ability of macroeconomic fundamentals. Mumtaz and Sunder-Plassmann (2013) showed that a structural time varying stochastic volatitity VAR, is superior compared to the constant volatility. Finally, Molodtsova and Papell (2009) and Inoue and Rossi (2012), support the Taylor rules[11], while Rogoff and Stavrakeva (2008) question its validity.

In this section I will forecast both exchange rates, as levels and as changes, over the next two years, based only on time series modelling, i.e. excluding the macroeconomic and financial factors. Although the pure time series modelling is agnostic and neglects the requirements for richer explanatory variables, this simplicity and dependence only on its past values makes it flexible, powerful and dynamic in nature and adapts well to the exchange rate process.
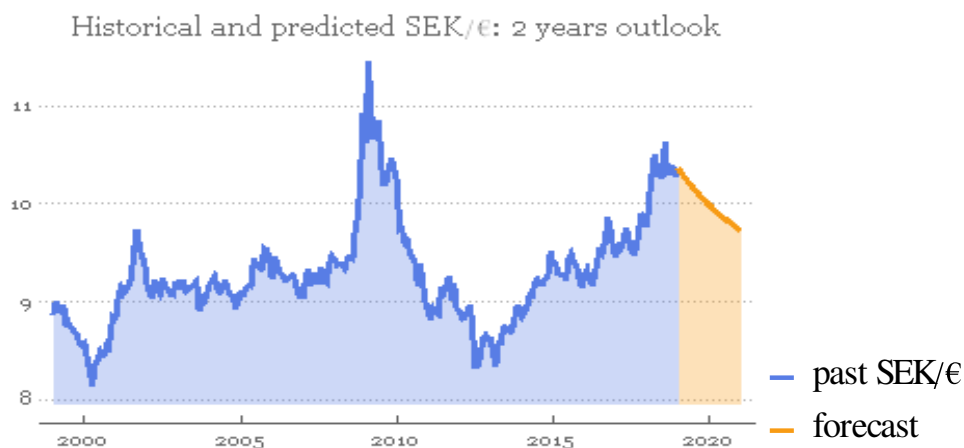
(i)   Exchange rates levels

The best fit for monthly SEK/$ (Feb 1993- Jan 2019) is an *ARIMA (0, 1, 0)* process. However, the process is not stationary and its value increases by 0.004 per month. The graph below shows that SEK is going to depreciate slightly against $ (to about 9.12 SEK compared to 9.02 SEK in Feb. 2019).

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[11] The Taylor rule is not valid for Sweden because the key interest rate is set solely as a function of inflation fluctuations.

Historical and predicted SEK/$: 2 years outlook

— past SEK/$
— forecast

Similarly, the best fit for SEK/€ is an *ARMA (1,1)* process, which is weakly stationary.

Historical and predicted SEK/€: 2 years outlook

— past SEK/€
— forecast

Contrary to the SEK/$, the SEK/€ stationary *ARMA (1,1)* process shows that SEK is going to appreciate against €. By the end of 2019 the € is expected to cost around 10 SEK and by the end of 2020 is going to cost around 9.73 SEK, compared to 10.37 in Feb. 2019.
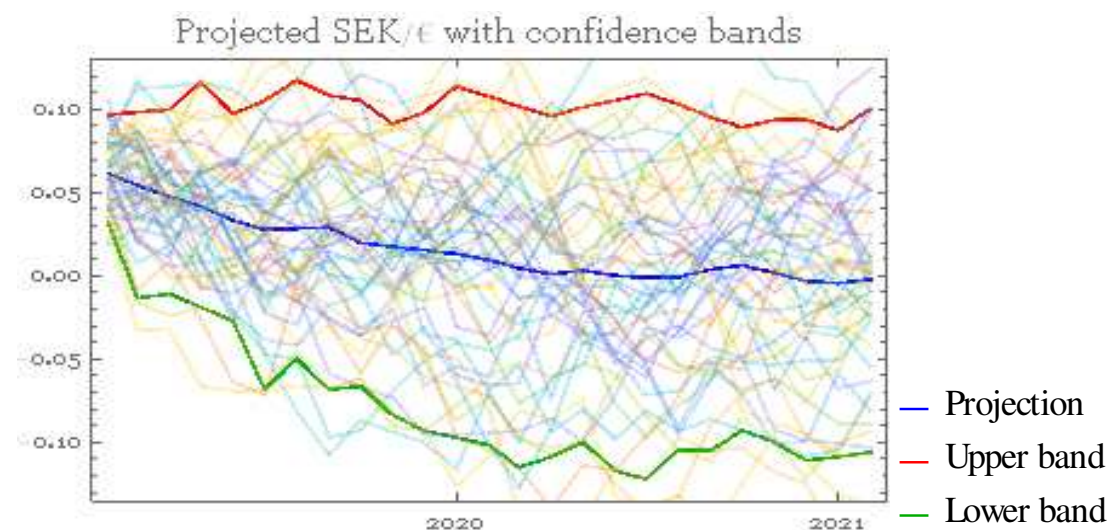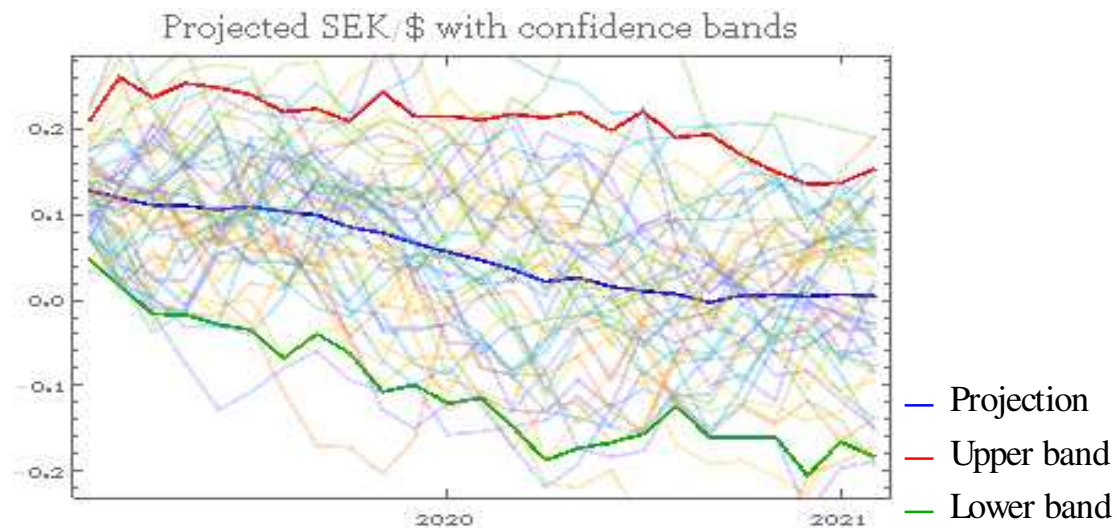
(ii)   Exchange rates changes

If we turn to exchange rates changes, (differences in logarithms, month-to-month over subsequent years), both series are stationary. The best fit for SEK/$ is an *ARMA (1,1)* process, while the best fit for SEK/€ is an *AR (1)* process. Below I forecast the upper and lower bounds, by computing the standard errors and reviewing the entire model with the error bands (see Appendix G for the Mathematica code).

% SEK/$ forecst with prediction errors

- past SEK/$
- forecast
- upp err band
- low err band

% SEK/€ forecst with prediction errors

- past SEK/€
- forecast
- upp err band
- low err band

We can see where the predicted exchange rate value can go during the next two years. The SEK/$ bounds are larger than the respective SEK/€ bounds. Again, some appreciation of the SEK is expected against both currencies. For instance, the upper bounds at the end of the forecasting period are almost equal to the last exchange rates (Feb 2019), while the lower bounds indicate clear appreciations against both currencies. By the end of 2020, the SEK will be slightly depreciated against the $ (by almost 2%, compared to 14% in Feb 2019). Similarly, the SEK will be slightly depreciated against the € (by almost 1%, compared to 6% in Feb 2019).

Finally, we can examine the stochastic nature of the model. I have simulated 50 future exchange rate paths over the next 24 months, determined two distributional quantiles (5% & 95%) and visualized them on the following graphs. As this is often true in all future predictions, we can detect where seasonality effect can influence exchange rate forecast. This can be seen as additional 'risk factor' in the outcome prediction. From the above analysis we can easily locate the quantile values as *extreme outcomes* within some prediction tolerance (see Appendix G for the Mathematica code).

Projected SEK/$ with confidence bands

— Projection
— Upper band
— Lower band

Projected SEK/€ with confidence bands

— Projection
— Upper band
— Lower band

The projected exchange rates (middle, blue line) shows a strengthening of the SEK against both $ and €. Moreover, given the fact that during the first four months in 2019 the SEK was depreciated against both $ and € by about 4-5% (i.e. seems to lie above the blue line), the SEK might not appreciate as gradual and smooth as the projected blue line shows. Perhaps its appreciation is going to follow some rather sharp and volatile paths.

Conclusion

Neither of the four fundamental theories tested (PPP, UIP, trade balance ratio and debt ratio) explain the "weak" SEK. The lower inflation rate in Sweden over the recent years was not sufficient to strengthen the currency. Similarly, the theoretically stronger SEK implied by the lower interest rates in Sweden as the UIP predicts, has not emerged yet. Its weakness only against the $ supports, very weak though, the carry trade hypothesis. Finally, neither the persistent trade balance surpluses, nor the declining

and very low debt ratio have had any positive effects on the currency. Perhaps, two other factors, GDP or GDP/capita differentials, can explain the weakening of the SEK.

If most of the economic fundamentals are in favor and the currency is not "appreciated" by the market, it seems that the traders and investors speculate against the SEK and keep it undervalued. Moreover, a number of simulated paths, predicted from various ARIMA-processes, based on the historic exchange rates, show that the worse exchange rates have already gone and by the end of 2020 the $ and the € will cost around 8 and 9.8 SEK respectively.

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Appendix A

SEK/$ (Levels)
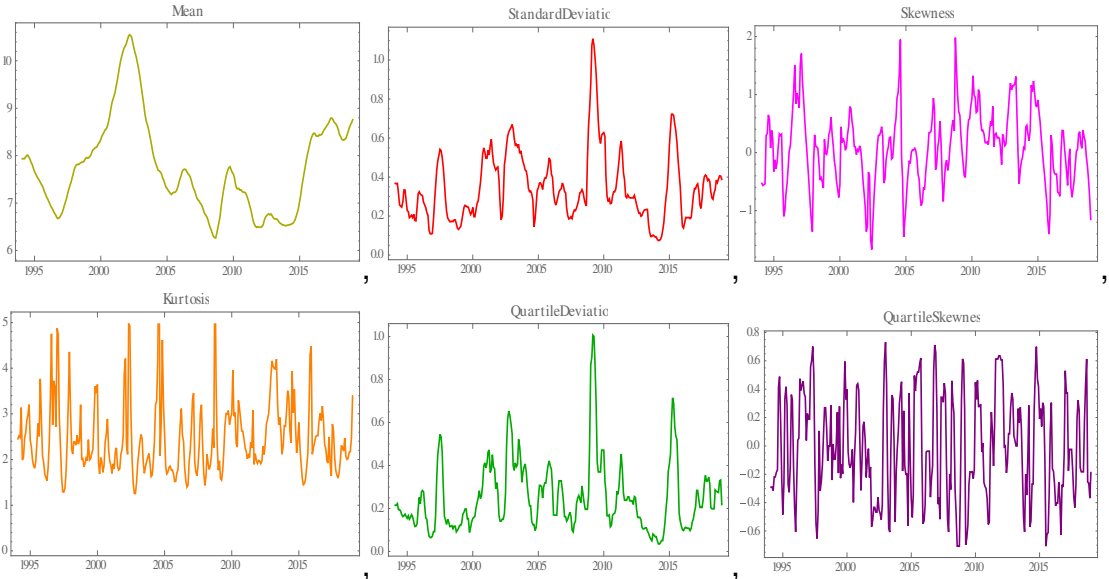
SEK/€ (Levels)
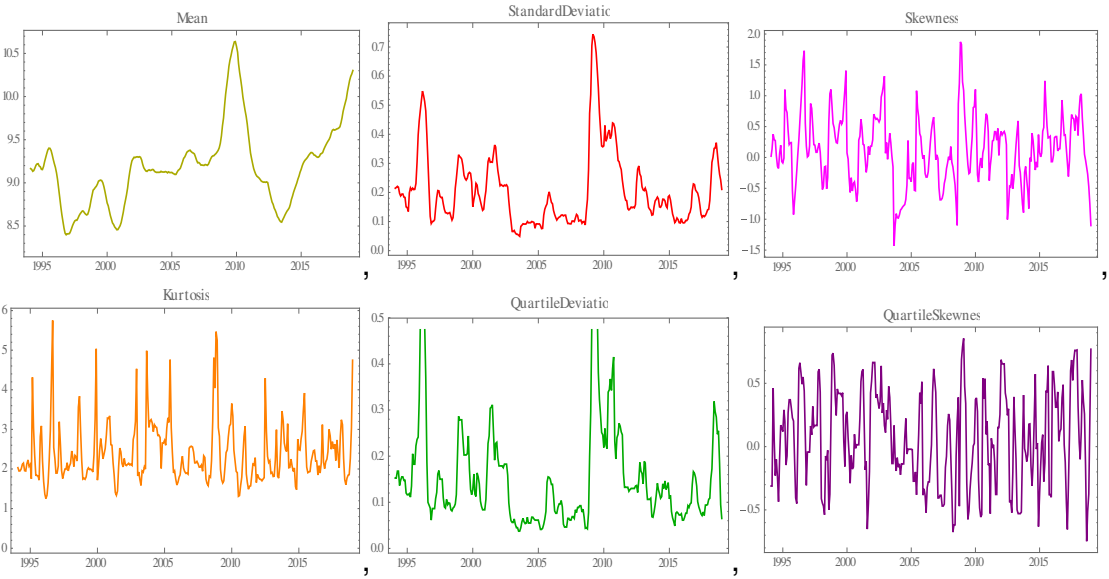
## Histograms (Levels)
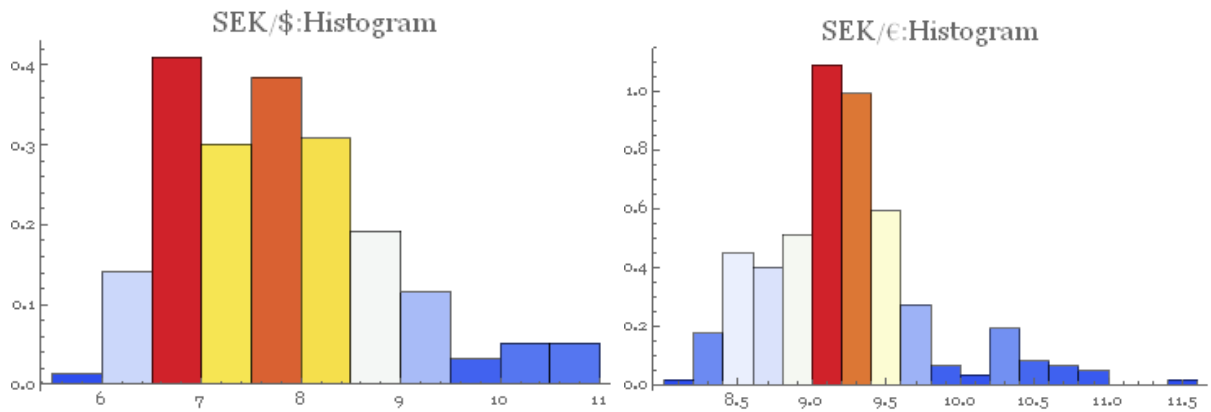
Best Kernel Distributions (Levels)

Three Best Distributions	SEK/€		
Mixture {0.91029, 0.08971}	Normal [9.093, 0.39014]		Normal [10.489, 0.41107]
Extreme Value	{8.96299, 0.46271}		
Mixture {0.71641, 0.28359}	Normal [8.98939, 0.348979]		Log-Normal [2.2804, 0.0573663]
	SEK/$		
Mixture {0.121621, 0.82547, 0.052908}	Normal [6.56485, 0.108846]	Normal [7.78085, 0.835565]	Normal [10.5398, 0.245357]
Mixture {0.361208, 0.451173, 0.187619}	Normal [6.8098, 0.38691]	Normal [8.10056, 0.477758]	Uniform [5.93588, 10.9395]
Extreme Value	{7.27895, 0.868243}		

Appendix B

SEK/$ (changes)
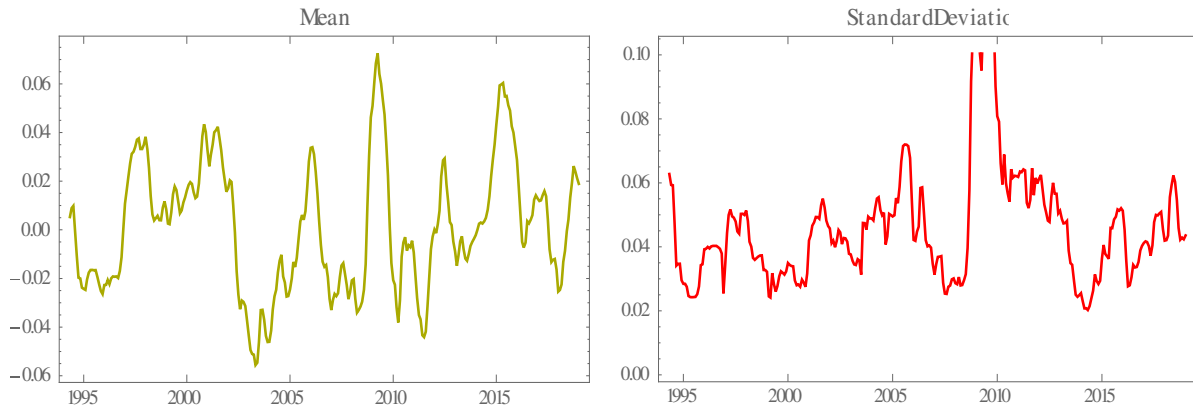
SEK/€ (changes)
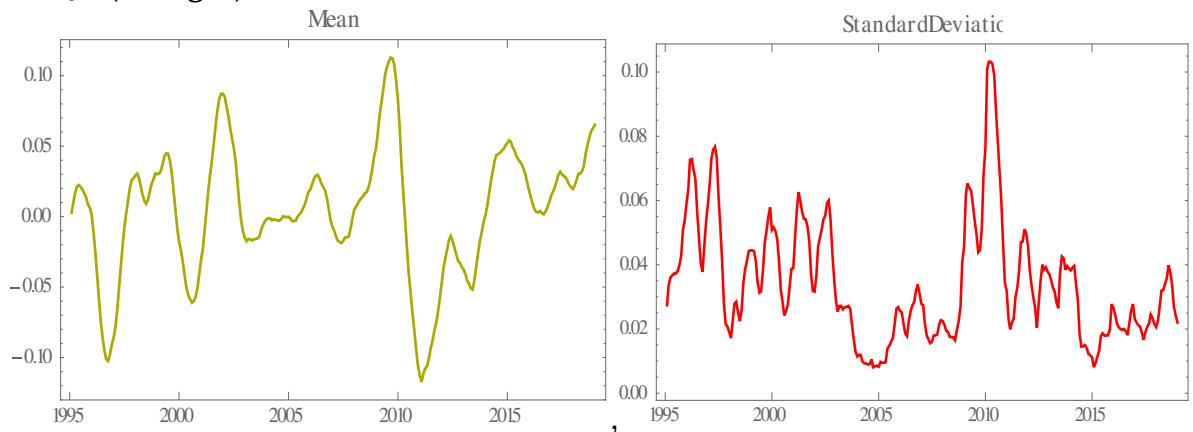
Histograms (Changes)

Appendix C

Inflation differences & SEK/$

Inflation differences & SEK/€
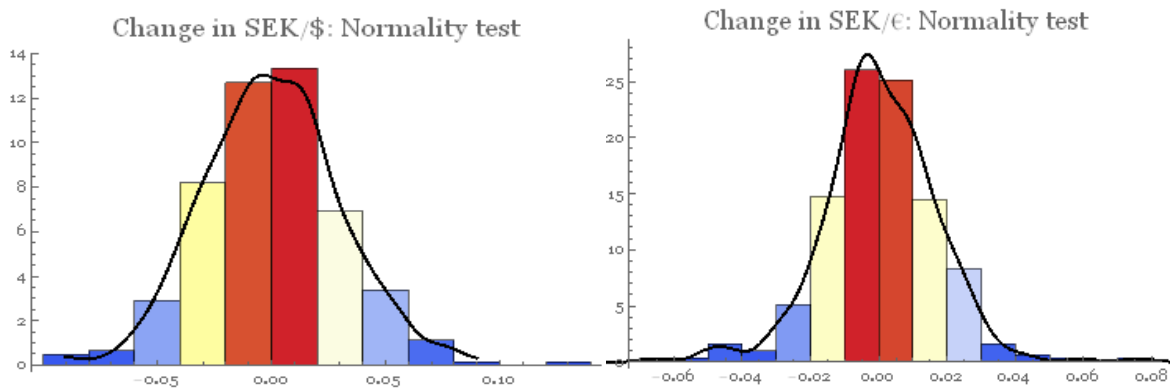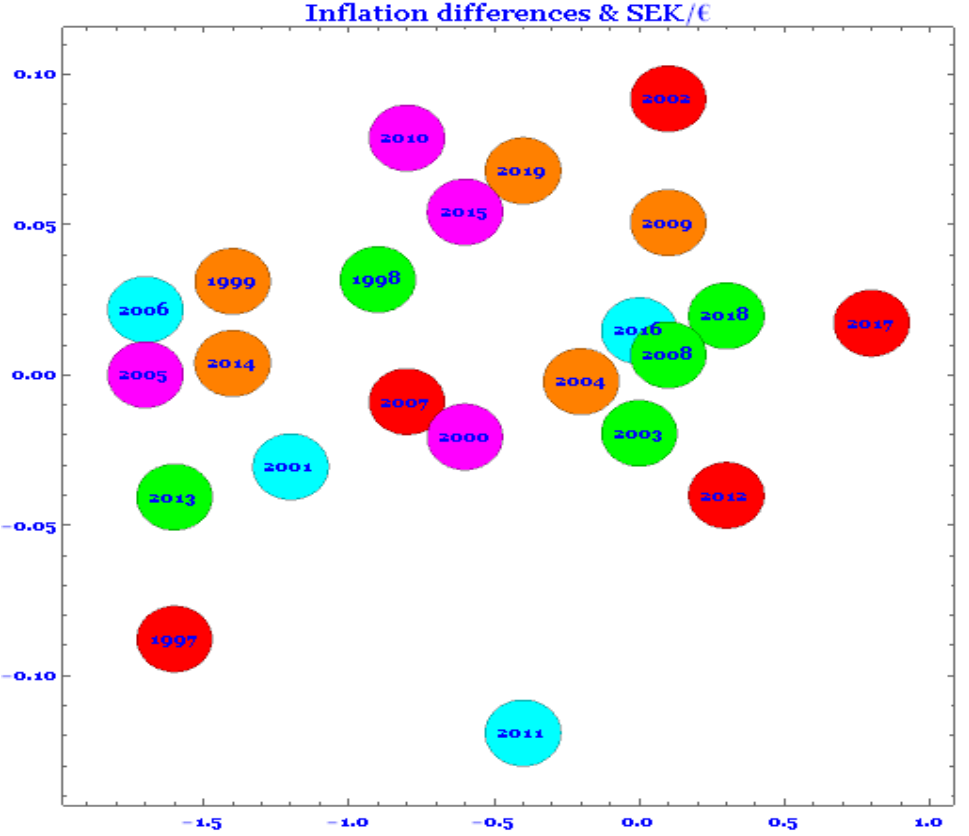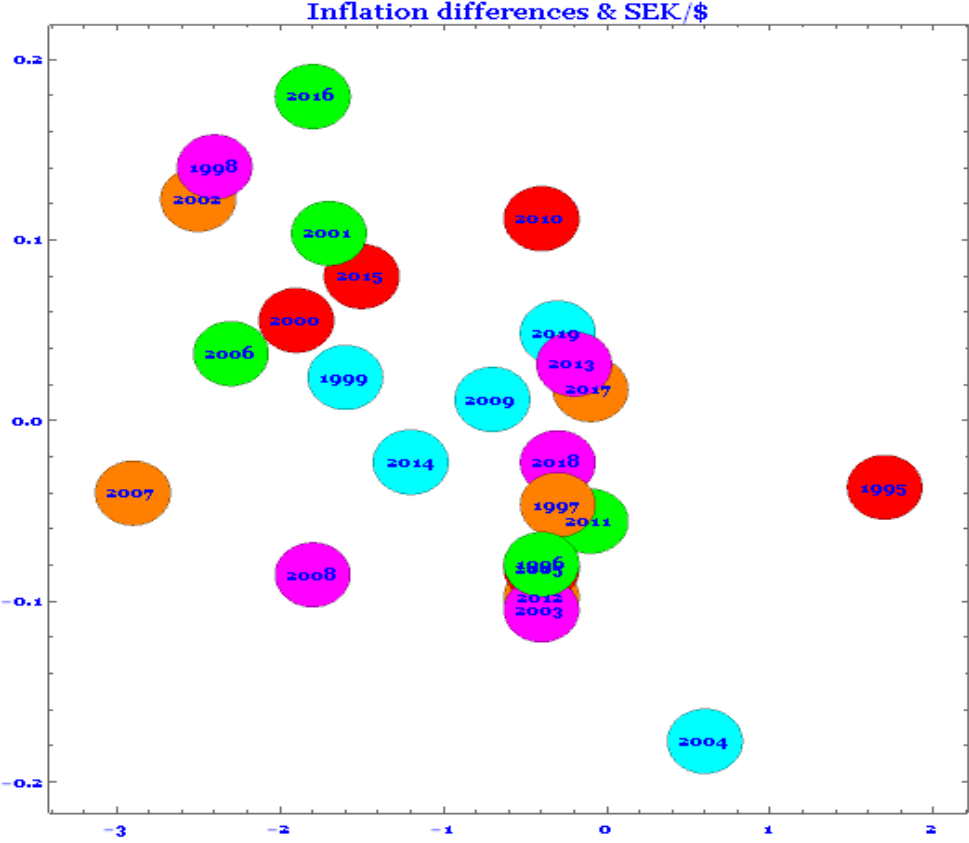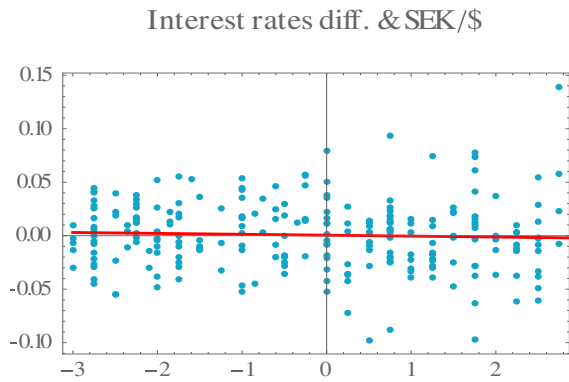
Appendix D

SEK/$ and Relative PPP (Additional methods)
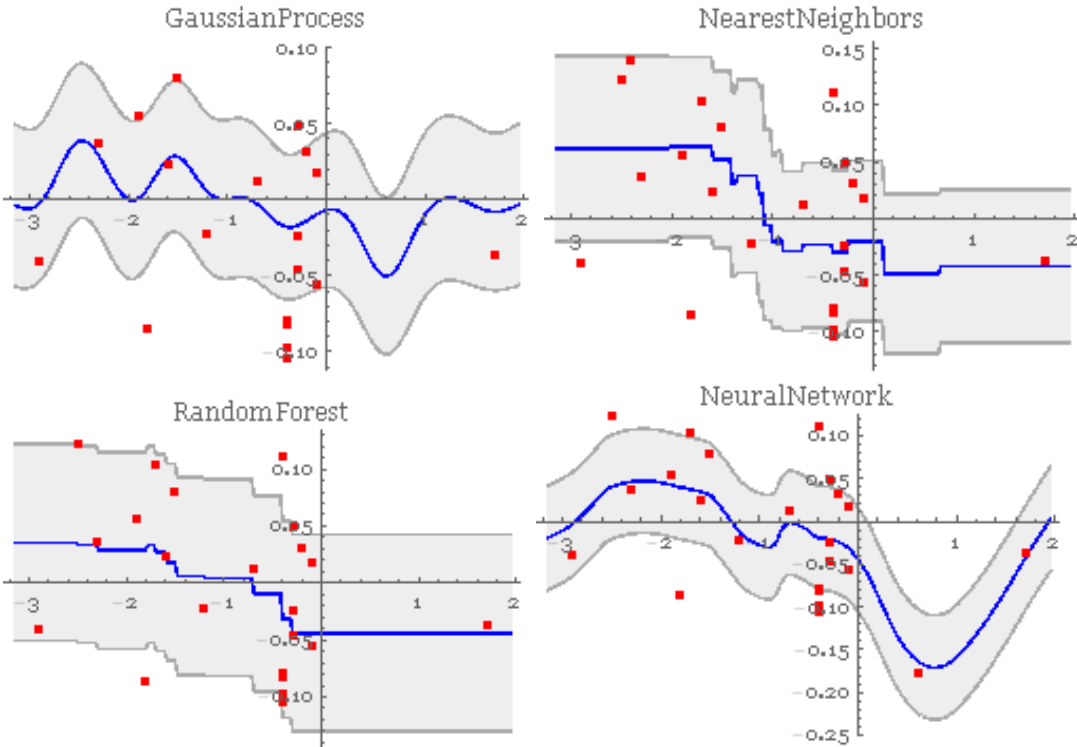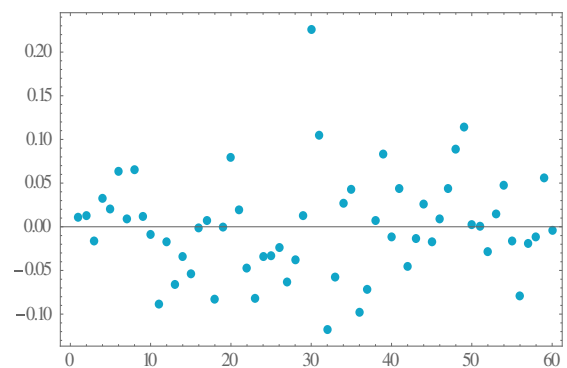

SEK/€ and Relative PPP (Additional methods)
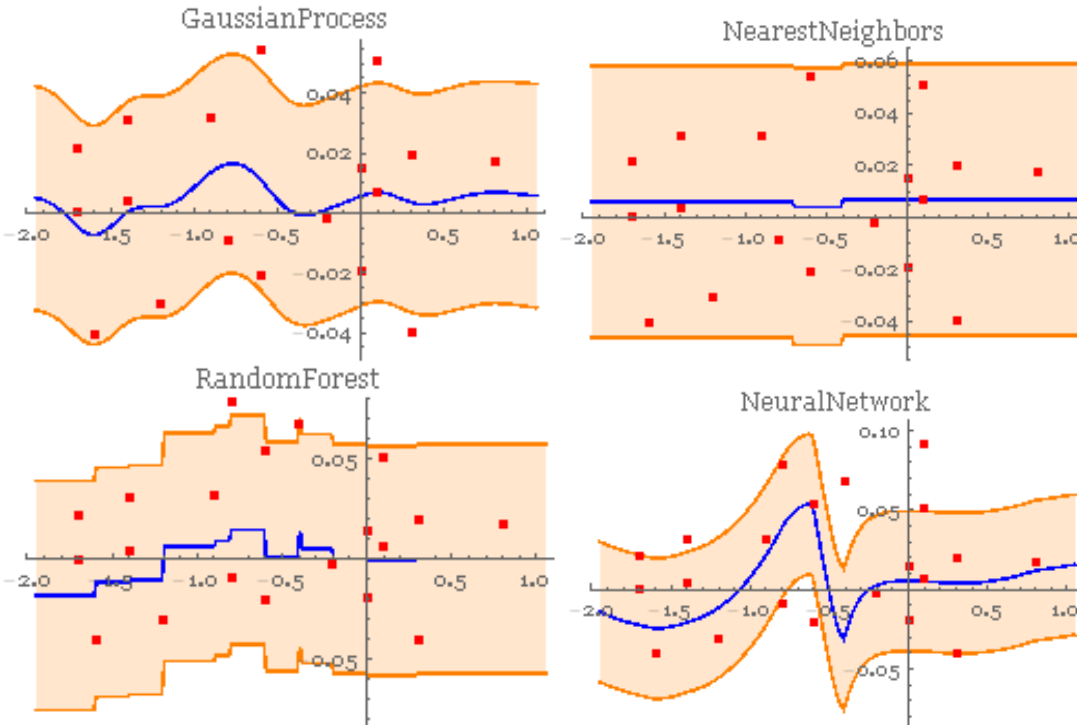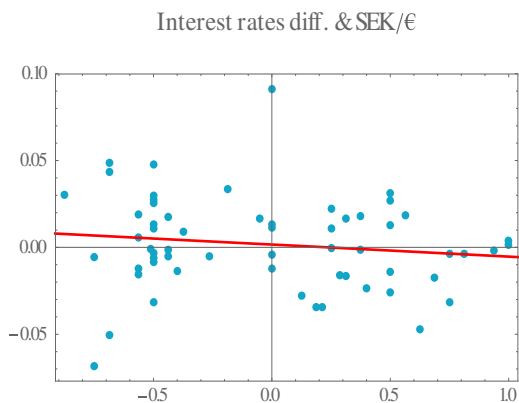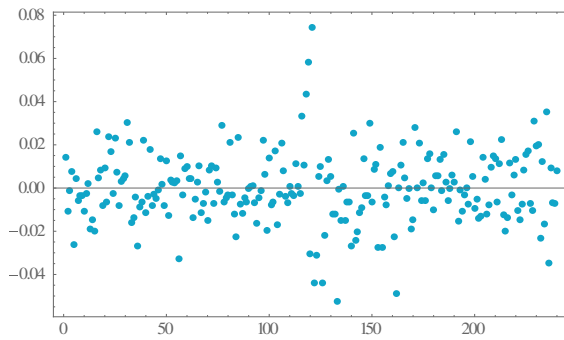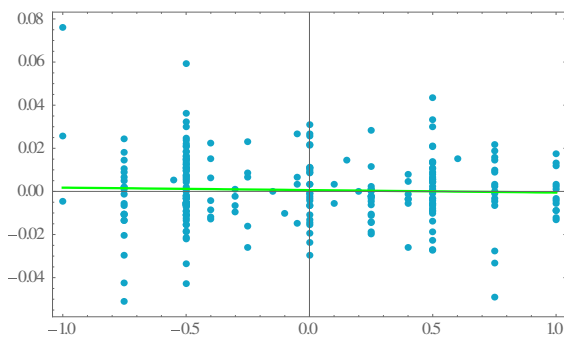
Appendix E

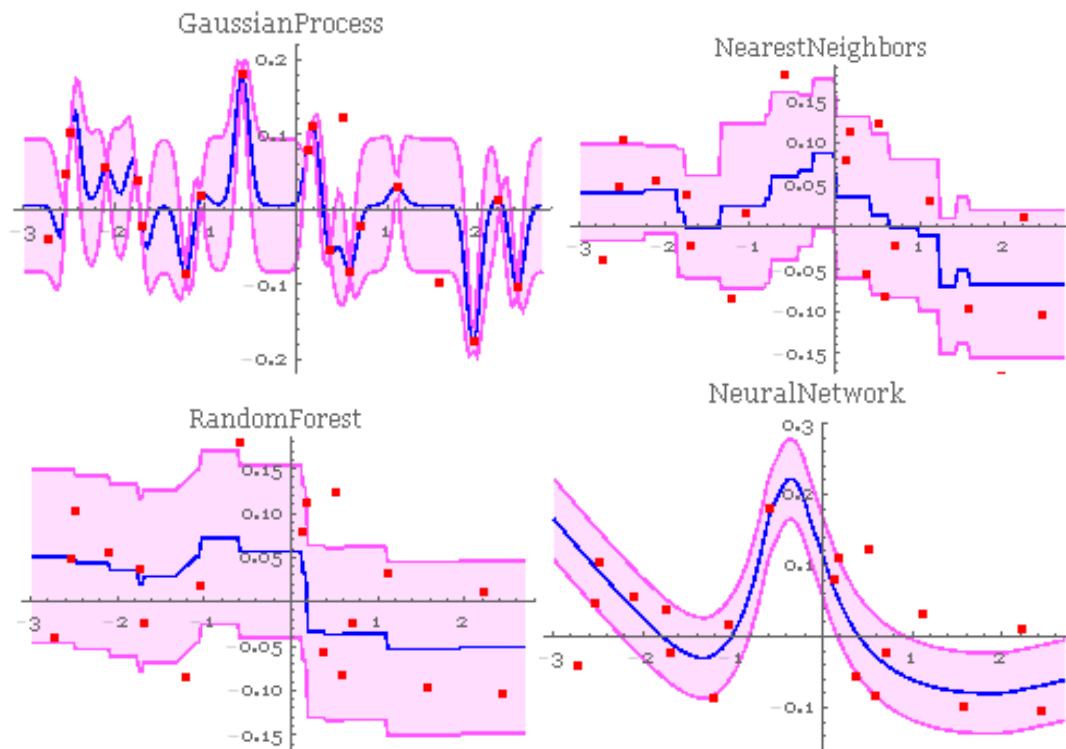### SEK/$ and IRP estimates with monthly and quarterly data

Interest rates diff. & SEK/$

Interest rates diff. & SEK/$

SEK/€ and IRP estimates with monthly and quarterly data

Interest rates diff. & SEK/€
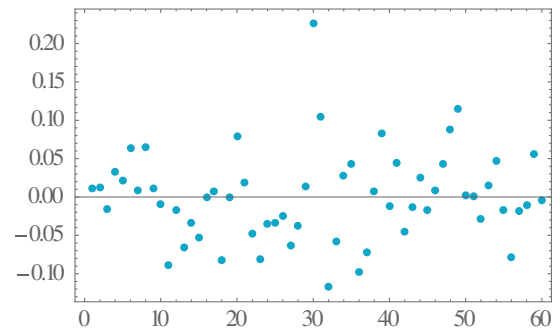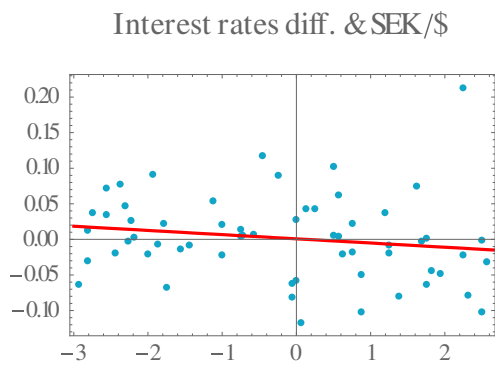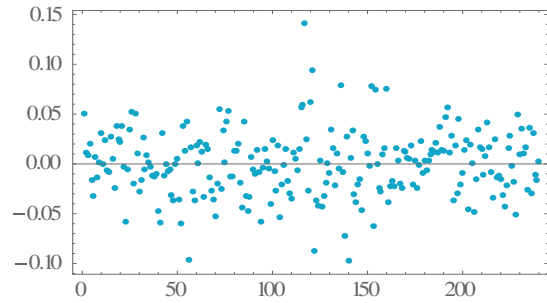
Appendix F

SEK/$ and IRP (Additional methods)

GaussianProcess

NearestNeighbors

RandomForest

NeuralNetwork

SEK/€ and IRP (Additional methods)

GaussianProcess

NearestNeighbors

RandomForest

NeuralNetwork

Appendix G

Mathematica code for forecasting SEK/$ changes over 24 months

tsdata$=**TimeSeries**[SEK/$]; *(*Make a Time Series of the monthly SEK/$ exchange rates; 312 obs.*)*
dlogSEK$=**Log**[tsdata$]; *(*Take their logarithms*)*
dlogdata$=**Differences**[dlogSEK$,1,12]; *(*Take their month to month differences in subsequent years; 300 obs.*)*

tmf$ = **TimeSeriesModelFit**[dlogdata$]; *(*Fit a Time Series Model; it is an ARMA (1, 1) process; ARMAProcess[0.000378,{0.913206},{0.107103},0.001956]*)*

forecast =**TimeSeriesForecast**[tmf$["Process"], dlogdata$,{0,2*12}]; *(*Using the ARMA (1,1) process, make 24 temporal data with mean zero*)*

TimeSeriesModelFit[forecast]; *(*Fit a Time Series Model; it is an ARIMA (0, 2, 0) process; ARIMAProcess[0.000165,{},2,{},0.000001]*)*

moderr=$\sqrt{\text{forecast}[\textbf{"MeanSquaredErrors"}]}$;
uperr=**TimeSeriesThread**[{1,1}.#&,{forecast, moderr}];
dnerr=**TimeSeriesThread**[{1,-1}.#&,{forecast, moderr}]; *(*Model the forecasting errors, as well as the upper and down errors*)*

DateListPlot[{**TimeSeriesWindow**[dlogdata$,{{2009,1,1}, {2019,1,1}}], forecast, uperr, dnerr}, Joined->True, PlotTheme->"Business", Filling->{3->{4}}, PlotLegends->{"past SEK/$", "forecast", "upp err band", "low err band"}, PlotLabel->Style["% SEK/$ forecst with prediction errors",15]] *(*Use a Times Series Window and Plot that, together with the forecasted SEK/$ changes and their upper and lower errors*)*

Mathematica code for simulating 50 SEK/$ changes, over 24 months

sim=**RandomFunction**[tmf$, {0, 24}, 50];
stmean=**TimeSeriesThread**[Mean, sim];
stup=**TimeSeriesThread**[Quantile[#,0.95]&, sim];
stdown=**TimeSeriesThread**[Quantile[#,0.05]&, sim];
sim2=**DateListPlot**[sim, PlotStyle->Directive[Opacity[.30]], Joined->True, PlotRange->All];
Show[DateListPlot[{stmean, stup, stdown}, PlotStyle->{Blue,Red, Darker[Green]},
PlotLabel->Style["Projected SEK/$ with confidence bands",15],
PlotLegends->{"Projection", "Upper band", "Lower band"}], sim2]