On the Weakness of the Swedish Krona[1]

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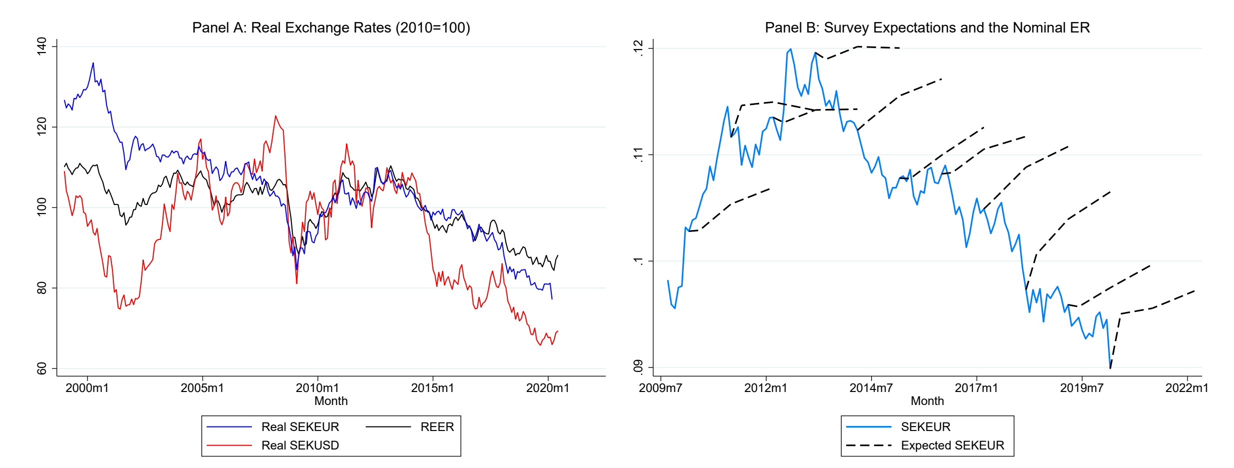
Abstract

The Swedish krona depreciated sharply between 2013 and early 2020 but standard models are unable to explain this depreciation. This paper reviews the experience of the krona. By estimating an "equilibrium" value for the real exchange rate, we confirm a growing undervaluation after 2014. The depreciation could initially be explained by a decline in interest rates and then by quantitative easing and the Riksbank communication regarding the krona. However, monetary policy cannot explain the extent of the depreciation nor the long depreciation period of seven years. We then review various complementary explanations proposed in the literature including, imperfect information, financial frictions, the role of financial shocks and the convenience yield. Many of these elements can plausibly explain the weakness of the krona, but cannot be quantified.

1 Introduction

Exchange rates are notably difficult to explain and to predict. An interesting illustration of this is the Swedish krona in recent years. Indeed, the krona has depreciated in real terms over the last decades. Panel A of Figure 1 shows the real value of the krona in terms of the euro, the dollar and a BIS trade-weighted rate for 27 countries. With respect to the euro, the krona has been continuously depreciating from March 2013 to March 2020, with a cumulative real depreciation of about 30 percent. This continuous depreciation has been totally unexpected. Both the central bank and market participants forecasted an appreciation during six years while the currency kept depreciating. Panel B of Figure 1 compares 24-month ahead survey expectations to the actual evolution of the nominal euro-krona exchange rate. From 2013 to 2020, the krona had been expected to appreciate, while it kept depreciating. A recent study on forecasting the krona by the Riksbank writes that over the recent period "... all the relationships and models considered ... underestimate the exchange rate ...".[1]

Figure 1: The Weakening Swedish Krona



Panel A compares real exchange rate indices. The black line corresponds to the real effective exchange rate for 27 countries given by the BIS, while the red and the blue lines correspond to bilateral real exchange rates of the Swedish krona against the US dollar and the euro, respectively. Real exchange rates are CPI-adjusted. In Panel B, the continuous blue line shows the nominal value of the Swedisk krona in terms of euros. The dashed black lines show Prospera surveys up to 24 months ahead.

These developments complicate the conduct of monetary policy. Overestimating the value of the currency will lead to an underestimation of imported prices and thus of inflation.[2] But it is also a challenge for economic analysis, since standard models seem unable to explain the krona's behavior. The first objective of this paper is to review the existing

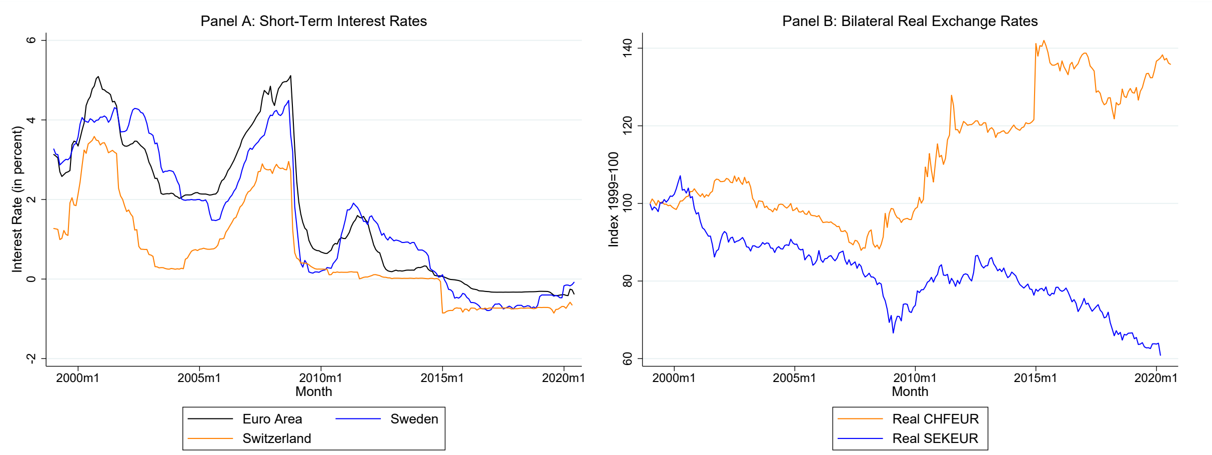
[1] Askestad et al. (2019).

[2] See Corbo and Di Casola (2020) for a recent study on exchange-rate pass-through in Sweden.

evidence and standard explanations for the Swedish krona's weakness. The second objective is to examine alternative explanations recently proposed in the literature.

We confirm the difficulties in explaining the recent evolution of the krona based on standard macroeconomic fundamentals. It is true that the Swedish central bank has conducted expansionary monetary policy since 2014. But this factor is not a sufficient explanation. As an illustration, it is interesting to compare Sweden to Switzerland, another small open economy with low government debt, a current account surplus, and very low nominal interest rates. Panel A of Figure 2 shows the evolution of nominal interest rates in Sweden and in Switzerland, compared to the Eurozone. Panel B shows the evolution of the exchange rate with respect to the euro, normalized in 1999 (an increase means an appreciation). While we notice the same trend in short-term interest rates over time, the gap between the two exchange rates increases substantially, with the well-known strong appreciation for the Swiss franc and the depreciation of the krona. This difference in behavior points towards the role of non-traditional factors in explaining currency behavior. The continuous depreciation of the currency over a long period of seven years is also puzzling.

Figure 2: The Weak Swedish Krona vs the Strong Swiss Franc



Panel A shows short-term nominal interest rates for the Euro Area, Sweden and Switzerland. Panel B compares the path of the bilateral exchange rate indices of the Swedish krona and the Swiss franc against the euro, normalized to 1999. Real exchange rates are CPI-adjusted.

We start the analysis by attempting to estimate an "equilibrium" real value for the krona, following the recent literature. We use both quarterly and annual data for Swedish data and a panel of ten countries. We find several variables that significantly co-move with real exchange rates: terms of trade, GDP per capita, government consumption or relative traded-non traded sector productivities. Estimates based on country-level regressions turn out to better track real exchange rate movements than those based on panel regressions. Using this methodology, we confirm that the krona has been undervalued since 2014 and that the degree of undervaluation has been growing over time.

We then analyze the potential reasons behind this undervaluation. We start by discussing the role of monetary policy. Beyond a low and mainly negative interest rate, the Sveriges Riksbank also implemented quantitative easing measures and a communication strategy. The switch to a more expansionary policy in April 2015 clearly contributed to the depreciation. However, the krona kept depreciating when monetary policy stabilized and even after the Riksbank increased its interest rate at the end of 2018. On the other hand, quantiative easing was still active and the Riksbank kept talking down the currency until early 2019.

In the last part of the paper, we review several factors mentioned in the academic literature that could explain the continuing weakness. First, imperfect information has been shown to disconnect exchange rates from fundamentals and, at times, give an excessive role to some factors. This could have played a role in the context of the krona, although this cannot explain by itself the depreciation over so many months. Another perspective is the role of "financial shocks", which can be seen as changes desired portfolios by investors that are unrelated to observed fundamentals. While this is conceptually important, it is difficult to find precise measures for financial shocks. At least, global financial shocks do not appear to play a role. One financial factor that could play a role is the liquidity of bonds markets, as measured by the convenience yield. We show that this convenience yield appears to be related to the value of the krona, but that there are both econometric and conceptual issues that make it difficult to interpret this relationship.

There could also be various types of financial frictions that influence the dynamics of exchange rates. In particular, gradual portfolio adjustment could explain a delayed response to fundamental changes. Finally, exchange rate expectations may differ from the standard assumption of rational, forward-looking, investors. Expectations could be influenced by various types of information frictions or deviations from rational expectations. At this stage, however, the impact of this factor on the krona is unclear.

The remainder of the paper is organized as follows. Section 2 estimates an equilibrium value of the krona and documents periods of over- and undervaluation. Section 3 examines the role of monetary policy. Section 4 discusses the potential impact of financial factors and financial frictions and Section 5 concludes.

2 Estimating the Equilibrium Real Exchange Rate

2 .1 Analyzing Real Exchange Rates

We follow the standard approach of estimating an "equilibrium" real exchange rate and determining to what extent the actual exchange rate deviates from its equilibrium value. The first step is to choose the price levels to construct the real exchange rate. The most common measure is CPI and is the one we will consider: we use the narrow BIS real effective exchange rate index (trade-weighted with 27 economies), which uses CPI. The Riksbank's KIX exchange rate index has 32 countries and uses CPIF, which excludes the effect of changes to fixed mortgage interest rates.[3] Moreover, it is interesting to notice that the extent of real depreciation of the krona is smaller when using unit labor costs or purchasing power parity measures (see Sveriges Riksbank, 2019).[4]

There is a vast literature attempting to estimate equilibrium exchange rates using panel data over a set of countries. Some recent papers include Ricci et al. (2013), Adler and Grisse (2017), Berka and Steenkamp (2018), or Ca'Zorzi et al. (2020). This literature estimates reduced form regressions relating the real exchange rate to macroeconomic variables. To illustrate this methodology, consider the following equation:

$$rer_{it} = \alpha_i + \mathbf{X}'_{it}\beta + \varepsilon_{it} \tag{1}$$

where rer_{it} is a measure of the log real exchange rate in country i and $\mathbf{X}_{it}$ is a set of macroeconomic variables. These are often relative variables, i.e., country i compared to an average of other countries. In panel data regressions, α_i allows for country fixed effects. The estimation methodologies differ across studies, but they often use a cointegration method assuming nonstationarity of the real exchange rate and a cointegration relationship with explanatory variables (e.g., Adler and Grisse, 2017, Ricci et al., 2013, or Ca'Zorzi et al., 2020). Thus, we estimate the latter relationship using Dynamic Ordinary Least Squares (DOLS). The fitted value of (1) represents the equilibrium exchange rate and is compared to the actual exchange rate. There are also numerous papers working with country-level data, estimating equation (1) without the i subscript. Papers focusing on the Swedish krona include Nilsson (2004), Lindblad and Sellin (2006), or Lane (2007).

In this section, we follow the literature to estimate an equilibrium real exchange rate for the krona. We consider both panel and country-level regressions with either quarterly or annual data. For panel data, we consider ten countries: Australia, Canada, Finland, Ireland, Japan, Korea, Netherlands, Sweden, United Kingdom, and United States.[5] We first consider regressions with quarterly data and then turn to annual data.

2 .2 Quarterly Data

We basically follow the methodology described in Ricci et al. (2013) with the same set of advanced economies, even though they consider annual data. In Appendix B, we follow the somewhat different approach of Ca'Zorzi et al. (2020), with a slightly different set of countries. We run the panel data regression (1) with four macroeconomic variables available at the quarterly level: GDP per capita, terms of trade, net foreign assets to GDP, and trade

[3] CPIF is the variable used for inflation target by the Riksbank.

[4] Part of the explanation may be that the Sweden makes more quality adjustment in computing the CPI than other countries. The difference appears substantial for various types of goods.

[5] This list of countries is determined by the availability of productivity data.

balance to GDP. The estimation period is 1975Q1 to 2018Q4. GDP per capita is a relative variable, divided by a weighted average of the countries of interest, the weights corresponding to the share of GDP (in PPP terms) of the ten countries in 2000Q4. Annual population size is interpolated, using cubic splines, in order to deal with quarterly data. It is worth noting that the terms of trade and the net foreign assets to GDP are already relative variables (with respect to the rest of the world), thus we do not take the relative value for these two variables. The terms of trade are defined as a ratio between export and import prices. More details on the construction of these series can be found in Appendix A.1. We then turn to a Sweden-only estimation of (1) using the same variables and the same time period. In particular, we still use relative variables.

Results for the panel and country-level regressions are shown in Table 1. We first notice that terms of trade are strongly significant with the expected sign, even though the magnitude of coefficients is much smaller with panel data.[6] GDP per capita is also significant and with a positive sign. Net foreign assets and trade balance to GDP are insignificant.[7] Results are similar under slightly different specifications.[8]

However, results differ if we adopt the approach of Ca'Zorzi et al. (2020) with their set of countries, as shown in Table 8 in Appendix B. Terms of trade are still significant and with coefficients of similar magnitude. But the trade balance to GDP becomes significant, while GDP per capita becomes insignificant.[9]

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[6] Notice that there is no claim of causality between these variables and the real exchange, but a cointegrating relationship. For example, terms of trade will naturally be affected by the exchange rate, so it is not surprising to find a strong relationship.

[7] The trade balance is significant for the earlier sampler, e.g. until 2005.

[8] For example, we used OLS with and without fixed effects or we introduced crisis dummies as in Lindblad and Sellin (2006).

[9] GDP per capita has a positive sign if we restrict the data to the earlier sample, e.g., until 2005, although it is hardly significant. Ca'Zorzi et al. (2020) also mention this feature. In the case of Sweden, it is not surprising to see a negative relationship in the latest part of the sample as we observe a strong relative growth at a time of real depreciation in the last decade. The Riksbank Monetary Policy Report (Sveriges Riksbank, 2018) discusses this issue. One hypothesis is that GDP growth could have been driven by an increase in productivity in the non-traded good sector, which would lead to a depreciation.

Table 1: Dependent Variable: log real effective exchange rate

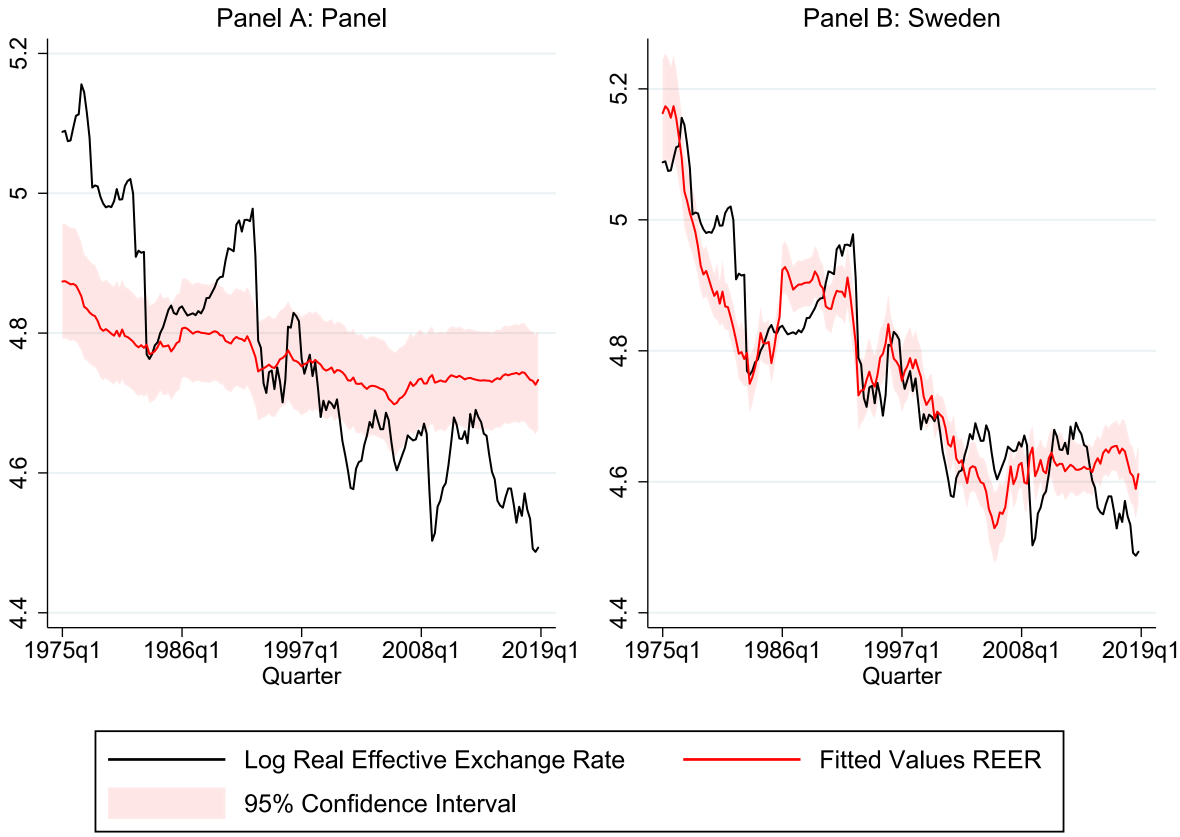
	Panel			Sweden		
	(1)	(2)	(3)	(4)	(5)	(6)
Log Terms of Trade	0.453***	0.475***	0.452***	1.927***	1.797***	1.719***
	(0.0966)	(0.0988)	(0.0968)	(0.189)	(0.253)	(0.279)
Relative GDP per Capita	0.255**	0.277***	0.272**	0.525**	0.942	0.305
	(0.104)	(0.106)	(0.124)	(0.262)	(0.609)	(0.376)
NFA to GDP		0.0375			-0.156	
		(0.0486)			(0.200)	
TB to GDP			-0.0629			-0.775
			(0.235)			(0.818)
Observations	1757	1757	1757	173	173	173
R^2	0.598	0.602	0.599	0.843	0.849	0.854

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

While regression results are not robust to the approach used, the fitted value of these regressions, representing the equilibrium exchange rate, is similar under the various specifications we analyzed. Figure 3 shows the equilibrium exchange rate compared to the actual exchange rate using columns (1) and (4) of Table 1. Panel A of Figure 3 is computed from panel data estimation and Panel B shows the case based on the estimation with Sweden only. Figure 19 in the Appendix B shows similar graphs using the methodology of Ca'Zorzi et al. (2020).

Figure 3: Equilibrium vs Actual Real Exchange Rate: Quarterly



Panel A displays the fitted values of the equilibrium real exchange rate using a panel of countries, while Panel B shows the predicted exchange rate when we estimate for Sweden only. We use the coefficients estimated in columns (1) and (4) of Table 1.

The difference between the two panels of Figure 3 is striking. The equilibrium real exchange rate estimated from panel data, in Panel A, tends to move very little over time. By comparing with the actual exchange rate, we find that the krona has been below its equilibrium real value in the last two decades and that this divergence has been increasing over time. In other terms the estimated panel hardly matches the evolution of the real exchange rate in the last two decades.[10] Using panel data is useful if we can assume cross-sectional similarities. But it may be that the assumption of equal coefficients across countries made in the reduced-form equation (1) may not be appropriate. In the context of Table 1, the panel data coefficients could be biased downwards for example if the terms of trade do not matter for some countries. Notice that the issue appears more problematic for Sweden than for other countries in the sample. Appendix C shows the equilibrium exchange rate with panel data estimates for the ten countries in our sample.

In contrast, Panel B shows a relatively good fit if we only use data for Sweden. The

[10]Notice that Ca'Zorzi et al. (2020) find a similar result for Sweden (Figure 3).

model explains most fluctuations. If we focus on the more recent period, however, we see that the actual value of the krona is below its equilibrium value since 2014. We can also notice the appreciation period 2010-2012 which is above the equilibrium value.

It is interesting to notice that in a Riksbank staff memo, Belfrage et al. (2020) only find an overvaluation since 2018. Their two main variables are also terms of trade and relative GDP per capita.[11] However, they use the Riksbank KIX index and a different methodology. They consider a time-varying autoregressive model with three additional variables for shorter-term fluctuations: the current account, the policy rate differential, and the VIX index. These variables turn out to be insignificant in our framework.

While quarterly data provides more data points and more precise fluctuations periods, only a limited set of variables is available across countries. When we turn to annual data we can consider a wider set of variables.

2 .3 Annual Data

The estimation strategy is the same as in the previous section, but we can consider more variables in addition to terms of trade, net foreign assets or the trade balance. The sample runs from 1970 to 2018.

Theoretically, a key variable determining real exchange rates is relative productivity in traded and non-traded sectors. This data is not available at the quarterly level. Even at the annual level we need to construct imperfect estimates. In this paper, we follow Ricci et al. (2013) and construct a labor productivity measure based on output per worker which distinguishes the productivity in tradables and nontradables (see Appendix A.1 for details on data construction). In addition to that specificity, we adjust the latter variable using the same method described in Subsection 2 .2, dividing by a weighted average of the countries of interest, the weights corresponding to the GDP PPP share of the ten countries in 2000. It is interesting to mention that Berka and Steenkamp (2018) find that measures of total productivity are similar to labor productivity for Sweden.

Another variable that should matter is the fiscal stance.[12] We consider the impact of government consumption per GDP, as in Ricci et al. (2013). We use government consumption to GDP relative to the weighted average of the other countries. Finally, we also consider unit labor cost as suggested by Berka and Steenkamp (2018) and Berka et al. (2018). As the data used by Berka and Steenkamp (2018) is not available after 2012, we use a unit labor cost index based on the number of persons employed (relative to the weighted average of countries).

Table 2 presents the results with panel data and time-series data for Sweden with four

[11] They use population aged 15-64 to compute GDP per capita, while we use total population. However, our results change very little when we consider working age population.

[12] E.g., see Ricci et al. (2013), Adler and Grisse (2017), Goldfajn and Valdes (1999), and Lindblad and Sellin (2006).

variables: terms of trade, (relative) government expenditure per GDP, (relative) per capita GDP, (relative) traded minus non-traded productivity differential. We do not show the results with with unit labor costs, trade balance to GDP or net foreign assets to GDP as these variables are typically insignificant. Columns (1) and (4) show that terms of trade, government consumption, and GDP per capita are significant with the right sign.

Table 2: Dependent Variable: log real effective exchange rate

	Panel			Sweden		
	(1)	(2)	(3)	(4)	(5)	(6)
Log Terms of Trade	0.437***	0.119***	0.308***	1.279***	1.318***	1.310***
	(0.0872)	(0.0311)	(0.0591)	(0.0591)	(0.0581)	(0.0795)
Gov. Consumption to GDP	1.026***	-0.293***	0.657***	1.215***	0.331*	0.526
	(0.246)	(0.0644)	(0.171)	(0.111)	(0.181)	(0.646)
Relative GDP per Capita	0.790***		0.802***	0.453***		0.00526
	(0.149)		(0.0941)	(0.0632)		(0.274)
Log Productivity Differential		-0.248***	-0.239***		-0.254***	-0.229
Traded-Non Traded Sectors		(0.0239)	(0.0422)		(0.0382)	(0.164)
Observations	487	487	487	46	46	46
R^2	0.687	0.653	0.727	0.936	0.944	0.948

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

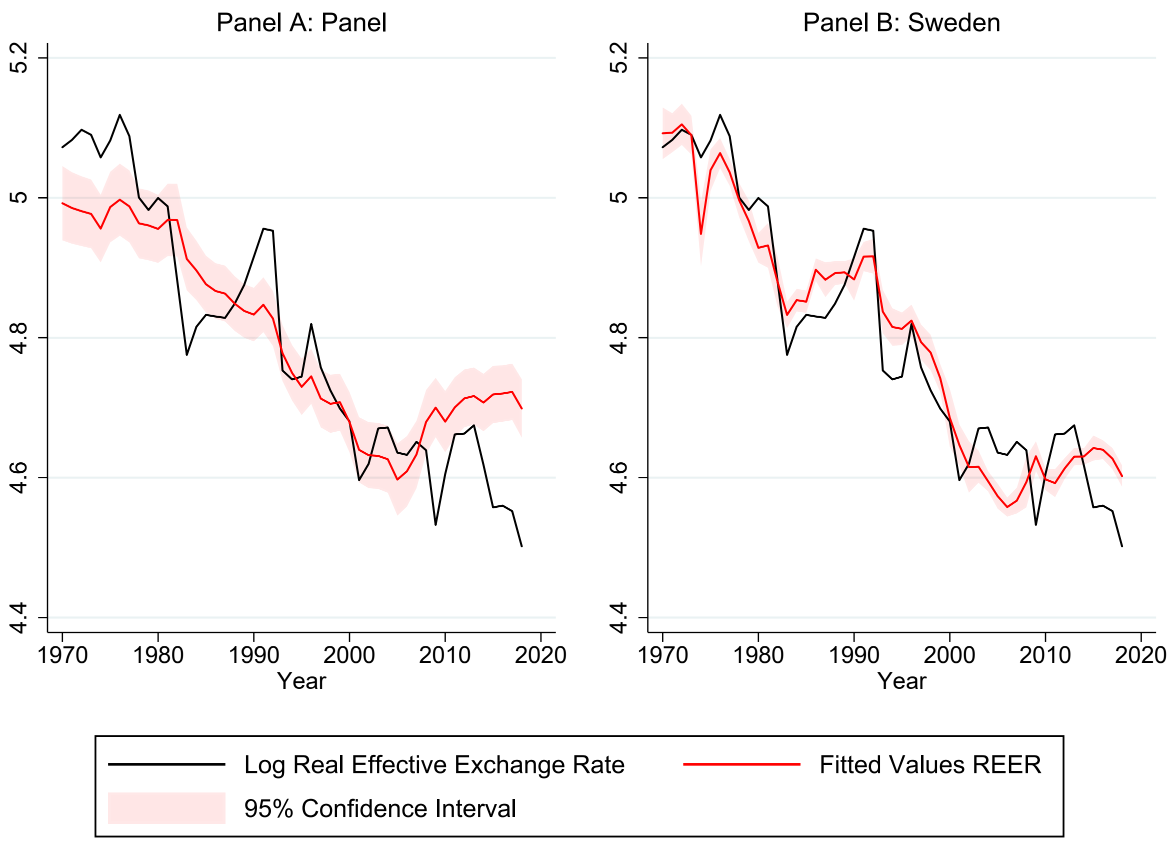
Adding relative productivity between tradables and non-tradables in columns (2), (3), (5) and (6) of Table 2 gives a more complex picture. First, this affects the value of the other coefficients, reducing their significance (columns (5) and (6)) or even changing their sign (column (2)). Moreover, relative productivity is significant, both with panel and Sweden-level data. However, the sign is negative, while the Balassa-Samuelson effect implies a positive impact: an increase in traded sector productivity increases wages and thus prices throughout the economy, which leads to a real appreciation. This negative sign is not specific to Sweden as it also holds for panel data.[13] A negative sign for developed countries has been found previously in the literature (Ricci et al., 2013, Bordo et al., 2017, Gubler and Sax, 2019). Theoretically, the Balassa-Samuelson effect is positive when tradable goods are identical. However, if export and import goods are different, there may be a terms-of-trade impact that changes the sign of the productivity differential (Benigno and Thoenissen, 2003).

[13]We find negative coefficients for eight out of the ten countries in the sample when we run country-level regressions.

There may also be a reverse sign if productivity growth in the traded sector is associated with higher productivity in the distribution sector (Devereux, 1999). Another potential explanation is that our measure of productivity captures demand rather than supply changes. More generally, the Balassa-Samuelson is more likely to apply when comparing countries with significant differences in development, while productivity differences across developed countries may be small and our relative TFP measures may capture other factors.

Figure 4 compares the actual real exchange rate with equilibrium values computed from columns (3) and (6) in Table 2. Using panel data, the equilibrium moves closer to the actual rate than with our quarterly data estimates. However, it would imply that the krona has been undervalued since 2008. On the other hand the equilibrium exchange rate estimated with Sweden-only data is close to the actual exchange rate, similarly to the case of quarterly data. The undervaluation only starts in 2014.

Figure 4: Equilibrium vs Actual Real Exchange Rate: Annual



Panel A displays the fitted values of the equilibrium real exchange rate using a panel of countries, while Panel B shows the predicted exchange rate when we estimate for Sweden only. We use the coefficients estimated in columns (3) and (6) of Table 2.

To summarize this section, we find several variables that are significantly related to the real exchange rate: terms-of-trade, per capita GDP, relative productivity and government consumption. Using these variables with country-level data for Sweden, we find an equilibrium exchange rate that broadly moves in line with the actual exchange rate. However, in recent years the actual exchange has been weaker that the estimated equilibrium value. The challenge is to determine the shorter-run factors that have influenced the krona in recent years. One obvious factor is monetary policy and is discussed in the next section. There may be other macroeconomic factors, like increasing trade uncertainty, that are difficult to evaluate. However, our focus in Section 4 will be on alternative explanations for exchange rate behavior.

3 The Role of Monetary Policy

In the last decade, one can see a direct link between the value of the Swedish krona and the Sveriges Riksbank policy rate. From Figure 2, one can see that the interest rate hike in 2010-2012 was associated with an appreciation of the krona, while the subsequent interest rate decline in 2015 paralleled the currency depreciation. While we observe a clear positive correlation between interest rate and exchange rates over the 2010-2012 and 2014-2016 subperiods, no such relationship can be observed in other periods, for example between 2017 and early 2020 where the krona kept depreciating with no decline in interest rate. Therefore, interest rate differentials alone cannot explain the continuous depreciation.

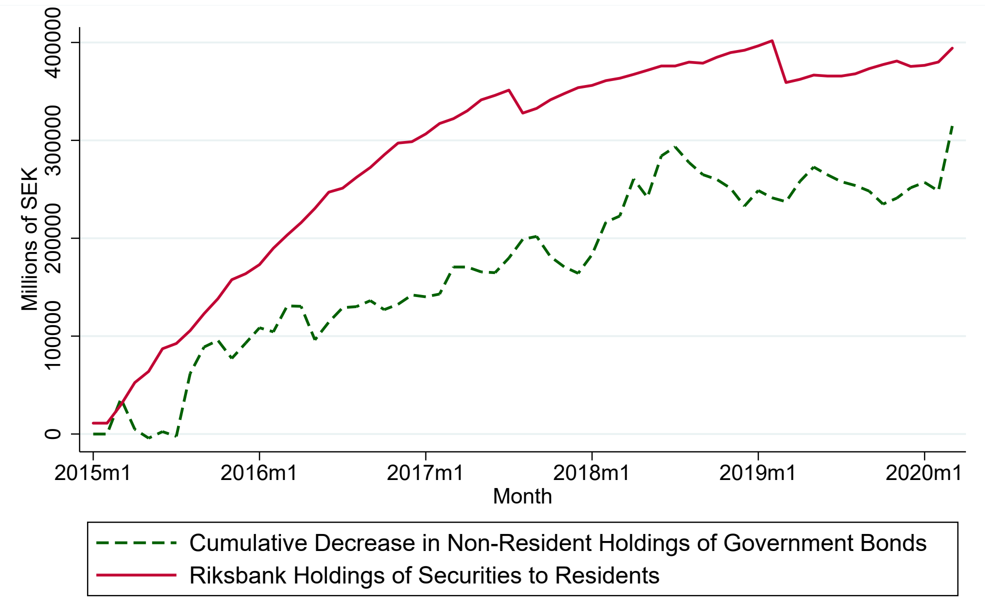
However, monetary policy is not only measured by current interest rates. The Riksbank engaged in substantial quantitative easing (QE) starting in Spring 2015, purchasing government bonds for more that 7 percent of GDP until 2019. These purchases implied a portfolio balance effect for the exchange rate, reducing the supply of krona assets to the private sector.[14] The reduction of available government bond in kronas is likely to push investors towards foreign currency bonds. To illustrate this point, Figure 5 shows the increase in central bank holdings of krona securities as well as the cumulative sales of krona government debt by non-resident investors. These non-resident holdings had been steadily increasing until May 2015, but started to decline thereafter.[15] At the same time, one can see an increase in Swedish residents holdings of foreign currency securities. Overall, there is a net portfolio shift towards foreign currency assets that coincides with QE operations. This QE-induced portfolio shift obviously puts downward pressure on the krona. In a sense QE purchases of domestic currency assets can have effects similar to direct FX interventions.[16]

[14]The recent literature has re-emphasized the role of these portfolio-balance effects (e.g., Gabaix and Maggiori, 2015).

[15]Notice, however, that non residents do not necessarily repatriate all these funds as they could invest in other krona assets, in particular covered bonds.

[16]Theoretically, if we consider a standard small open economy model with Ricardian equivalence and perfect asset substitutability, QE purchases can be equivalent to FX intervention.

Figure 5: Quantitative Easing and the Decline in Non-Resident's Holdings



The continuous red line shows the holdings of securities from the Swedish Central Bank and the dashed green line shows the cumulative decrease in non-resident holdings of government bonds, starting in 2015m1.

Moreover, expectations of future monetary policy also matter. Central banks can influence these expectations through their communication. In the Swedish case, the central bank started to talk down the currency in 2015 and continued until 2019. The somewhat controversial tightening of Riksbank's policy in 2010-2011[17] was associated with an appreciation of the krona, as mentioned above. When the Riksbank started to lower its interest rate in April 2015 it also made clear that a stronger krona would not be desirable (see its Monetary Policy Report). Moreover, in January 2016 the central bank announced that it was prepared to use FX intervention to weaken the currency, although it never did. In subsequent years, the Riksbank kept insisting that a stronger krona was not desirable, even though the krona had already been depreciating for several years. This was still mentioned in the Monetary Policy Report of February 2019 (p. 10): "The krona could be both stronger and weaker than the Riksbank is forecasting, but the effects on inflation of a stronger krona than forecast would be more problematic to manage with the prevailing interest rate levels." This communication lead to an asymmetric framework where the central bank is more likely to intervene when the currency is strong, thus lowering the probability of a strong appreciation. It is obviously difficult to quantify the impact of this communication on exchange rate expectations. Panel B of Figure 1 shows that the krona was always expected to appreciate, but the extent of expected appreciation in 2018-2019 was not so large.

[17] See Svensson (2018).

4 The Role of Financial Factors and Financial Frictions

In this section we examine various potential explanations for the weakness of the krona in recent years. We focus on the nominal exchange rate. Standard models also fail to explain the nominal weakness (e.g., see Papahristodoulou, 2019, or Askestad et al., 2019). For example, uncovered interest rate parity (UIP) would imply an appreciation of the krona since Sweden has a negative interest rate differential with most countries. There might be shocks to the perceived riskiness of the currency, e.g., a decline in its hedging properties. This would be like an anti safe-haven effect. One could argue that the krona became less attractive as an alternative to the euro once the eurozone crisis was resolved after 2012. But it is difficult to see what factors would lead to an increase in this effect in more recent years.

The literature has explored several deviations from standard models, in particular deviations from UIP. It is not the purpose of this paper to provide an exhaustive review of the literature, but we will examine approaches that appear particularly relevant.

4 .1 Imperfect Information

A strong assumption in standard models is that all market participants have the same information on fundamental variables or on the underlying model. When this is not the case, the exchange rate will deviate from the value implied by fundamental variables. For example, Bacchetta and van Wincoop (2006) develop a simple monetary model with dispersed information about future fundamentals. They show that non-fundamental, or financial, shocks can have large effects leading to a disconnect from fundamentals. The reason is that if market participants observe for example a currency depreciation they might revise their expectations of future fundamentals, assuming other participants have information of fundamental weakness. This disconnect coming from rational confusion should evaporate over time (after several months). Applying these ideas to the krona, it could be that the continuous depreciation has led to expectations of more expansionary monetary policy. While this could be part of the story, it is unlikely to apply over several years.

One should also notice that the model of Bacchetta and van Wincoop (2006) implies a strong relationship between exchange rates and order flow, which is consistent with what is found in the literature initiated by Evans and Lyons (2002). While the evidence on order flow could be informative about short-term exchange rate dynamics and about the type of investors affecting exchange rate,[18] it would still beg the question of why investors want to sell the krona for a prolonged period.

Another implication from imperfect information is the scapegoat effect. Bacchetta and van Wincoop (2004) analyze a model where investors have dispersed information about

[18] See Bjønnes et al. (2014) for an interesting application to the Swedish krona.

the model parameters. They show that this implies that markets, at times, give too much weight to a specific variable. Bacchetta and van Wincoop (2013) also show that this leads to time-varying coefficients. However, this is also based on rational confusion that should disappear over time.[19] In the case of the krona, it could be that excessive weight has been given to some variable, e.g., expansionary monetary policy. However, this is difficult to confirm empirically. And again, it is unlikely that such effect could last for many years.

4 .2 Financial Shocks

The recent literature also shows that in order to explain the data on exchange rate fluctuations, one needs to assume large financial shocks (e.g. Itskhoki and Mukhin, 2019).[20] These financial shocks may include numerous factors affecting investors portfolio behavior and in general cannot be measured directly. So one could argue that investors have shied away from krona assets for reasons that cannot be captured by fundamental variables. But since it is difficult to be more precise, this is not very informative. There are measures of global financial shocks, e.g., related to the VIX or to US monetary policy, that can affect the value of emerging market currencies. However, there is no clear relationship with the krona's value in recent years.

One more precise factor associated with financial shocks could be the relative liquidity of domestic currency assets, often referred to as the convenience yield.[21] While the FX market is liquid, the krona bond market may be less liquid. The question is whether the relative liquidity has declined in recent years. Du et al. (2018a) propose a measure of the convenience yield as the difference in government bond yields adjusted by the forward discount. More precisely, the convenience yield is defined as $\eta_{j,t} = i_t^{*G} - i_t^G + f_t - s_t$, where i_t^G and i_t^{*G} are domestic and foreign government yields, f_t is the forward rate, and s_t is the nominal exchange rate. Jiang et al. (2020) and Engel and Wu (2020) (henceforth EW) relate the value of the convenience yield to the exchange rate, focusing on one-year government yields. Following EW (see their Figure 1), Figure 6 shows the convenience yield and the exchange rate for two countries, Sweden and Switzerland.[22] In Panel A, one can see that the depreciation of the krona coincides with a lower convenience yield. In contrast, in Panel B the strength of the Swiss franc coincides with an increase in the convenience yield.

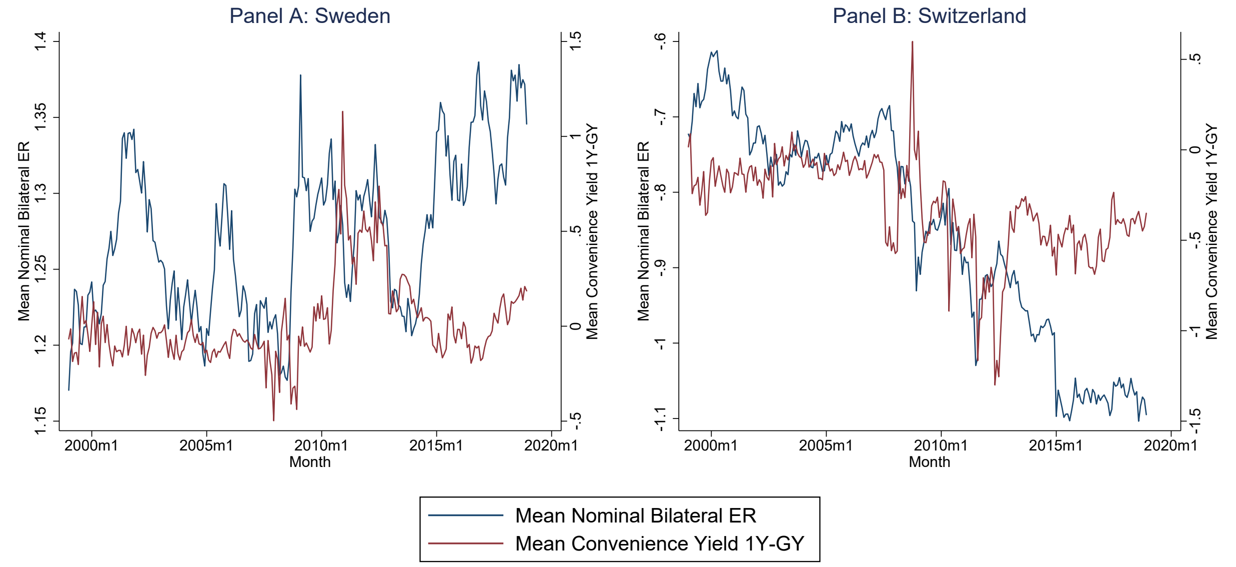
[19] Fratzscher at al. (2015) provide support for the scapegoat model using surveys about the perceived role of fundamentals. Unfortunately, these surveys are not available for Sweden.

[20] With imperfect information, the financial shocks do not need to be large as there can be an amplification mechanism.

[21] E.g., Engel and Wu (2020), Jiang et al. (2018, 2020), or Valchev (2020).

[22] In this figure an increase in the average bilateral exchange rate implies a currency depreciation. The ten currencies included in the sample are Swedish krona, Swiss franc, Australian dollar, Canadian dollar, euro, Japanese yen, New Zealand dollar, Norwegian krona, British pound and US dollar.

Figure 6: Average Convenience Yield and Nominal Exchange Rate



Panel A displays in blue the average nominal bilateral exchange rate between Sweden and nine different countries. In red, it shows the average of the convenience yield between Sweden and nine other countries. Panel B shows the same variables between Switzerland and the other nine countries.

To analyze this relationship more precisely, EW consider the following panel regression:

$$\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\eta_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4\eta_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t} \tag{2}$$

where $i^R_t = i^G_t - i^{G*}_t$. They focus on one-year government yields and find that both the interest differential and the convenience yield are strongly significant. Table 3 presents evidence on equation (2) for Sweden, using the same methodology as in EW, for both one-year and one-month yields.[23] Our results are quite similar to those of EW. Column (1) shows strong significance with both the interest differential and the convenience yield (as in their Table 1A). Column (2) shows significance for the interest differential only, but with a lower R^2 (as in their Table 1B). Column (3) shows significance of the convenience yield without the interest differential. Using one-month yields in column (4) confirms the results of column (1) (as in their Table 1F). The number of observations is smaller in the latter case as one-month yields are not always available.

[23]We consider the Swedish krona with respect to 9 other currencies, as in Figure 6. We use OLS with country dummies.

Table 3: Dependent Variable: $\Delta s_{j,t}$

	1Y-GY			1M-GY		
	(1)	(2)	(3)	(4)	(5)	(6)
Lag log RER	-2.556***	-2.494***	-2.237***	-3.596**	-3.571**	-4.136***
	(0.412)	(0.398)	(0.370)	(1.089)	(1.076)	(0.904)
Delta Interest Rates Differential	-2.691***		-4.396***	-0.894		-19.49***
	(0.453)		(0.541)	(0.491)		(4.924)
Lag Interest Rates Differential	-0.0855		-0.0955	-0.0824		-13.21***
	(0.0840)		(0.0696)	(0.0974)		(3.055)
Delta Convenience Yield		-2.379***	-4.696***		0.736	-19.82***
		(0.492)	(0.659)		(0.451)	(4.880)
Lag Convenience Yield		-0.654*	-0.479		0.0831	-14.38***
		(0.299)	(0.304)		(0.107)	(3.366)
Constant	3.392***	3.376***	2.976***	6.327**	6.288**	7.225***
	(0.518)	(0.526)	(0.471)	(1.859)	(1.837)	(1.539)
Observations	2104	2104	2104	1258	1258	1258
Within R-squared	0.0531	0.0332	0.119	0.0223	0.0203	0.0497

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Although Table 3 shows strong significance of the convenience yield, there are various econometric issues with that regression. First, it assumes that the convenience yield is exogenous. But changes in the measured convenience yield could be fully endogenous. For example, imagine that there is a portfolio shift by international investors against krona bonds. This portfolio shift will weaken the currency, but it will also put pressure on krona government yields. Thus, we might observe a reduction in the convenience yield accompanied by a weakening of the currency. To correct for this endogeneity, EW use instrumental variables and still find significant coefficients that are even of a higher magnitude. However, correcting econometrically for endogeneity does not yield causality. If, as in the example above, the exchange rate and the convenience yield are jointly affected by an unobserved financial shock, establishing an econometric link between the two variable does not really inform us about the source of exchange rate fluctuations.

A second econometric problem comes from overlapping data when using one-year yields with monthly data. This problem can be alleviated by adjusting standard errors and parameters remain significant. This is the case, for example, when using Newey-West standard errors or time clusters.

Using one-month yields avoids this overlapping data problem, although it reduces the number of observations. However, the results in columns (4) to (6) of Table 3 point to a third econometric problem: the multicollinearity between the convenience yield and the return differential. Columns (5) and (6) show that neither the interest differential nor the convenience yield are significant. But when they are put together in the regression in column (4) they, somewhat miraculously, become strongly significant with coefficients of very similar magnitude. The explanation for this result is that the correlation between the convenience yield and the interest differential is -0.99. This multicollinearity fully explains the significance with one-month yields. With one-year yields, the correlation is lower at -0.47.[24] However, it still explains part of the significance and the fact that the coefficients for the convenience yield and the interest differential are very similar for all countries.[25]

Fluctuations in the convenience yield may come in part from deviations of covered interest rate parity (CIP). Deviations from CIP are reported by Du et al. (2018b) for Sweden and other countries (see their Figure 2) and show clear deviations from CIP for the Swedish krona since 2008.[26] Following EW, define the deviation from CIP as $\tau_t = f_t - s_t + i_t^* - i_t$, where i_t^* and i_t are Libor rates. We can then decompose the convenience yield as $\eta_t = \tau_t + \lambda_t$, so that λ_t is a relative liquidity measure after adjusting for CIP deviations. Figure 7 shows the evolution of η_t, τ_t, and λ_t averaged over the nine currency pairs for one-year yields.[27] We see that fluctuations in η_t are dominated by fluctuations in λ_t. It is still interesting to examine the differentiated impact of τ_t and λ_t on the krona value, as done in EW (Table 2A). Table 4 shows that both τ_t, and λ_t are significant, with a coefficient of similar magnitude.[28] Similar to η_t, the coefficient of λ_t appears overestimated as its value drops when we do not include the interest differential in the regression.

[24]It also surprising to see that one-month and one-year convenience yields are uncorrelated.

[25]The multicollinearity problem is no longer present when we consider 10-year yields.

[26]Notice that these deviations are similar to several other currencies, in particular the euro and the Swiss franc.

[27]Libor rates are only available until 2013 for Sweden. To complete the sample, we use one-year deposit rate.

[28]The equation also includes lagged variables in levels, but the coefficients are not shown in Table 4.

Figure 7: Convenience Yield Decomposition

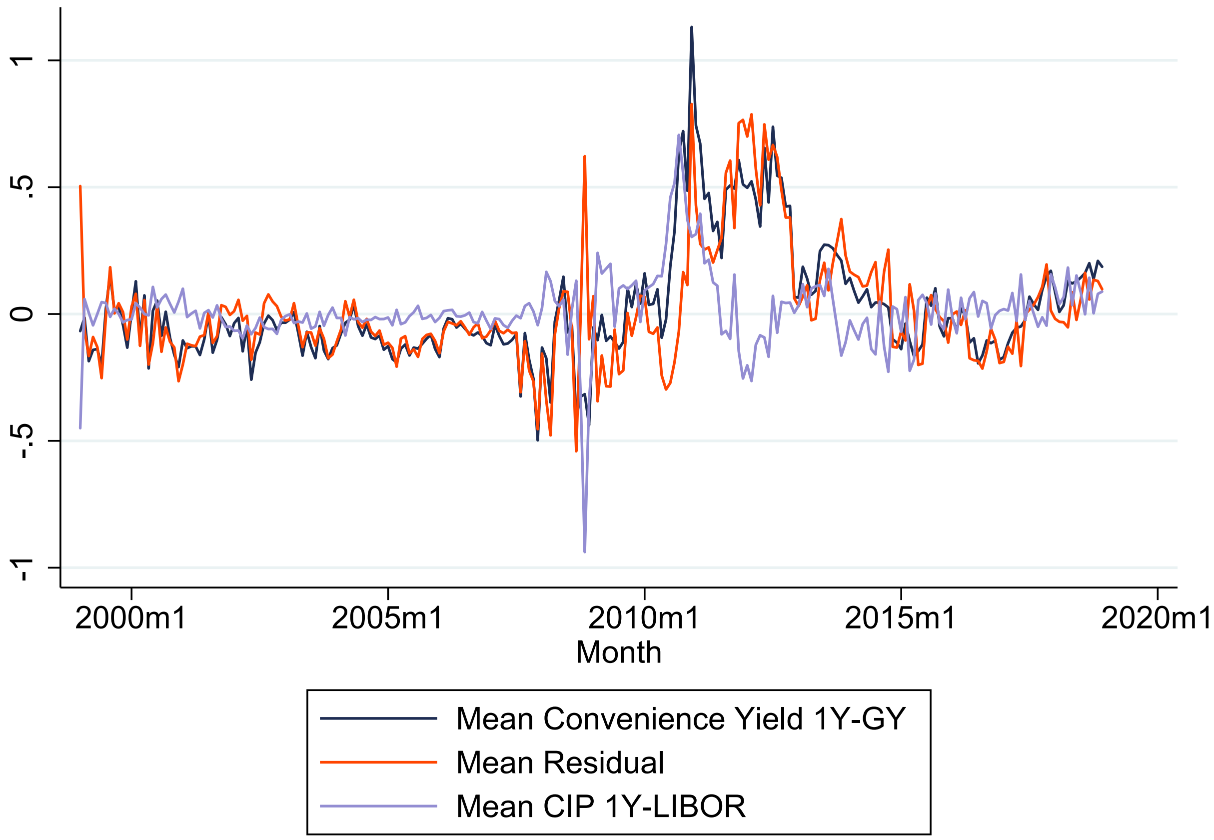


Figure 7 represents the decomposition of the convenience yield η_t into the CIP deviation τ_t with one year libor rates, and its residuals λ_t, such that $\eta_t = \tau_t + \lambda_t$. Each line shows the average between Sweden and nine other countries.

The econometric issues recommend caution in interpreting the results from convenience yield regressions. More importantly, even if one find a relationship between the krona and the convenience yield, there still remains the question of what underlying financial shocks influence the convenience yield. Finally, changes in the convenience yield cannot explain the krona depreciation in recent years, as Figure 6 shows an increase in the convenience yield while the krona kept depreciating.

Table 4: Dependent Variable: $\Delta s_{j,t}$

	Convenience Yield (CY)	Decomposed CY	Decomposed CY
Lag log of RER	-2.237***	-2.248***	-2.295***
	(0.370)	(0.365)	(0.400)
Delta Interest Rates Differential	-4.396***	-3.987***	
	(0.541)	(0.504)	
Delta Convenience Yield	-4.696***		
	(0.659)		
Delta CIP Deviation		-5.710***	-4.747***
		(0.983)	(1.017)
Delta Residual		-4.153***	-1.719***
		(0.664)	(0.493)
Observations	2104	2104	2104
Within R-squared	0.119	0.126	0.0624

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

4 .3 Other Financial Frictions

While there can be various explanations for a weak krona, the continuous depreciation is difficult to explain. This means that on average investors wish to keep selling the krona over long periods. One explanation is that many investors change their portfolio gradually. If they expect the return in krona assets to be low, not all investors will immediately adjust their portfolios. The adjustment will be done over time. The hypothesis of gradual adjustment would be consistent, for example, with the gradual increase in purchases of foreign government bonds by Swedish investors. Substantial increases can be observed until mid-2019. Bacchetta and van Wincoop (2010, 2020) show that this gradual portfolio adjustment implies exchange rate dynamics that are consistent with the data.[29] In particular, it is consistent with the exchange dynamics considered in the Riksbank DSGE model of the Swedish economy.[30]

Moreover, investors may not be as forward looking or as rational as standard models assume. Actually, Bacchetta and van Wincoop (2010, 2020) argue that gradual adjustment should be combined with expectations based on limited information to match the dynamic

[29]Bacchetta, Tièche and van Wincoop (2020) show that this explanation is also consistent with the behavior of international equity portfolios by mutual funds.

[30]See Adolfson et al. (2008).

relationship between nominal exchange rates and interest rates. There are obviously numerous reasons why expectations are not fully forward looking and "rational". There may be costly information, heterogenous beliefs, psychological biases, simple trading rules, etc. For example a simple momentum strategy would keep selling the krona. The fact that survey expectations overpredict the value of the krona for seven years, shows a systematic expectational error that is inconsistent with rational expectation models. However, these expectational errors cannot explain the weak value of the krona, as they would encourage krona purchases.

5 Conclusions

The continuing depreciation of the Swedish krona from 2013 to 2020 is a puzzling phenomenon for an advanced economy. The initial depreciation could easily be rationalized as it was associated with a reduction in interest rates and followed a period of appreciation. But the krona kept depreciating even when the interest differential stabilized. Quantitative easing operations, however, continued and put pressure on the krona through a portfolio balance effect. Moreover, the central bank kept talking down the currency until early 2019. It may appear surprising that the Riksbank was still worried about a strong krona when it had been so weak for many years. Probably its reasoning was that since the krona was undervalued an appreciation was bound to occur. Given that the main focus was inflation, an appreciation was not welcome as it reduces imported inflation. The scenario of an appreciating krona was indeed plausible, as illustrated by the events of 2020 (notice that despite the rapid appreciation in 2020, the level of the krona-euro exchange rate is about the same as in early 2019). However, given the huge uncertainty regarding the timing of an appreciation, one might wonder whether the focus on relatively short-term inflation prospects was fully optimal.

This paper has also allowed us to revisit empirical methodologies used in exchange rate analysis. Using standard methods to estimate an equilibrium real exchange rate, we found that using pooled cross-country panel data had shortcomings and we preferred the estimates with Swedish time series. We also found that the real exchange rate could not be explained by a Balassa-Samuelson effect, a typical result for advanced economies. On the other hand we found terms of trade, government consumption, and GDP per capita to be significantly associated with the real exchange rate. Moreover, the finding that the krona had been undervalued in recent years is robust across methodologies.

Financial shocks, in the form of desired portfolio shifts by investors, are likely to be a major driving force for exchange rates. Their impact can be amplified by imperfect information. However, these shocks are typically not observable and will impact many financial variables. For example, we have analyzed the relationship between the value of the krona and the convenience yield on krona government bonds. Putting aside the econometric issues with this analysis, finding a relationship between the exchange rate and the convenience yield may simply reflect the impact of financial shocks. This still begs the question of where the shocks come from. The same can be said for the relationship between exchanges rates and order flow. Moreover, financial shocks alone are unlikely to explain the long period of depreciating krona. There may be mechanisms at work such as imperfect information, gradual portfolio adjustment, or biases in expectations.

All in all, part of the krona depreciation is still a puzzle. Exchange rate economists have been humble since Meese and Rogoff (1983). There have been many interesting development in the field in the last decades. These developments help us understand better the forces that potentially move exchange rates, but, as this paper illustrates, they do not give precise quantitative explanations. Therefore, we have to keep being humble.

Appendices

A Data

A.1 Data Description

Table 5: Quarterly Data - 1975Q1-2018Q4

Variable	Details	Source
Real Exchange Rates	Real Effective Exchange Rate BIS27.	BIS
Relative GDP per Capita	Real GDP in PPP terms, interpolated population data (cubic spline) relative to a weighted average of all countries (weighted by the share in total GDP PPP of the countries in 2000Q4).	OECD National Account, United Nations
Terms of Trade	Ratio of export to import goods and services deflators.	OECD Economic Outlook
Net Foreign Assets to GDP	Balance of payments data (following Lane and Milesi-Ferreti (2017) definition), complete the database with interpolated data (cubic spline) from the annual database of Lane and Milesi-Ferretti (2018), divided by real GDP in PPP terms.	IMF IFS, External Wealth of Nations database (Lane and Milesi-Ferretti, 2018), OECD National Accounts
Trade Balance to GDP	Difference between exports and imports of good and services.	OECD Economic Outlook

Table 6: Annual Data - 1970-2018

Variable	Details	Source
Real Exchange Rate	Real Effective Exchange Rate BIS27.	BIS
GDP per Capita	Real GDP per capita in PPP terms.	OECD National Account
Productivity Differential	Difference between the log productivity of tradables and nontradables relative to a weighted average of all countries (weighted by the share in total GDP PPP of the countries in 2000). Productivity is defined as output per worker (in USD). Tradables and nontradables are separated using the ISIC industry classification (A-E, F-U respectively).	United Nations (output per industry), ILOSTAT (workers per industry), IMF (bilateral exchange rate against USD)
Terms of Trade	Ratio of index of export to import prices.	OECD data

Net Foreign Assets to GDP	Annual database developped by Lane and Milesi-Ferretti (2018), complete missing years with balance of payments data (following Lane and Milesi-Ferreti (2017) definition), divided by real GDP in PPP terms.	External Wealth of Nations database (Lane and Milesi-Ferretti, 2018), IMF IFS, OECD National Account
Trade Balance to GDP	Difference between exports and imports of good and services from the balance of payments.	IMF IFS

Table 7: Monthly Data - 1999M1-2018M12

Variable	**Details**	**Source**[31]
Exchange Rates	Bilateral Nominal Exchange Rate against USD.	Datastream
1-Year Forward Rates	1-Year Forward Rates against USD.	Datastream
1-Month Forward Rates	1-Month Forward Rates against USD.	Datastream
1-Year Government Bond Yield	1-Year Government Bond Yield, with German government yield for the Euro Area.	Global Financial Data, Datastream
1-Month Government Bond Yield	1-Month Government Bond Yield, with German government yield for the Euro Area.	Global Financial Data, Datastream
1-Month LIBOR	1-Month LIBOR.	Datastream
Consumer Price Index	Consumer price index, interpolated data (linear) when quarterly data only (Australia and New-Zealand).	IMF IFS
12-Month LIBOR	12-Month LIBOR and 12-Month deposit rate when former not available	FRED, Datastream

[31] See Engel (2019) for the exact ticker in Datastream.

A.2 Quarterly Variables

Figure 8: Real Effective Exchange Rate, Index 2010

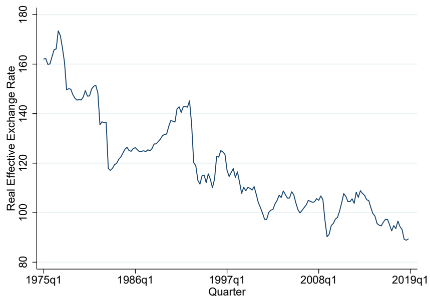


Figure 9: Net Foreign Assets to GDP

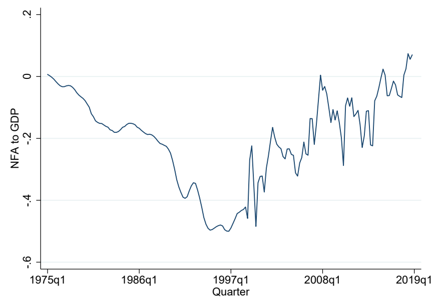


Figure 10: Trade Balance to GDP

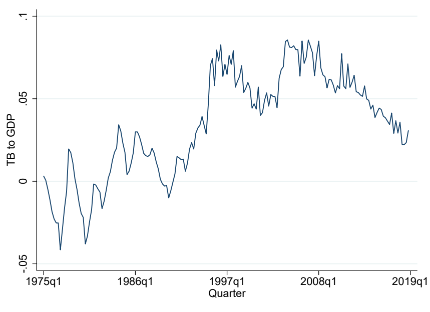


Figure 11: Terms of Trade, Index 2015

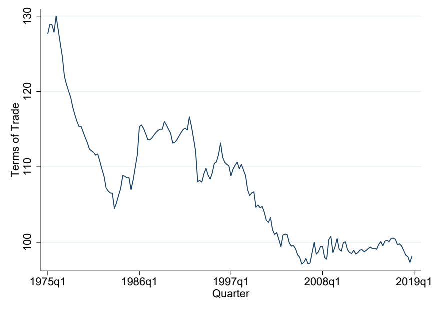
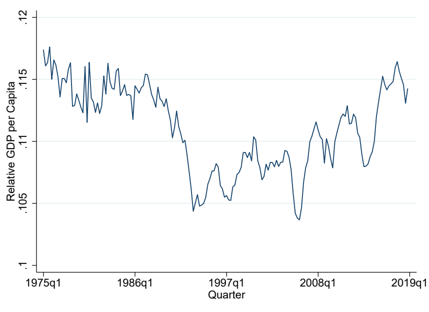


Figure 12: Relative GDP per Capita[32]



[32]Swedish GDP per capita relative to a weighted average of the 10 countries in the quarterly sample: Australia, Canada, Finland, Ireland, Japan, Korea, Netherlands, Sweden, United Kingdom and United States. The weights correspond to the share of each country in the total of the GDP in PPP terms in 2000Q4, 1975Q1-2018Q4.

A.3 Annual Variables

Figure 13: Real Effective Exchange Rate

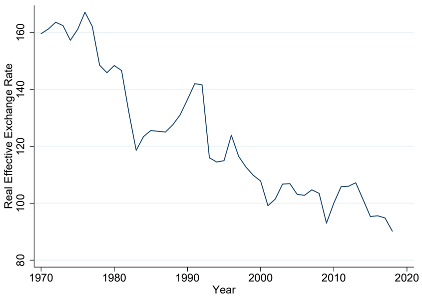


Figure 14: Relative GDP per Capita[33]

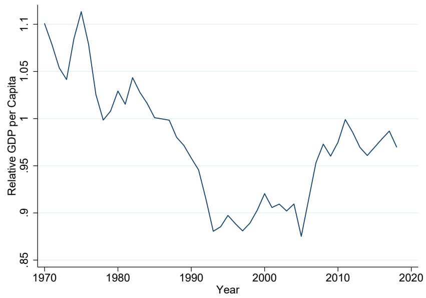


Figure 15: Trade Balance to GDP

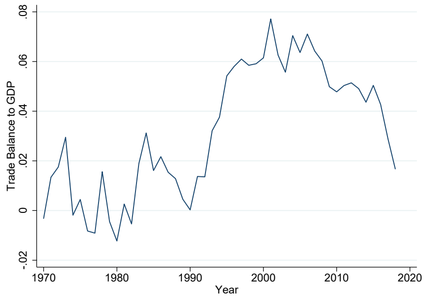


Figure 16: Terms of Trade, Index 2015

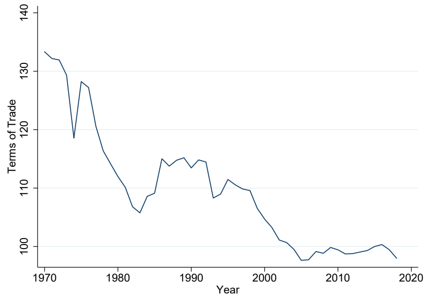


Figure 17: Relative Log Productivity Differential[34]

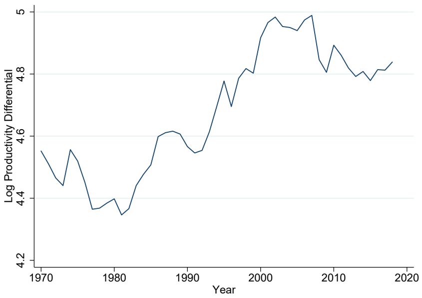
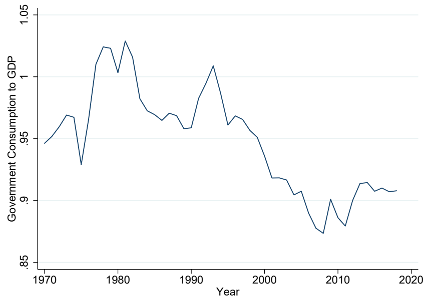


Figure 18: Relative Government Consumption[35]



[33] Swedish GDP per capita relative to a weighted average of the 10 countries in the annual sample: Australia, Canada, Finland, Ireland, Japan, Korea, Netherlands, Sweden, United Kingdom and United States. The weights correspond to the share of each country in the total of the GDP in PPP terms in 2000, 1970-2018.

[34] See footnote [33] for the explanation of the relative Swedish log productivity differential computation.

[35] See footnote [33] for the explanation of the relative Swedish government consumption computation.

B Estimation Following Ca'Zorzi (2020)

In Subsection 2 .2, we estimate the log real effective exchange rate using the set of regressors proposed by Ca'Zorzi et al (2020). Table 8 reproduces their estimation, taking the same regression and set of countries: Australia, Canada, Euro Area, Japan, New-Zealand, Norway, Sweden, Switzerland, United Kingdom and United States. GDP per capita is computed relative to foreign values only and real exchange rate and terms of trade are not in logs. We finally add an estimation with the trade balance as proposed by Lane (2007).

Table 8: Dependent Variable: real effective exchange rate

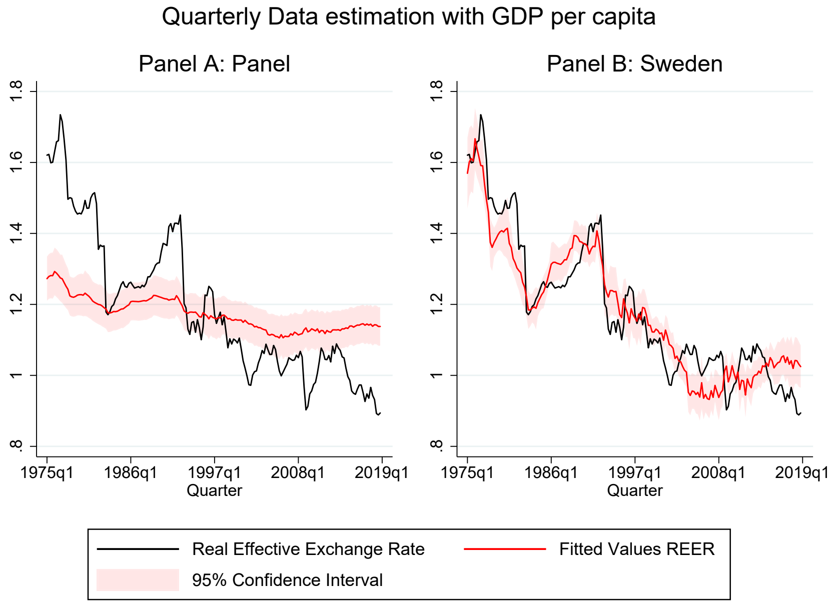
	Panel		Sweden	
	(1)	(2)	(3)	(4)
Relative GDP per Capita	-0.174	-0.119	-1.796	-1.465
	(1.405)	(1.330)	(10.26)	(6.287)
Terms of Trade	0.411***	0.431***	2.307***	1.737***
	(0.0998)	(0.0992)	(0.313)	(0.275)
NFA to GDP	-0.0315		0.221	
	(0.0391)		(0.224)	
TB to GDP		-0.541		-1.857**
		(0.355)		(0.906)
Observations	1757	1757	173	173
R^2	0.575	0.580	0.847	0.865

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

In this setting, relative GDP per capita and is insignificant, while trade balance is significant. Only terms of trade remain consistent with Table 1 in Subsection 2 .2. In Figure 19, we show the fitted values of our estimation above for column (2) and (4).

Figure 19: Equilibrium vs Actual Real Exchange Rate: Quarterly



Panel A displays the fitted values of the equilibrium real exchange rate using a panel of countries, while Panel B shows the predicted exchange rate when we estimate for Sweden only. We use the coefficients estimated in columns (2) and (4) of Table 8.

C Equilibrium Exchange Rate with Panel Data Estimates

Figure 20: Equilibrium Real Exchange Rate: Quarterly

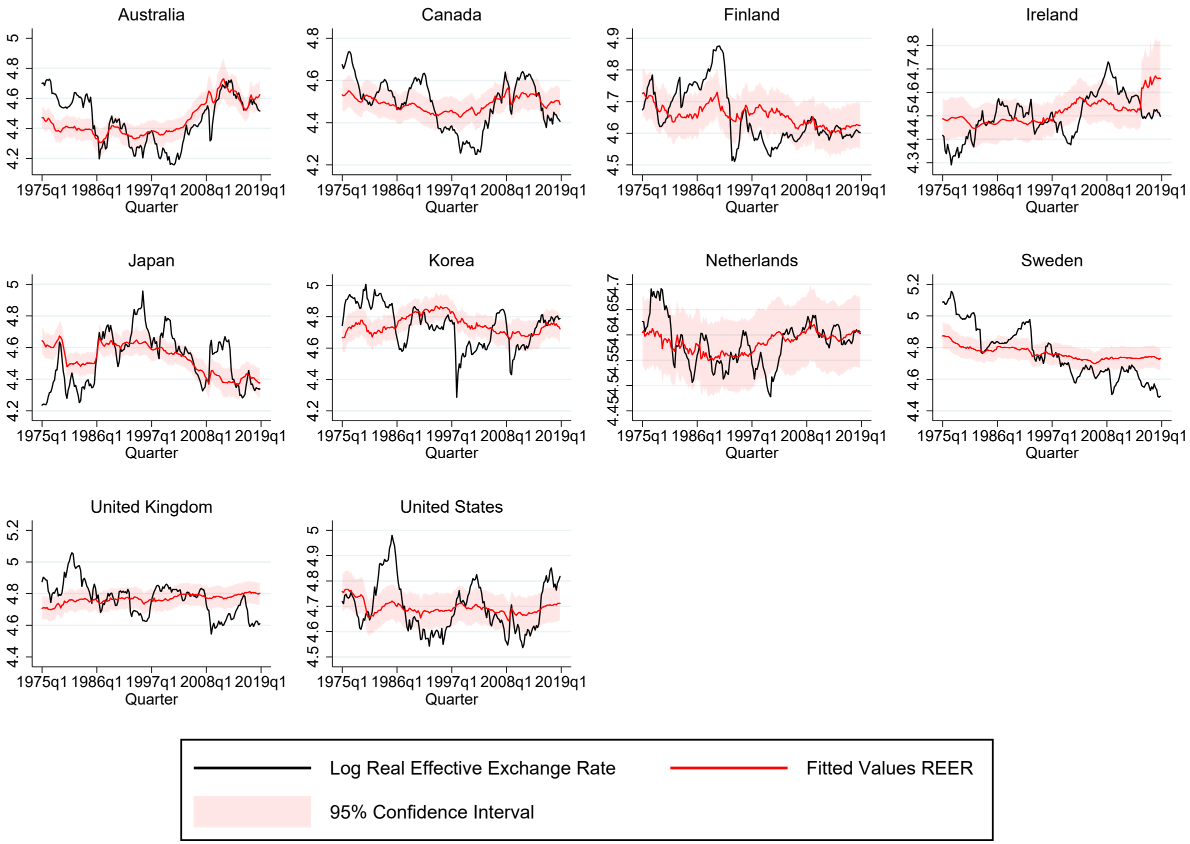


Figure 20 displays the fitted values of the equilibrium real exchange rate using this panel of countries. We use the coefficients estimated in column (1) of Table 1.

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