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Abstract

This paper presents a simple reduced-form error correction model for forecasting nominal exchange rates. The model is inspired by the classical monetary model of exchange rates. However, the commonly used monetary aggregates were replaced by loans to corporations. The reason for this change is that our goal is to focus on corporate deposits, for which corporate loans act as a proxy. For presentational purposes, we focus on eight major trading currency pairs: AUD/USD, CAD/USD, CHF/USD, EUR/USD, GBP/USD, NZD/USD, SEK/USD and JPY/USD, for which we use data from approximately the last two decades. We empirically show statistically and economically significant exchange rates forecastability in the medium and long run, and we also present some findings on predictability even in the short run. In short, our results suggest that corporate loans are a significant driver behind exchange rate movements.

Abstrakt

Článek představuje jednoduchý redukovaný model korekce chyb pro prognózování nominálních měnových kurzů. Inspirací pro tento přístup je klasický monetární model měnových kurzů, kde běžně používané peněžní agregáty byly nahrazeny úvěry podnikům. Důvodem této změny je, že se zaměřujeme na podnikové vklady, jež lze aproximovat pomocí podnikových úvěrů. Pro účely prezentace se soustředíme na osm významných měnových párů: AUD/USD, CAD/USD, CHF/USD, EUR/USD, GBP/USD, NZD/USD, SEK/USD a JPY/USD, pro které používáme data za přibližně poslední dvě desetiletí. Empiricky dokládáme statisticky a ekonomicky významnou predikovatelnost měnových kurzů ve střednědobém a dlouhodobém horizontu. Stejně tak ukazujeme nové poznatky ohledně krátkodobé predikovatelnosti. Naše výsledky tedy naznačují, že podnikové úvěry jsou významným hybatelem vývoje měnových kurzů.

JEL Codes: C5, F31, F32, F37.
Keywords: Exchange rates, forecasting, forecast evaluation.

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1. Introduction

Exchange rates are notoriously hard to forecast, and it seems to be extremely challenging to consistently outperform the random walk benchmark in forecasting. This is a well-known fact that has not changed much since Messe and Rogoff's seminal paper (Meese and Rogoff, 1983a,b). This paper attempts to show that this does not always have to be the case. On the contrary, we present some findings here that indicate significant predictability in the medium and long run and even some predictability at the short-term horizon.

We succeeded in using an error correction model inspired by the classical monetary model of the exchange rates, where the monetary aggregates (M1, M2, M3, etc.) were swapped for the loans to (non-financial) corporations. This modification, as is argued later, does not significantly change the logic of the monetary model but enhances it with emphasis on real-world financial transactions between banks (correspondent account transactions). This is due to the fact that our goal is to focus on corporate deposits, for which corporate loans act as a proxy. Or more generally, corporate loans are one of the key determinants of the creation of a new deposit linked to the real economy. The approach presented in this paper loosely follows the spirit of Cesa-Bianchi et al. (2019) and Kumhof et al. (2020), where the authors present a DSGE model where the exchange of bank deposits explains currency movements.

The topic presented here is of great importance to central bank and private business practitioners. Specifically, the variables forecasted by the practitioners often include exchange rates, which also influence current account projections as well as other variables. Exchange rate forecasts are also often used as input variables, affecting the overall accuracy of other forecasts. Exchange rate projections are essential for the central banks of countries with small open economies, as these countries are often heavy importers/exporters (Rossi, 2013). Predictability plays a vital role in the monetary policy horizon, especially in the medium run. For this reason, our conclusion that there is significant predictability of exchange rates even at the one-year horizon is an important finding.

This paper's main contribution to the existing literature is an out-of-sample forecasting exercise, where we show forecasts of the nominal exchange rates using an error correction model without short-term adjustments. We observe a significant forecast improvement over almost all previous studies. Specifically, we illustrate that there is significant medium and long-term predictability in line with Ca'Zorzi and Rubaszek (2020), which is, to our knowledge, the most recent example illustrating long-term predictability. Furthermore, the paper's contribution to the existing literature in the theoretical part consists of a careful specification of variables that can act as a proxy for money and the logic behind this reasoning.

The rest of this paper is structured as follows: Section 2 presents the existing literature on forecasting exchange rates and credit creation. We then present the standard monetary model of exchange rates from a theoretical perspective. We also show the implications of credit creation and deposit transfers for defining an empirical proxy for money. Finally, in sections 3, 4, and 5, we perform an empirical analysis of the monetary model. In these parts, we perform out-of-sample forecasts for the AUD/USD, CAD/USD, EUR/USD, CHF/USD, GBP/USD, NZD/USD, SEK/USD and JPY/USD nominal exchange rates and compare them to the random walk without drift benchmark.

2. Literature Review

The literature dealing with exchange rate prediction is relatively dense. For this reason, the article does not present a complete summary but focuses only on a small portion of the main contributions, specifically the monetary exchange rate model. For a complete review of the literature regarding the forecast of exchange rates, see Rossi (2013).

The monetary models of the exchange rate are mostly based on papers by Dornbusch (1976); Frankel (1979); Mussa (1977, 1982) and, as already discussed, they do not fare particularly well in the prediction race. This was established in early papers by Meese and Rogoff (1983a,b). However, certain authors show that it is possible to improve their predictive abilities somewhat, for example, by using the panel regression approach (Mark and Sul, 2001; Groen, 2005; Engel et al., 2007, 2015), or machine learning and the Bayesian approach (Carriero et al., 2009; Beckmann and Schüssler, 2016; Amat et al., 2018). It has also been established that forecasting performance depends on the chosen time horizon, with the literature suggesting that there may be some predictability with a longer time horizon (Macdonald and Taylor, 1993; Mark, 1995; Chinn and Meese, 1995; Macdonald, 1995; MacDonald, 1998; Chinn and Quayyum, 2012; Huber, 2016; Ca'Zorzi and Rubaszek, 2020; Ren et al., 2021). However, these results of predictability are not that robust due to highly persistent independent variables or even the sample period selected (Kilian, 1999; Berkowitz and Giorgianni, 2001; Cheung et al., 2005).

Models inspired by the Taylor rule are similar to classical monetary models. Central banks set the nominal rate based on their inflation and output (unemployment) gaps. Therefore, this policy rule can be inserted into the uncovered interest rate parity equation, which gives an expression for the exchange rate. The main difference between this approach and the monetary approach is that an endogenous monetary policy rate replaces money demand. Examples of papers examining this topic are Engel and West (2006); Molodtsova et al. (2008); Molodtsova and Papell (2009, 2013); Byrne et al. (2016).

The situation is all the more difficult because both classical monetary models and models with rational expectations based on the Taylor rule imply a forward-looking solution. If the fundamentals (independent variables) are highly persistent or directly follow a random walk, then the exchange rate itself will behave similarly (Engel and West, 2005; Evans and Lyons, 2005; Engel et al., 2007, 2010). That said, this does not change the fact that these factors may determine the exchange rate. Engel (2014, 2016) further show the significance of the risk premium, which can be a significant determinant and is an omitted variable in forecasting literature. More recent studies such as Cheung et al. (2019); Engel et al. (2019) further diminished the results of possible exchange rate predictability, at least at the short-term horizon and in terms of economic significance.

The monetary model of the exchange rate is consequently about money. For this reason, this article is also inspired by the fast-growing literature that examines the effect of credit, the main counterpart of money, on the economy but also examines credit itself, specifically its creation. (Jílek and Matousek, 2010; Biggs and Mayer, 2013; McLeay et al., 2014; Werner, 2014; Bundesbank, 2017; Gross and Siebenbrunner, 2019). Kumhof and Benes (2012); Jakab and Kumhof (2018); Kumhof and Wang (2021) then integrate credit into the new Keynesian DSGE models.

Many other articles incorporate this concept of credit into international economics and finance literature. Borio and Disyatat (2015) presents a two-country model, where authors illustrate that the net payment flows do not have to equal the financial (gross) flows and emphasize the distinction between them. A somewhat similar approach was chosen by Bruno and Shin (2015), which is based on the portfolio theory. Cesa-Bianchi et al. (2019) and Kumhof et al. (2020) followed these articles, extending the logic of the new Keynesian DSGE model with the banking sector to a two-country model. The authors show that the exchange rate is determined by the credit activity of the banking sector, which is limited by capital requirements and the incentives to maintain a closed foreign exchange rate position. Itskhoki and Mukhin (2021), which builds upon the heterogeneity of different agent types, presents a different exposition of the monetary model in the DSGE framework.

3. Model Formulation

This section presents a well-known partial equilibrium framework for explaining exchange rate movements, which is a standard asset pricing approach for exchange rate dynamics. Specifically, we present the monetary model with rational expectations. The exposition closely follows Kilian (1999), Evans and Lyons (2005), and Engel et al. (2007).

Most monetary models can be expressed in terms of the money demand equation and the relationship between the interest rate and the nominal exchange rate. he first building block is a log-linearized demand for money equation, which can be expressed as follows:

$$m_t - p_t = \alpha + \gamma y_t - \lambda i_t + v_t \tag{1}$$

where m_t is the money supply, p_t is the price level, y_t represents the output, i_t is the nominal interest rate and v_t expresses the stochastic term, i.e. shocks to money demand. γ is the income elasticity of money demand and λ represents interest rate semi-elasticity. All variables , with the exception of the interest rate, are expressed in log form and represent the home country values. Note that the equation implicitly assumes that money demand equals its supply and we did not specify whether the money supply is exogenous or endogenous.[1]

We also assume that money demand abroad can be expressed in the same way as money demand in the home country, with the foreign variables denoted by an asterisk. Assuming both functions also have the same parameters, we obtain the following expression by subtracting the money demand equations in both countries from each other:

$$m_t - m_t^* - p_t + p_t^* = \gamma(y_t - y_t^*) - \lambda(i_t - i_t^*) + v_t - v_t^* \tag{2}$$

We also need the relation between nominal interest rates and the nominal exchange rate. This relation is not precisely the uncovered interest rate parity due to the existence of an additional term denoted by ρ_t, which represents either an ex-post deviation from the uncovered interest rate parity or an ex-ante FX risk premium, depending on the interpretation. In the latter case, the FX risk premium may express a convexity adjustment of the lognormal pricing kernel, specifically, the difference between home and foreign country convexity adjustment (Backus et al., 2001; Engel, 2016). Another option is to model the risk premium as a function of foreign-owned assets as in Schmitt-Grohé and Uribe (2003), and Itskhoki and Mukhin (2021). The relation between the nominal interest rates and the exchange rate can be expressed as follows:

$$i_t - i_t^* = E_t e_{t+1} - e_t + \rho_t \tag{3}$$

[1] Money supply can, for example, be modeled in a similar way as in Kumhof and Wang (2021).

By combining the expressions above, we obtain the following equation:

$$e_t = \frac{1}{1+\lambda}[m_t - m_t^* - q_t - \gamma(y_t - y_t^*) - v_t + v_t^*] + \frac{\lambda}{1+\lambda}\rho_t + \frac{\lambda}{1+\lambda}E_t e_{t+1} \tag{4}$$

where we use the fact that the real exchange range, q_t, can be expressed as the nominal exchange rate adjusted for different price levels, i.e. $q_t = e_t - p_t + p_t^*$. The above equation expresses the fact that the nominal exchange rate is a function of the expected future exchange rate, the discounted[2] expected future values of the fundamental factors (hereinafter the terms in the square brackets are denoted by f_t) and the risk premium. Note that if we assumed purchasing power parity to hold, the term q_t would be eliminated from the equation. By assuming uncovered interest parity to hold, ρ_t would also be eliminated. Also, as illustrated in Itskhoki and Mukhin (2021), in a general equilibrium setting, the fundamentals are reduced to only the difference in the money stocks, i.e. $f_t = m_t - m_t^*$.[3] Iterating the above expression forward, we get the following:

$$e_t = \frac{1}{1+\lambda}E_t \sum_{i=0}^{\infty}\left(\frac{\lambda}{1+\lambda}\right)^i f_{t+i} + \frac{\lambda}{1+\lambda}E_t \sum_{i=0}^{\infty}\left(\frac{\lambda}{1+\lambda}\right)^i \rho_{t+i} \tag{5}$$

This is, of course, done by abstracting from the rational bubble term which would be: $b_{t+1} = ((1+\lambda)/\lambda)b_t$. If we substract the fundamentals from both sides of the expression - assuming without loss of generality that the expected risk premium is, for example, an AR(1) process[4] - and rearranging the expression above, we get the following equation, which implies the existence of a cointegration relation:

$$e_t - f_t = E_t \sum_{i=1}^{\infty}\left(\frac{\lambda}{1+\lambda}\right)^i \Delta f_{t+i} + \frac{\lambda}{1+\lambda-\gamma\lambda}\rho_t \tag{6}$$

where f_t, therefore, represents the long-run "equilibrium" value of the nominal exchange rate if we assume that Δf_t is a stationary and serially correlated process, see Campbell and Shiller (1988); Engel et al. (2010). Engel and West (2005), Evans and Lyons (2005), and Engel et al. (2010) further show that as the discount factors $(\lambda/(1+\lambda))$ approach unity and the fundamentals are highly persistent, the nominal exchange rate behavior will closely follow random walk behavior. Nevertheless, if the model is correctly specified, the error correction term is an indirect observation of the risk premium ρ_t.

In line with the general equilibrium results of Itskhoki and Mukhin (2021), we focus primarily on money, which represents the fundamental factors in this setting. However, the main problem is defining the fundamental factors for the forecasting exercise. Defining money in empirical terms is notoriously hard, and we have decided to replace commonly used monetary aggregates with loans to non-financial corporations. Corporate loans are one of the key determinants of real economy dynamics, see Biggs and Mayer (2013), and the creation of new deposits is linked to the real economy. Alternatively, we can also argue that this use of corporate loans is motivated by the fact that our goal is to focus on corporate deposits, for which corporate loans act as a proxy.

[2] The discount factor is expressed through the semi-elasticity of money demand.

[3] On the other hand, we do not impose the same functional form on the risk premium.

[4] Engel and West (2005) and Engel et al. (2007, 2010) show that outperforming the the random walk requires a stationary risk premium.

From an accounting perspective, these loans are asset counterparts to (part of) monetary aggregates. For example, M1 is usually defined as the sum of currency in circulation and overnight deposits. Broad money (M2, M3) mainly consists of the very liquid liabilities of the domestic banking sector: currency in circulation, overnight deposits, deposits with short-term maturities, deposits redeemable at notice, repurchase agreements, and money market fund units. If we used total loans or broad monetary aggregates such as M2 or M3, which do not differ much from total loans in our estimation, then we would also include, for example, mortgages. Mortgages have an average maturity of over 20 years in developed countries and make up about half of total credit. Their inclusion would make the whole time series of credit extremely persistent, as we effectively have autocorrelation over a twenty-year period by default. Given the length of this period, it can be reasonably assumed that these effects are already included in the price level. On the other hand, corporate loans usually have a maturity of up to five years. Therefore, by using this data, we are able to filter out other influences commonly included in monetary aggregates that primarily affect domestic variables and the price level.

Furthermore, the reason we have chosen to use corporate loans is that most retail consumers do not transfer significant sums between multiple countries. Therefore, corporate deposits should be one of the main drivers behind the exchange rate movement as deposit transfers (currency conversions) indirectly affect the order books regarding exchange rates, which are the primary determinant of exchange rate adjustment.[5] However, due to the unavailability of deposit data, we use corporate loans as a proxy variable for deposits. Therefore, loans to corporations can intuitively be considered as a certain kind of liquidity constraint as they have a better chance of entering the FX market upon their creation. This leads to them being more closely connected with exchange rate movements in the tradition of order flow models. For more details, see Appendix A.

4. Data

The data used for the empirical exercise are the loans to non-financial corporations of the given countries denominated in national currencies and the AUD/USD, CAD/USD, CHF/USD, EUR/USD, GBP/USD, JPY/USD, NZD/USD and SEK/USD nominal exchange rates. In short, the primary specification only uses data for nominal exchange rates and loans to non-financial corporations, which is in line with the theoretical general equilibrium model presented in Itskhoki and Mukhin (2021). In a robustness check, we also use the price level and the unemployment rates of the given countries. The choice of the variables was primarily motivated by the theoretical monetary model (Engel et al., 2007) described above and also by other studies that found some predictive power in the variables used (Molodtsova and Papell (2013), Ince (2014), and Cheung et al. (2019)). The unemployment rate acts as a proxy for output due to the monthly periodicity of the forecasting exercise, although we are aware that the time-series properties of these two series are very different. The price levels implicitly account for the real exchange rate term in the fundamentals.

All data were obtained either from Datastream or the national/international statistics databases (Bank of Canada-BoC, Bank of Japan-BoJ, ECB Statistical Data Warehouse, Eurostat, FRED, Reserve Bank of Australia-RBA, Reserve Bank of New Zealand-RBNZ, Statistics Sweden-SCB and the Swiss National Bank-SNB). Data, where available, were collected on a monthly basis, and we used the seasonally unadjusted end-of-period values in all cases. Regarding the credit data, it is important to emphasize that stock values (outstanding amounts at the end of the period) were

[5] The money of retail customers can, of course, be transferred to the deposit accounts of corporations, and then abroad. This is, however, a lengthy process that does not occur immediately after the money is created.

used.[6] Since we were unable to obtain non-revisited credit data, we use the revised data set available in December 2021. This, however, should not be a significant problem, with data on credit not undergoing significant revisions. More precisely, in some cases, we were unable to obtain non-revisited data at all (Japan, New Zealand and Switzerland). In other cases, we were able to obtain non-revisited data; however, in most cases, the non-revisited data did not begin before 2010.[7] On the other hand, we admit that the data on unemployment may have been somewhat affected, but we decided not to use older vignettes for consistency reasons. Further information on all series used can also be found in Table B1, which shows individual data sources. Table B2 then shows the basic summary statistics regarding the final data that enter the estimation.

A few more remarks regarding the data used: In the case of Australia, only the quarterly price index is available. We use piecewise constant interpolation to transform the series to monthly values. This is because we want to avoid using unpublished data in the forecasting exercise. In the case of Japan, we did not find a time series for non-financial corporations, and therefore we used a time series for all corporations as a proxy. The Swiss statistics on credit data are the sum of loans to corporations of different sizes as the Swiss National Bank does not provide the total value. The monthly unemployment rate for New Zealand was constructed using registered unemployment, which is published on a monthly basis, and the labor force population was calculated from the unemployment rate, which is published quarterly.

Our calculations were performed using monthly data: January 1997-October 2021 in the case of AUD/USD and CAD/USD, January 2002-October 2021 in the case of CHF/USD, January 2003-October 2021 in case of EUR/USD, September 1997-October 2021 in the case of GBP/USD, October 2000-October 2021 in the case of JPY/USD, June 1998-October 2021 in the case of NZD/USD, and December 2001-October 2021 in the case of SEK/USD. It is noteworthy that the time series are significantly different in length. For reasons of comparability, January 1997 was chosen as the first date, despite the availability of earlier observations. This is the case for CAD/USD and AUD/USD for which longer time series on credit data are available.

The main disadvantage of the approach presented in this paper is the relatively short data span. As a result, the analysis is performed only for a period of slightly over 20 years, or even 15 years in some cases. Furthermore, due to the use of national data statistics, the data are not easily comparable because of the different national taxonomy used, which may consequently somewhat weaken the forecasting power, for example, the unavailability of the loans to non-financial corporations time series for Japan mentioned above.

5. Estimation Methodology

In this part, we describe the methodology for estimating the monetary model. We also show the methodology for accessing the result of the forecasting exercise, which is inspired by Meese and Rogoff (1983a) and is standard in exchange rate forecasting literature.

We estimate the monetary model using an error correction methodology (ECM) as the cointegration relation is implied by equation 6. As Mark (1995) points out, we basically project the h step change in the nominal exchange rate on the current deviation from the fundamental value. We primarily use a direct (multi-step) forecast and recursive (expanding) window approach, i.e. for

[6] However, we believe that data regarding new loans (flow data) could provide better results at the short-term horizon (see Appendix A), but these data, to our knowledge, are not available for all countries.
[7] However, we used these older vignettes for a sensitivity analysis, and the results did not differ significantly.

every period, we add the actual realization of the exchange rate and other explanatory variables (loans to corporations, price levels, unemployment rates) as additional data points at the end of the sample, and re-estimate the model.[8] An h period-ahead forecast is generated at each step (time period) and for every forecasting horizon from a different model. As a robustness check, we also employ a rolling window estimation, i.e. for every period, we add the actual realizations of a given time series as an additional data point at the end of the sample, but we also remove the first observations from our sample. This ensures that the model's training period remains fixed.

In the out-of-sample forecasting exercise, we use the sample of the first 72 periods as a training period for the estimation of coefficients. In other words, a period of 6 years, which is similar to the length which was used, for example, in the seminal paper by Carriero et al. (2009). The forecast horizon is from one to thirty-six months. The first prediction is January 2003 in the case of AUD/USD and CAD/USD and the out-of-sample forecast starts in January 2009 in the case of EUR/USD, September 2003 in the case of GBP/USD, January 2008 in the case of CHF/USD, January 2004 in the case of NZD/USD, December 2007 in the case of SEK/USD, and October 2006 in the case of JPY/USD. The last prediction is October 2021 for each series. Also, note that the last period used for estimating the forecast depends on the chosen time horizon, i.e. the last period used for the estimation is different for each h. This is because we need the actual realization of the given series to evaluate the forecast accuracy.

The implied joint time-series process for a monetary model may be represented as a vector error correction model (VECM). Like many other studies, for example (Mark, 1995; Cheung et al., 2005, 2019), we use a single equation ECM stripped of short-term adjustment terms. This allows us to forecast the exchange rate using the past values of other variables only and thus avoid a multi-variable framework. The ECM framework seems to be appropriate given the nonstationarity of the time series used (Table B2). Formally, the existence of cointegration was tested using the Johansen trace test. We also look at the stationarity of residuals and the stability of the cointegration vector (regression coefficients), as illustrated in detail below in the Empirical Results section. The resulting reduced form error correction model can be written in standard notation as follows:

$$\Delta_{t+h}e_t = c + \delta(e_t - \gamma f_t + d) + \varepsilon_{t+h} \tag{7}$$

where Δ_{t+h} denotes the h step forward difference operator (with a slight abuse of notation), and h is the number of leads, i.e. $\Delta_{t+h}e_t = e_{t+h} - e_t$.[9] Furthermore, e_t denotes the nominal exchange rate, c is the constant term, d is the possible constant term inside the error correction term, γ, δ are regression parameters, and ε_{t+h} denotes the stochastic term following normal distribution. X_t denotes the vector of possible explanatory variables used in the models, i.e. f_t is created from the following variables: $(credit_{US}, credit_{other}, p_{US} - p_{other}, un_{US}, un_{other})$, where $credit_{US}$ is loans to non-financial corporations in the US, $credit_{other}$ is loans to (non-financial) corporations of the other country in the chosen currency pair. $p_{US} - p_{other}$ denotes the price level ratio between the two countries[10], un_{US} and un_{other} are the unemployment rates given the chosen currency pair. More precisely, the following specifications are used in the empirical exercise: $f_t = (credit_{US}, credit_{other})$, $f_t = (credit_{US}, credit_{other}, p_{US} - p_{other})$, $f_t = (credit_{US}, credit_{other}, un_{US}, un_{other})$, $f_t = (credit_{US}, credit_{other}, p_{US} - p_{other}, un_{US}, un_{other})$. We prefer to use fewer explanatory variables, as this mitigates the problem of potentially obtaining a large number of cointegration relationships.

[8] Unlike, for example, Macdonald and Taylor (1993), where the cointegration relationship is estimated over the entire sample. The advantage is that as much information as possible is used to obtain the implied cointegration estimates. However, the main disadvantage is that these results are not true ex-ante forecasts.

[9] Due to the fact that a separate model is estimated for each forecast horizon, the lead length h depends on the horizon of the forecast chosen.

[10] The difference relation is imposed because of purchasing power parity.

In summary, the models are estimated using a time series of exchange rates and loans to non-financial corporations. In terms of the credit data, each time series enters the model separately as we do not impose an a priori cointegration vector of $(1,-1)$. There is no reason to a priori assume that the credit time series (money demands) are homogeneous functions of degree one, given the fact that credit payments are usually ordinary annuities, i.e. the credit stock is a highly nonlinear function (see Appendix A). Likewise, there is no reason to assume that the parameters of these functions are the same in both countries, i.e. fundamental variables can have different weights in the cointegration relation. Furthermore, the cointegration vector (1,-1) means that the exchange rate must move to compensate for the long-run growth differential between the two countries. Although this is, at first glance, quite a reasonable assumption, there may be some underlying (medium-term) process in the economy in which the exchange rate depreciates or appreciates systematically, e.g. financial deregulation. Additionally, we also include the price levels and the unemployment rates in a robustness check. All variables enter the model in log form, and in the case of price levels, we use the difference between two time series $(p_{US} - p_{other})$, which enter the model as one variable.[11]

The expression above can be rewritten in the following way:

$$\Delta_{t+h} e_t = A + Be_t + Cf_t + \varepsilon_{t+h} \tag{8}$$

A is the new constant term, and B, C are new re-indexed parameters. The other notations are the same as in the previous case. The relationship between the parameters is as follows: $C = -\gamma\delta, B = \delta, A = c + \delta d$. Note that this is the most parsimonious expression, where we do not impose the cointegration relation a priori, but it is implicitly accounted for in the estimation. Also, note that if we use the lagged exchange rate as the explanatory variable only, this is one of the specifications used in Ca'Zorzi and Rubaszek (2020). Contrary to our example, however, the authors justify this specification by a mean reversion in the (real) exchange rates. We admit that the results do not differ significantly in the long run. However, our specifications have markedly better results in the shorter term. This can theoretically be explained by the fact that the above specification changes the term structure of exchange rate changes.

Two different estimation approaches are used: the first is the one-step simple ECM regression as described in equation 6. The second is the two-step estimation method, where the cointegration relation is estimated by the Johansen procedure with automatic lag selection based on BIC in the first step, and the forecast is then estimated by exchange rate regression on the cointegration vector in the second step.

Predictive accuracy was tested in several ways. First of all, we compare the root-mean-square-forecast-error (RMSFE) of the VAR model to the root-mean-square-forecast-error (RMSFE) of the random walk benchmark. For clarity, the random walk without drift produces the following h step ahead forecast: $\hat{y}_{t+h} = y_t$. The h step ahead RMSFE is defined as:

$$RMSFE_h = \sqrt{\frac{1}{T}\sum_{i=1}^{T}(\hat{y}_{i,t+h} - y_{i,t+h})^2} \tag{9}$$

where $\hat{y}_{i,t+h}$ denotes the h step ahead forecast, $y_{i,t+h}$ denotes the actual realization, and T is the total number of computed forecasts. The ratio of the RMSFE of the prediction model and the RMSFE of

[11] This specification is inspired by purchasing power parity but has no material impact on the results.

the random walk is often called Theil's U-statistic. We used it here to facilitate comparison. If the RMSFE ratio is below one, the model outperforms the random walk benchmark.

For comparison, we also use the mean absolute forecast error (MAFE), which can be defined in the following way:

$$MAFE_h = \frac{1}{T}\sum_{i=1}^{T} |\hat{y}_{i,t+h} - y_{i,t+h}| \tag{10}$$

The inclusion of this metric is motivated by the fact it assigns a smaller weight to large forecast errors than the RMSFE. The ratio of the MAFE of the prediction model and the MAFE of the random walk has the same interpretation as in the previous case.

The test statistics (DMW) by Diebold and Mariano (2002) were also employed for a more formal approach, which tests the null hypothesis that the root-mean-square-forecast-error (RMSFE) of the prediction model and the random walk model are equal. The alternative hypothesis is that the prediction model outperforms the random walk benchmark. Furthermore, we also employed test statistics (CW) by Clark and West (2007) using the HAC estimator for the calculation of a variance. Clark and West (2007) prove that the asymptotic distributions of the sample difference between the two RMSFE ratios are not identical, but are biased downward from zero. The CW "correction" takes this into account. Simply put, whenever we are comparing two models and one model is nested in another, the nested model has fewer parameters to estimate; therefore, there is less estimation error. This is mostly for illustration purposes, as we are aware that our recursive approach does not fulfill the assumptions. In the empirical part, we report the corresponding p-value of the DMW and CW test statistics of the one-sided test with the alternative hypothesis that a given model performs better than the random walk.

The results are further supplemented by a standard in sample R-squared ratio for assessing the economic significance of forecast results, which was calculated for each horizon h using forecast values and realized changes in the exchange rate. In practice, this is a squared correlation coefficient of prediction and actual realization. For discussion about the R-squared ratio, see, for example, Campbell and Thompson (2008).[12]

6. Empirical Results

In this section, we present the results of the forecasting exercise. We estimate the monetary model in the base specification using only loans to (non-financial) corporations and the nominal exchange rate. As a robustness check, we also include the price levels and the unemployment rates. The models were primarily estimated using a one-step error correction model without short-run dynamics.

Figure 1 shows the sequential out-of-sample forecast of all eight nominal exchange rates, and, as already mentioned, the error correction models were estimated in differences by the one-step method. However, for this chart, the differences were subsequently transformed back to levels using the last-known exchange rate in the forecast for a given horizon h. It is generally difficult to assess the quality of the short-term forecast using the chart; for this reason, we consider Figure 1 more as a supplement to cointegration analysis. Nevertheless, we can observe a very precise

[12] Although the measure used in our article is slightly different.

estimate of future nominal exchange rates, which clearly and consistently beat the random walk in the long run.

The results of the out-of-sample forecast are further described in detail in Table 1. The table is divided into sections for each nominal exchange rate, where each section shows the results for the given currency. Every section of the table is structured in the same way. The first row shows the ratio of the RMSFE of the estimated model and the random walk at different time horizons. The next row shows the same ratio for the MAFE. The third row shows the R-squared at a given horizon explained by the model. The next two rows display the Diebold Mariano and Clark-West statistics, or more precisely, their p-values. The last row specifies the number of forecast periods.

The main findings are thus as follows: The error correction model estimated by a recursive window approach outperforms the random walk benchmark based on the RMSFE and MAFE ratio in most of the periods and for most of the exchange rate pairs, except in the first six-month period. When examined in greater detail, we observe that no model can beat the random walk at the one-month horizon. At the three-month horizon, the error correction model provides a better forecast for three of the eight currencies (AUD/USD, EUR/USD, GBP/USD) according to the RMSFE ratio. That said, the predictability at the three- and six-month horizons is diminished by the existence of a publication lag[13], which seems to be more pronounced than for other time series commonly used for forecasting. The results of the short-term forecasts are in line with the existing literature, where our results support the claim that it is very difficult to find forecasts from a model that can consistently beat the random walk benchmark using standard RMSFE and MAFE criteria. On the other hand, the RMSFE and MAFE ratios are surprisingly stable in the short term and do not differ much from the random walk benchmark. According to the RMSFE and MAFE ratios and CW statistics, all models, with the exception of the JPY/USD currency pair, beat the random walk benchmark over a six-month period. However, according to DMW statistics, except for AUD/USD and SEK/USD, it is still not possible to distinguish between the forecasts at the five percent significance level even in a 12-month period. Generally, there is significant medium-term predictability, and only the JPY/USD currency pair results are somewhat disappointing.[14]

Furthermore, we find strong predictability in the long-term in line with Rossi (2013), specifically at the two- and three-year horizon. This can be illustrated by inspecting the RMSFE and MAFE ratios, which appear to be declining, i.e. growing predictability for the first two years, after which the ratios remain approximately constant. Therefore, the monetary model specification at this forecasting horizon produces significantly better forecasts than the random walk benchmark and, according to DMW statistics, even produces statistically significantly better forecasts in some cases. As expected, the results are further confirmed by CW test statistics, where the CW test - in all cases except one - distinguishes the models at a five percent significance level. In short, the model shows the highest predictive power in the period between two and three years and still defeats a random walk at six months with one exception. The results cast some doubt on the results of Engel and West (2005), as the fundamentals are highly persistent, and the discount factor is probably close to one. Alternatively, according to Engel and West (2005), the forecasts obtained are, in reality, based on the stationarity and predictability of risk premia, which is indirectly estimated by the fundamental factors. We believe that this result is due to the fact that exchange rate dynamics are obscured by

[13] In the of case the USA, there is a one-week publication lag. In the case of Australia, Canada, the United Kingdom, Japan, and New Zealand, the publication lag is almost two months. In the euro area, Sweden, and Switzerland, the publication lag is approximately a month.

[14] Also note that the Swiss National Bank implemented a one-sided exchange rate target zone vis-à-vis the euro from September 2011 to January 2015 in the case of the CHF/USD currency pair, which may affect the results obtained.

high-frequency "non-fundamental" noise that is hard to predict. If a model successfully filters out this noise, it may prove to be a good predictor in the medium to long run precisely because it does not target unpredictable high-frequency fluctuations. This is also the reason we use a direct forecast for which the prediction errors do not accumulate.

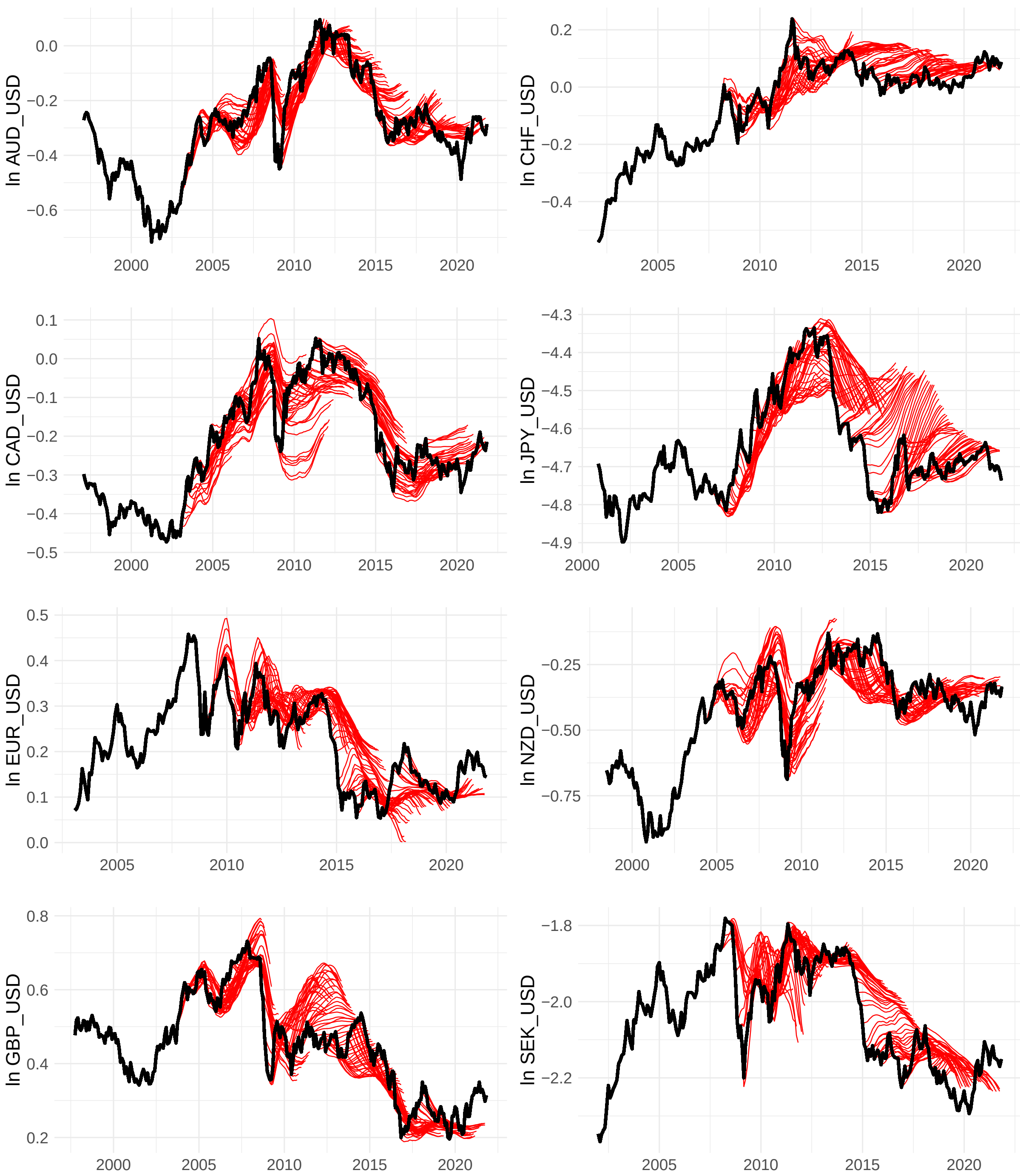
For comparison purposes, the long-term forecast results are comparable, and in some cases better, than the nominal exchange rate forecast conducted by Ca'Zorzi and Rubaszek (2020), where the authors primarily argue using the mean reversion property of inflation and the real exchange rate. The medium-term predictability, i.e. at the one-year horizon, seems to be somewhat more pronounced. Furthermore, the results for the long-term forecast are significantly better than those presented in Cheung et al. (2019), where the authors use monetary aggregates based on the monetary model in their predictions. Other studies are not comparable due to the different periods used.

However, given the use of the overlapping data framework and the nonstationarity of the explanatory variables, it is important to interpret the results with caution, as their reliability depends on the existence of cointegration. Non-cointegration combined with a large overlapping period induces positive autocorrelations in both the dependent and explanatory variables, resulting in a spurious regression problem. This affects not only in-sample results but also causes an artificially good out-of-sample forecast (Berkowitz and Giorgianni, 2001; Kilian, 1999).

We tackle this problem in several ways. First, as already mentioned, the Johansen cointegration tests were used (Figure C1, C2, C3). The figures show test statistics indicating whether there is at least one cointegration vector. In more detail, the red line represents Johansen trace test statistics. The black line represents 10 percent test statistics, and the blue line represents 5 percent test statistics. In line with the forecasting approach, we also use the recursive window estimation for the Johansen test to further evaluate the robustness of the cointegration. The results show some weak evidence of cointegration in the case of loans to corporations (Figure C1), where the test statistics oscillate around a 10 percent confidence interval. This relationship seems to be significantly stronger when unemployment rates or price levels are included (Figure C2, Figure C3).

Second, as a rule of thumb, we look at the stationarity of residuals. Table C1 shows the results of the Augmented Dickey-Fuller (ADF) test of residuals from the one-step error correction model. These are the median p-values of all the estimated models for a given horizon in an out-of-sample exercise. The results up to a one-year horizon show that most residuals can be considered stationary at the 10 percent significance level. The results over a one-year period are much more mixed. However, we consider them acceptable given the use of overlapping differences and the generally high persistence of the exchange rate (see Huang (2004)). Note that we have introduced an autocorrelation of up to order 36. The results are also somewhat inflated because the value 0.01 means equal to or smaller than this value. We also want to emphasize that in the case of the full sample, all residuals are mostly to be considered stationary at the ten percent significance level. We also used the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test as another robustness check. The reported values are the median p-values of all the estimated models for a given horizon. Unlike the Augmented Dickey-Fuller test, the null hypothesis is that the time series is stationary. Table C4 shows the results. Overall, the results are similar, and stationarity also seems to prevail in longer periods.

Figure 1: Out-of-Sample Sequential Forecast



Note: The black line represents the realized outcome (the log of the nominal exchange rate), while the red lines represent the 36 months ahead forecast calculated at different points in time. The explanatory variables (in logs) are US loans to non-financial corporations and loans to corporations of other countries given the chosen currency pair. A recursive window approach was used for the estimation.

Source: Author's calculations, BoC, BoJ, Datastream, ECB DW, FRED, Eurostat, RBA, RBNZ, SCB, SNB.

Table 1: Out-of-Sample Forecast Evaluation (Base Specification)

AUD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.00	0.95	0.87	0.79	0.74	0.57	0.61
MAFE_M/MAFE_RW	1.00	1.00	0.95	0.92	0.88	0.75	0.76
R2	0.02	0.15	0.32	0.46	0.54	0.70	0.72
DMW	0.63	0.14	0.08	0.06	0.04	0.00	0.01
CW	0.04	0.00	0.00	0.00	0.00	0.00	0.00
N	225	223	220	217	214	202	190
CAD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.03	1.02	0.99	0.96	0.93	0.74	0.57
MAFE_M/MAFE_RW	1.02	1.01	1.00	0.97	0.95	0.85	0.76
R2	0.02	0.01	0.06	0.12	0.19	0.47	0.69
DMW	0.99	0.74	0.46	0.27	0.21	0.10	0.03
CW	0.95	0.35	0.13	0.04	0.02	0.01	0.01
N	225	223	220	217	214	202	190
CHF/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.02	1.02	0.99	0.95	0.89	0.88	0.74
MAFE_M/MAFE_RW	1.01	1.01	1.00	0.99	0.97	0.98	0.90
R2	0.00	0.00	0.04	0.10	0.21	0.20	0.66
DMW	0.92	0.75	0.42	0.23	0.16	0.32	0.32
CW	0.61	0.16	0.02	0.01	0.01	0.04	0.10
N	165	163	160	157	154	142	130
EUR/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.02	0.99	0.96	0.91	0.89	0.81	0.76
MAFE_M/MAFE_RW	1.00	0.97	0.95	0.96	0.95	0.86	0.90
R2	0.00	0.06	0.17	0.26	0.28	0.31	0.24
DMW	0.86	0.42	0.28	0.12	0.08	0.00	0.11
CW	0.36	0.03	0.01	0.00	0.00	0.00	0.03
N	153	151	148	145	142	130	118
GBP/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.03	0.99	0.94	0.88	0.84	0.69	0.74
MAFE_M/MAFE_RW	1.02	1.02	0.98	0.96	0.94	0.86	0.84
R2	0.00	0.06	0.16	0.25	0.34	0.59	0.56
DMW	0.93	0.44	0.28	0.23	0.20	0.14	0.02
CW	0.20	0.01	0.01	0.01	0.01	0.00	0.00
N	217	215	212	209	206	194	182
JPY/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.06	1.07	1.07	1.04	1.01	0.87	0.71
MAFE_M/MAFE_RW	1.03	1.03	1.04	1.04	1.01	0.92	0.84
R2	0.06	0.01	0.00	0.00	0.00	0.34	0.75
DMW	1.00	0.97	0.97	0.86	0.61	0.22	0.19
CW	1.00	0.80	0.79	0.58	0.33	0.02	0.00
N	180	178	175	172	169	157	145
NZD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.02	1.03	0.98	0.90	0.85	0.79	0.82
MAFE_M/MAFE_RW	1.03	1.04	1.03	1.00	0.97	0.87	0.88
R2	0.02	0.09	0.24	0.37	0.47	0.60	0.55
DMW	0.87	0.70	0.43	0.32	0.26	0.04	0.25
CW	0.09	0.01	0.01	0.01	0.01	0.00	0.01
N	208.00	206.00	203.00	200.00	197.00	185.00	173
SEK/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.04	1.00	0.93	0.86	0.81	0.67	0.73
MAFE_M/MAFE_RW	1.01	1.00	0.98	0.95	0.93	0.80	0.86
R2	0.01	0.03	0.24	0.41	0.50	0.70	0.44
DMW	0.97	0.52	0.16	0.09	0.05	0.02	0.04
CW	0.88	0.12	0.02	0.01	0.01	0.01	0.00
N	166	164	161	158	155	143	131

Note: The explanatory variables are US loans to non-financial corporations and loans to corporations of other countries given the chosen currency pair. The dependent variable is the h step forward difference of the given currency pair. The individual columns (Mx) denote the results for the x-month-ahead forecast. RMSFE_M/RMSFE_RW denote the ratio of the root mean squared forecast error of the model and the random walk benchmark. MAFE_M/MAFE_RW is the ratio of the root mean absolute forecast error of the model and the random walk benchmark. R2 is calculated as the squared correlation coefficient of the prediction and the actual realization of the exchange rate. DMW and CW denote the p-values of Diebold Mariano and Clark-West statistics. N denotes the number of estimated forecasts. A recursive window approach was used for the estimation.

Lastly, we also look at the stability of the regression coefficients, i.e. the stability of the cointegration vector, see Figure C4, which displays parameters and their confidence intervals (Newey-West robust standard errors with 16 lags were used) for a twelve-month-ahead forecast in the base specification. This is because our main focus is on the medium-term forecast. Although there is some instability in the slope parameter estimates, we consider this result encouraging as the signs in the slope parameters do not generally change dramatically, and the movement in the parameters seems to be slow. This may be a reflection of some slow movements in the underlying economic process.

Furthermore, as a robustness check, Table C3 shows the results using the two-step estimation procedure. Overall, the results are significantly weaker than those presented in the base case, i.e. we found that the single-step method gives significantly better results than the two-step method. This is probably due to an additional error introduced by the two-step procedure, given that the single-step procedure, which is estimated using OLS, is super-consistent and is also likely to include some of the short-term adjustment effects of the full error correction model. Furthermore, the disappointing results may be because because we need to estimate more parameters. Hence, there is lower statistical efficiency, or there is a slow-moving component (structural breaks) in the cointegration, which causes lower efficiency.[15] Nevertheless, it should be noted that the results are not economically significantly worse than the random walk benchmark.

Given that the choice of prediction period is always largely arbitrary, we also employ a rolling window estimation as another robustness check of our results. Using this method, we also test the stability of the model over time because this method uses a fixed-length training period. Carriero et al. (2009) argues that using a short rolling estimation window is a natural way to reduce problems of instability. The length of this period is the same as the initial training period of recursive estimation, i.e. a 6-year horizon. Table C4 shows the results of this exercise. First of all, the long-term predictive power is maintained, although the results themselves differ for different currency pairs, i.e. we cannot say whether the results are generally better or worse. For example, the GBP/USD results according to the RMSFE and MAFE ratios are generally worse than in the recursive window. On the contrary, the JPY/USD and NZD/USD results are significantly better. There also seems to be medium-run predictability in seven of eight cases, even at the six-month horizon, (JPY/USD is the exception), and the results generally show lower RMSFE and MAFE ratios than in the base case. The results obtained, except for JPY/USD, are further confirmed by CW statistics for all exchange rates at a 5 percent significance level, and in the case of AUD/USD, EUR/USD and SEK/USD, even by DMW statistics at a 10 percent significance level. In summary, the various estimated models are more or less successful depending on the forecast horizon and the exchange rate chosen. Generally, the overall results further support and confirm our claim of significant nominal exchange rate predictability in the medium and long run.

Finally, Table C5 and C6 then show the results from additional robustness checks incorporating other variables (unemployment rates, price levels). The first specification extends the fundamentals by unemployment rates. This is more in line with the full, partial equilibrium monetary model presented above. However, the output is approximated by the unemployment rates due to the use of monthly data. Also, we are still assuming that purchasing power parity applies. The second specification includes price levels as an additional predictor. This, on the contrary, is motivated by the existence of real exchange rate terms in the fundamentals provided that purchasing power parity does not hold, which is again more in line with the partial equilibrium monetary model. The recursive window approach was used in both cases. The results generally show RMSFE and

[15] This is supported by the fact that using the rolling window in the two-step estimation gives better results.

MAFE ratios similar to those in the base case. A closer look reveals slightly worse results in the shorter term and, conversely, better results in the long run in most of the cases. This is probably associated with an estimation error, where the number of estimated model parameters increases significantly, and the one-step error correction method is not able to properly form a cointegration relation. However, the overall differences between these specifications and the base case are economically and statistically insignificant. Furthermore, it is again not clear which of these two specifications gives better predictions; the results seem to depend on the exchange rate chosen.

7. Conclusion

This paper presents a simple reduced-form error correction model, without short-term dynamics, for forecasting exchange rates inspired by the standard monetary model of exchange rates. The main contribution of this article is the use of loans to corporations, which represent money in our empirical exercise. Or, more precisely, we illustrate that loans to corporations, which act as a proxy for corporate deposits, are the main component of money that affects the nominal exchange rate because they have the highest chance of entering international transactions. By using the data on loans to corporations as explanatory variables, we are able to filter out other influences commonly included in monetary aggregates or total loans that primarily affect the domestic variables of the given countries and especially the overall price level.

Using monthly data, the study empirically shows the medium and long-term forecastability of the AUD/USD, CAD/USD, CHF/USD, EUR/USD, GBP/USD, JPY/USD, NZD/USD and SEK/USD nominal exchange rates in approximately the last two decades. We use a direct multi-step forecast and recursive window approach in the out-of-sample forecasting exercise. The reduced-form one-step error correction model can deliver a forecast which outperforms the random walk without drift benchmark based on the RMSFE ratio in seven out of eight cases in a nine-month period. Specifically, the long-term predictions, i.e. two and three years ahead, seem to be particularly impressive, although the results suffer from the classic shortcomings of long-horizon forecasts. On the other hand, the short-term predictive power is not that impressive, although we were able to beat the benchmark based on the RMSFE ratio at the three-month horizon in three out of eight cases.

Furthermore, we present a battery of different robustness checks. As a first robustness check, we use a rolling window estimation to evaluate the stability of the forecasts obtained. In general, we further confirm that there is significant medium and long-term predictability in all the cases considered, although the results differ for different currency pairs. The short-term predictive power is similar to the recursive window approach. As with other robustness checks, we also use other variables commonly used in exchange rate forecasting exercises. These robustness checks illustrate the similar predictive power of a simple three-variable error correction model, which uses only credit data and the lagged nominal exchange rate as explanatory variables. Therefore, credit data, specifically loans to corporations, appear to be a major factor influencing the long-term exchange rate. In short, the various specifications considered in robustness checks are more or less successful depending on the forecast horizon and exchange rate chosen.

Overall, the study allows for a better structural interpretation of exchange rate movements, as it shows some validity of the classical monetary model. In the general context of forecasting exchange rates, researchers should take more interest in credit (and deposits), specifically its creation and the consequences arising from its transfer. We would also like to point out that given the use of an error correction model without short-term dynamics, we did not exploit any other variables to forecast credit growth. A model that would make better use of well-known credit growth predictability can probably be utilized for further improvements in exchange rate forecasts, but it also presents us with the possibility to base future projections on easy-to-understand economic narratives.

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Appendix A: Accounting Example

In this part, we examine exchange rate transactions from an accounting perspective. We present a bookkeeping example of a simple two-country cross-border transaction, consisting of a typical US bank and a typical euro area bank inspired by McLeay et al. (2014); Werner (2014); Borio and Disyatat (2015); Bruno and Shin (2015); Bundesbank (2017); Gross and Siebenbrunner (2019). For simplicity, we do not consider central banks, governments, other countries, or shadow banking entities. At the same time, we also implicitly assume that banking sectors are operating in an environment with an abundance of liquidity or that the central bank always accommodates the need for liquidity. This assumption means that the banking sector can provide credit without acquiring deposits first. However, the banking sector is limited by the demand for credit, bank optimization, and capital requirements. We further abstract from the derivatives market, as these instruments only affect the spot market on physical settlement dates, and there must be an overall net position on the given date. We also abstract from the Repo market, which can also be used for short-term foreign currency financing.

Imagine the following situation describing a hypothetical US credit boom. A US commercial bank grants a new loan to a US company, which leads to an increase in the US bank's balance sheet. The company transfers its deposits to a European bank and converts them into EUR (it may be an importer or investor who wants to buy European assets). The US company is not involved in the international financial network and therefore deposits the money through the US bank, which, in turn, uses the corresponding banking system for the transaction. The European bank has an open FX position due to the conversion to EUR, which the bank has regulatory incentives to close.[16] This can be achieved by converting part of the deposits in EUR back into USD. However, if the bank is unable to do so because no client is willing to make the exchange at the current exchange rate, the bank will adjust the exchange rate until the FX position is closed.[17] In the long run, this money will be used in other transactions, and this will lead to an overall change in the price level.

Balance sheet positions are illustrated in Figure A1 and Figure A2. Figure A1 depicts the US bank's stylized balance sheet, and Figure A2 shows the same for the EU bank. Figure A3 describes the two possible outcomes of the given transaction. For a better understanding, the USD currency balance sheet items are in gray, and the EUR currency items are in white. The individual accounting transactions are in red, i.e. the individual bookkeeping entries. The opening balance on the assets side consists of central bank reserves, loans granted, and deposits in other banks. On the liabilities side, it consists of retail deposits, equity, and deposits from other banks. Deposits in other banks, in a currency other than the bank's domestic currency, are denoted as Nostro accounts. Deposits of other banks in a currency other than the bank's domestic currency are denoted as Loro accounts.

Figure A1 illustrates the process of granting a USD 10 million loan to a non-financial corporation. A company decides to transfer the borrowed money to a bank account in Europe. In the first step, the loan increases the US bank's balance sheet size. The transfer to the European bank itself causes an adjustment on the liabilities side of the balance sheet only. Note that the US bank's FX position is closed for all periods in this example.

[16] Likewise, we can assume that a US company buys EUR from a US bank. In this case, the US bank has an open FX position and the results are similar. On the other hand, we admit there is also the possibility that an EU bank will provide a EUR loan to a US company or a US bank will provide a EUR loan to a US company. In such cases, the bank's balance sheet increases, but the FX position remains closed.

[17] More specifically, banks usually place the order using EBS or Reuters. For more details see Evans (2018).

Figure A2 illustrates the same process from the point of view of the European bank. The transaction leads to growth in the balance sheet, but the FX position initially remains closed. The FX position only changes after the corporation decides to convert USD to EUR. The bank is forced to close its position again. Figure A3 shows the two possible outcomes of this decision by the bank. On the left panel, the balance sheet remains unchanged as the opposite transaction has occurred, and someone has converted the same amount of EUR to USD at the current exchange rate. On the right panel, nobody is willing to convert this amount of EUR at the current exchange rate. Therefore, the bank adjusts the exchange rate until the FX position is closed. Due to the interbank market and the arbitragers, this new level of exchange rate will be passed on to other institutions.

Several implicit assumptions were made in this example. First of all, we assume that the US company has an account with a European bank. If the US company did not have an account with a European bank, the US company would have bought EUR from a US bank, and the US bank would have an open FX position.

Figure A1: US Commercial Bank Balance Sheet

US commercial bank

Assets	Liabilities
Reserves	Equity
Nostro acounts	Deposits in EUR
Loans	Deposits in USD

US commercial bank

Assets	Liabilities
Reserves	Equity
Nostro acounts	Deposits in EUR
Loans	Deposits in USD
Additional loan +10	**Deposits in USD +10**

US commercial bank

Assets	Liabilities
Reserves	Equity
Nostro acounts	Deposits in EUR
Loans	Deposits in USD
Additional loan	**Loro account +10 (Deposits in USD -10)**

Note: We abstract from other items in the balance sheet. Equity includes equity and retained earnings and other items (capital). A Loro account is a bank account held by a foreign bank (EU) with a domestic bank (US). A Nostro account is an account that a domestic bank (US) holds with another bank in a foreign country (EU).

Figure A2: EU Commercial Bank Balance Sheet

EU commercial bank

Assets	Liabilities
Reserves	Equity
Nostro acount	Deposits in USD
Loans	Deposits in EUR

EU commercial bank

Assets	Liabilities
Reserves	Equity
Nostro acount	Deposits in USD
Loans	Deposits in EUR
Nostro acount +10	**Deposits in USD +10**

EU commercial bank

Assets	Liabilities
Reserves	Equity
Nostro acount	Deposits in USD
Loans	Deposits in EUR
Nostro acount	**Deposits in EUR +10 (Deposits in USD -10)**

Note: We abstract from other items in the balance sheet. Equity includes equity and retained earnings (capital). A Nostro account is an account that a domestic bank (EU) holds with another bank in a foreign country (US).

As shown in the accounting example above, an increase in credit (money supply) will cause an exchange rate movement only if it is accompanied by deposit transfers between banks in different countries.[18] However, the use of corporate loans only makes sense if we assume that most companies enter the international market, which means that only corporate deposits are essential

[18] We abstract from the possibility of the infinite elasticity of demand and supply curves in the foreign exchange market.

Figure A3: EU Commercial Bank Balance Sheet

EU commercial bank

Assets	Liabilities
Reserves	Equity
Nostro acount	Deposits in USD
Loans	**Deposits in EUR**
	Deposits in USD +10 (Deposits in EUR -10)
Nostro acount	**Deposits in EUR**

EU commercial bank

Assets	Liabilities
Reserves	Equity
Nostro acount	**Deposits in USD**
Loans	**Deposits in EUR**
	Deposits in USD +9 (Deposits in EUR -9)
Nostro acount	**Deposits in EUR**

Note: We abstract from other items in the balance sheet. Equity includes equity and retained earnings (capital).

for exchange rate movements. Furthermore, we also need to assume approximate parity between corporate deposits and corporate loans.

Let us now provide a somewhat more formal treatment of the accounting example. Let's first decompose total loans. First of all, we can divide total loans into loans to households and loans to corporations, which we denote by subscript i, where $i = (Corporations, Households)$. Second, the stock of loans consists of all loans granted in this and in previous periods minus all the repayments generated by those loans until that period. The decomposition of typical corporate and household loans can be written as follows:

$$L_{i,t} = \sum_{l=t-M_i+2}^{t+1} LN_{i,l} - \sum_{l=t-M_i+2}^{t} \sum_{\tau=1}^{M_i-l+1} R_{i,l} \qquad \text{(A1)}$$

where $L_{i,t}$ is the stock of loans of type i at time t and $\sum_{l=t-M_i+2}^{t+1} LN_{i,l}$ is the sum of all new loans (principal amounts), which have yet to be fully repaid. τ is the number of periods since the granting of the loan. M_i is the average maturity of the loan type i. $\sum_{l=t-M_i+2}^{t} \sum_{\tau=1}^{M-l+1} R_{i,t}$ denotes the sum of all repayments. For more details see (Adalid and Falagiarda, 2020).

We further assume that the demand for new corporate and household loans (principal amount of the loan) has the same functional form as the money demand equation, i.e. $LN_{i,t} - p_t = \alpha + \gamma y_t - \lambda i_t + v_t$. We can observe that even if we assume a simple linear demand function, the resulting expression for the stock of loans is highly nonlinear. However, the loans are still part of the banking sector's assets. As shown in the accounting example, deposit transfers are the main driver behind exchange rate movements. Therefore, we need to connect deposits to loans. First of all, remember that commercial bank balance sheet identity consists of loans and other assets on the asset side, and of deposits and other liabilities on the liability side. However, the amount of deposits changes due to the granting new loans, the repayment of loans, the transfer of other deposits created in previous periods, etc. In other words, deposits circulate between multiple agents within each period. The law of motion for deposits can be expressed as follows:

$$D_{i,t} = p_{i,i} \times D_{i,t-1} + p_{j,i} \times D_{j,t-1} - p_{i,j} \times D_{i,t-1} + LN_{i,t} - \sum R_{i,l} + \ldots \qquad \text{(A2)}$$

where $p_{i,j}$ denotes the transition probability (change in deposit ownership) from state i to state j. This relation is impossible to estimate using the loan data only. Therefore, in our monetary model empirical exercise, we need to assume deposits can be approximated as loans, which, in turn, means that transactions between deposits effectively net each other. (This is a similar assumption to the constant velocity of money.) We also assume that only companies engage in currency conversion. Furthermore, we also observe that the stock of loans is a weighted average of new loans and repayments. The resulting string of approximation is as follows, where ω_l denotes weights and δ_l approximate repayments:

$$M_t \approx D_{corp,t} \approx L_{corp,t} \approx \sum_{l=t-M+2}^{t+1} \omega_l (1-\delta_l) LN_{corp,t} \tag{A3}$$

Appendix B: Data

Table B1: Data Description

Name (Abbreviated)	Ticker	Source	Country
US Dollar to Australian Dollar Spot Exchange Rate	DEXUSAL	FRED	AUD/USD
Canadian Dollar to US Dollar Spot Exchange Rate	DEXCAUS	FRED	CAD/USD
Swiss Franc to US Dollar Spot Exchange Rate	DEXSZUS	FRED	CHF/USD
US Dollar to Euro Spot Exchange Rate	DEXUSEU	FRED	EUR/USD
US Dollar to Pound Sterling Spot Exchange Rate	DEXUSUK	FRED	GBP/USD
Japanese Yen to US Dollar Spot Exchange Rate	DEXJPUS	FRED	JPY/USD
US Dollar to New Zealand Dollar Spot Exchange Rate	DEXUSNZ	FRED	NZD/USD
Swedish Krona to US Dollar Spot Exchange Rate	DEXSDUS	FRED	SWD/USD
Credit: Commercial Banks	D2 LENDING AND CREDIT AGGREGATES	RBA	AU
Credit liabilities of private non-financial corporations		BoC	CA
Domestic loans (utilization and credit lines)	EPB@SNB.bakredbetgrbmAV1,KC5A,T1,F	SNB	CH
Domestic loans (utilization and credit lines)	EPB@SNB.bakredbetgrbmAV1,KC5A,T1,B	SNB	CH
Domestic loans (utilization and credit lines)	EPB@SNB.bakredbetgrbmAV1,KC5B,T1,F	SNB	CH
Domestic loans (utilization and credit lines)	EPB@SNB.bakredbetgrbmAV1,KC5B,T1,B	SNB	CH
Domestic loans (utilization and credit lines)	EPB@SNB.bakredbetgrbmAV1,KC5C,T1,F	SNB	CH
Domestic loans (utilization and credit lines)	EPB@SNB.bakredbetgrbmAV1,KC5C,T1,B	SNB	CH
Domestic loans (utilization and credit lines)	EPB@SNB.bakredbetgrbmAV1,KC5D,T1,F	SNB	CH
Domestic loans (utilization and credit lines)	EPB@SNB.bakredbetgrbmAV1,KC5D,T1,B	SNB	CH
Loans vis-a-vis euro area NFC reported by MFI	BSI.M.U2.N.A.A20.A.1.U2.2240.Z01.E	ECB	EU
Outstanding Loans and Bills Discounted/Corporations	MD11'DLCLAEDBLTCO	BoJ	JAP
Sector lending	CRDS.MALP3	RBNZ	NZL
Lending: Sweden, non-financial corporations		SCB	SWE
UK M4 LENDING: PRIVATE NON-FINANCIAL	UKBANKLPB	Datastream	UK
Commercial and Industrial Loans: All Commercial Banks	BUSLOANSNSA	FRED	US
Consumer Price Index for All Items in Australia	AUSCPIALLQINMEI	FRED	AU
Consumer Price Index for All Urban Consumers	CPIAUCSL	FRED	CA
Consumer Price Index for All Items in Switzerland	CHECPIALLMINMEI	FRED	CH
HICP - monthly data (index)	PRC_HICP_MIDX	Eurostat	EU
Consumer Price Index for all items in Japan	JPNCPIALLMINMEI	FRED	JAP
Consumer Price Index for All Items in New Zealand	NZLCPIALLQINMEI	FRED	NZL
Consumer Price Index for all Items in Sweden	SWECPIALLMINMEI	FRED	SWE
Consumer Price Index for All Items in the United Kingdom	GBRCPIALLMINMEI	FRED	UK
Consumer Price Index for All Urban Consumers	CPIAUCSL	FRED	US
Harmonized Unemployment Rate: Australia	LRHUTTTTAUM156N	FRED	AU
Unemployment Rate: Aged 15 and Over: Canada	LRUNTTTTCAM156N	FRED	CA
Unemployment by sex and age	UNE_RT_M	Eurostat	CH
Unemployment by sex and age	UNE_RT_M	Eurostat	EU
Unemployment Rate: Aged 15-64: All Persons for Japan	LRUN64TTJPM156N	FRED	JAP
Registered Unemployment Level for New Zealand	LMUNRLTTNZM647N	FRED	NZL
Unemployment Rate: New Zealand	LRUNTTTTNZQ156S	FRED	NZL
Harmonized Unemployment Rate: Total: Sweden	UNRATENSA	FRED	SWE
Harmonized Unemployment Rate: United Kingdom	LRHUTTTTGBM156N	FRED	UK
Unemployment Rate, Percent, Monthly	UNRATENSA	FRED	US

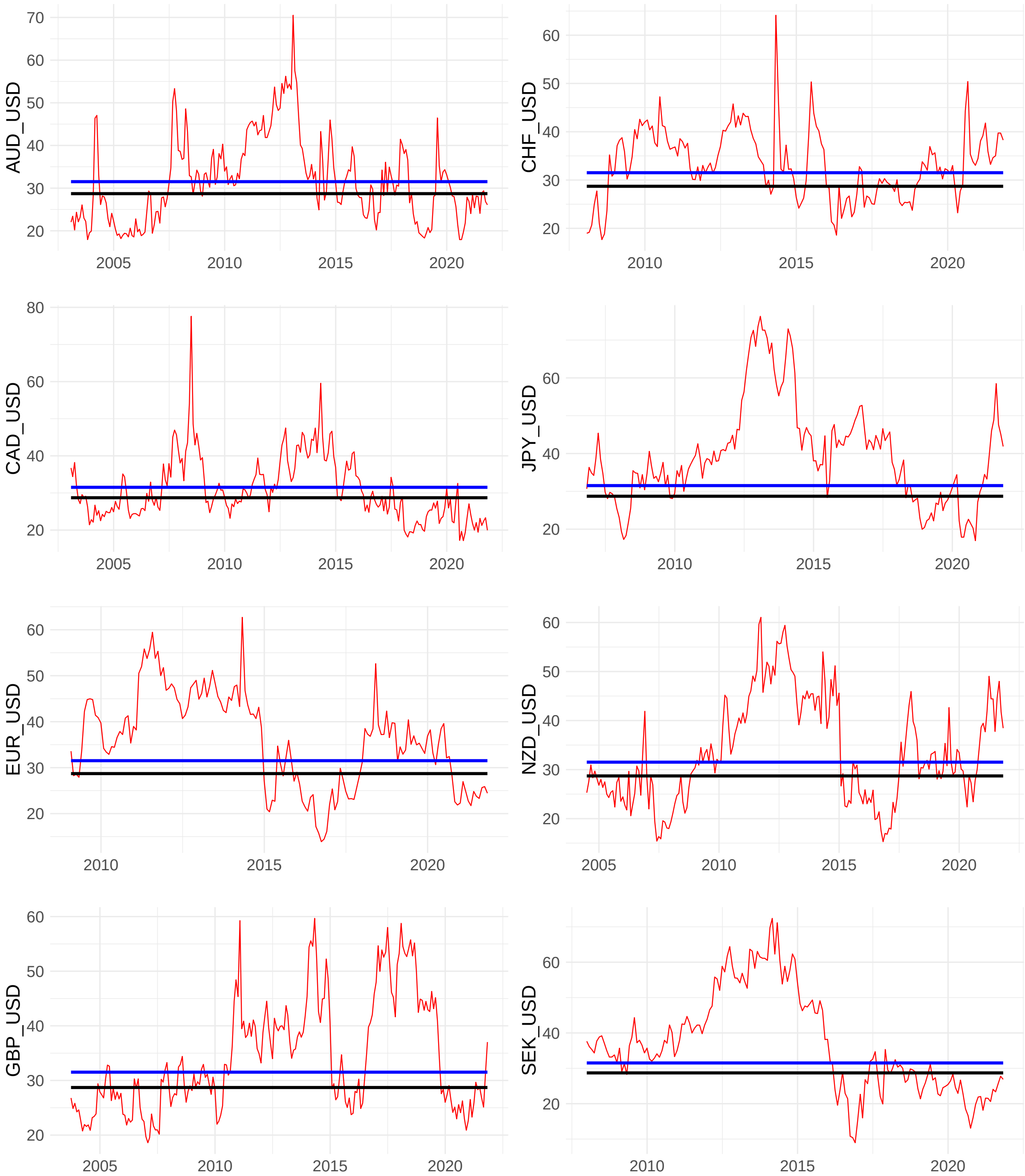
Table B2: Summary Statistics

Variable	Mean	Sd	Max	Min	Rho	ADF	KPSS	N
Nominal Exchange Rates								
AUD/USD	-0.29	0.19	0.10	-0.72	0.98	0.50	0.01	298
CAD/USD	0.22	0.15	0.47	-0.05	0.99	0.79	0.01	298
CHF/USD	0.06	0.15	0.54	-0.24	0.96	0.36	0.01	238
EUR/USD	0.22	0.10	0.46	0.05	0.95	0.05	0.01	226
GBP/USD	0.45	0.13	0.73	0.20	0.98	0.43	0.01	290
JPY/USD	4.66	0.13	4.90	4.34	0.98	0.78	0.01	253
NZD_USD	-0.43	0.19	-0.13	-0.93	0.98	0.50	0.01	281
SEK_USD	-2.05	0.14	-1.78	-2.37	0.96	0.13	0.01	239
Loans to Corporations								
Credit_Australia	6.35	0.44	6.95	5.47	0.99	0.70	0.01	298
Credit_Canada	10.89	0.28	11.51	10.13	0.98	0.60	0.01	298
Credit_Swiss	13.46	0.20	13.85	13.16	0.99	0.25	0.01	238
Credit_EU	8.34	0.15	8.49	8.00	0.98	0.42	0.01	226
Credit_UK	5.79	0.31	6.21	5.12	0.99	0.43	0.01	290
Credit_JAP	14.90	0.09	15.11	14.79	0.98	0.28	0.01	253
Credit_NZL	11.19	0.37	11.72	10.46	0.99	0.75	0.01	281
Credit_Sweden	14.26	0.25	14.67	13.84	0.99	0.68	0.01	239
Credit_US	7.22	0.36	8.03	6.66	0.99	0.43	0.01	298
Relative Price level								
AUD/USD price level	0.91	0.03	0.97	0.86	0.99	0.88	0.01	298
CAD/USD price level	0.85	0.03	0.90	0.79	0.99	0.55	0.01	298
CHF/USD price level	0.80	0.10	1.00	0.63	0.98	0.19	0.01	238
EUR/USD price level	-0.87	0.02	-0.84	-0.91	0.95	0.73	0.01	226
GBP/USD price level	-0.87	0.02	-0.82	-0.93	0.98	0.59	0.01	290
JAP/USD price level	0.80	0.11	1.00	0.56	0.98	0.72	0.01	253
NZD/USD price level	-0.87	0.01	-0.83	-0.90	0.92	0.22	0.02	281
SWE/USD price level	-0.82	0.05	-0.72	-0.92	0.98	0.43	0.01	239
Unemployment rate								
Australia_un	1.74	0.17	2.27	1.35	0.93	0.24	0.01	298
Canada_un	1.97	0.16	2.62	1.63	0.84	0.01	0.05	298
Swiss_un	1.65	0.34	2.88	0.83	0.90	0.49	0.02	238
EU_un	2.23	0.16	2.55	1.97	0.98	0.95	0.01	226
UK_un	1.72	0.22	2.15	1.28	0.99	0.87	0.01	288
JAP_un	1.40	0.26	1.79	0.79	0.98	0.55	0.01	253
NZL_un	1.61	0.22	2.07	1.16	0.96	0.66	0.03	281
SWE_un	2.00	0.15	2.33	1.67	0.79	0.18	0.02	239
US_un	1.71	0.30	2.67	1.19	0.95	0.48	0.02	298

Note: The table shows the time series used in the forecasting exercise. All variables are in log form. Rho denotes the autocorrelation coefficient at first lag. N denotes the number of observations. ADF and KPSS denote the p-values of the Augmented Dickey-Fuller and Kwiatkowski-Phillips-Schmidt-Shin statistics. The number of lags in each of the two tests was selected to minimize the AIC.

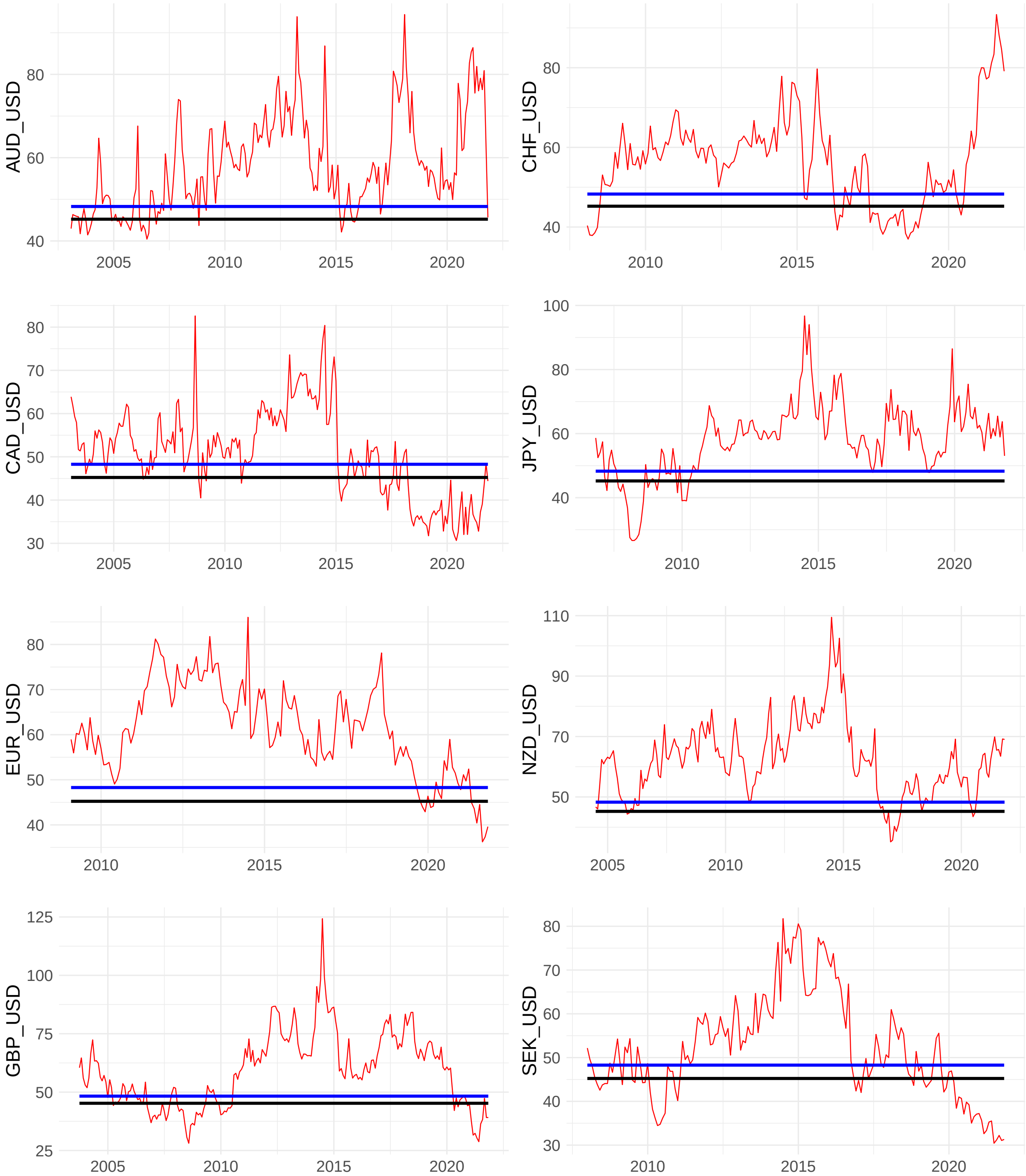
Appendix C: Robustness Checks

Figure C1: Johansen Trace Test (Base Specification)



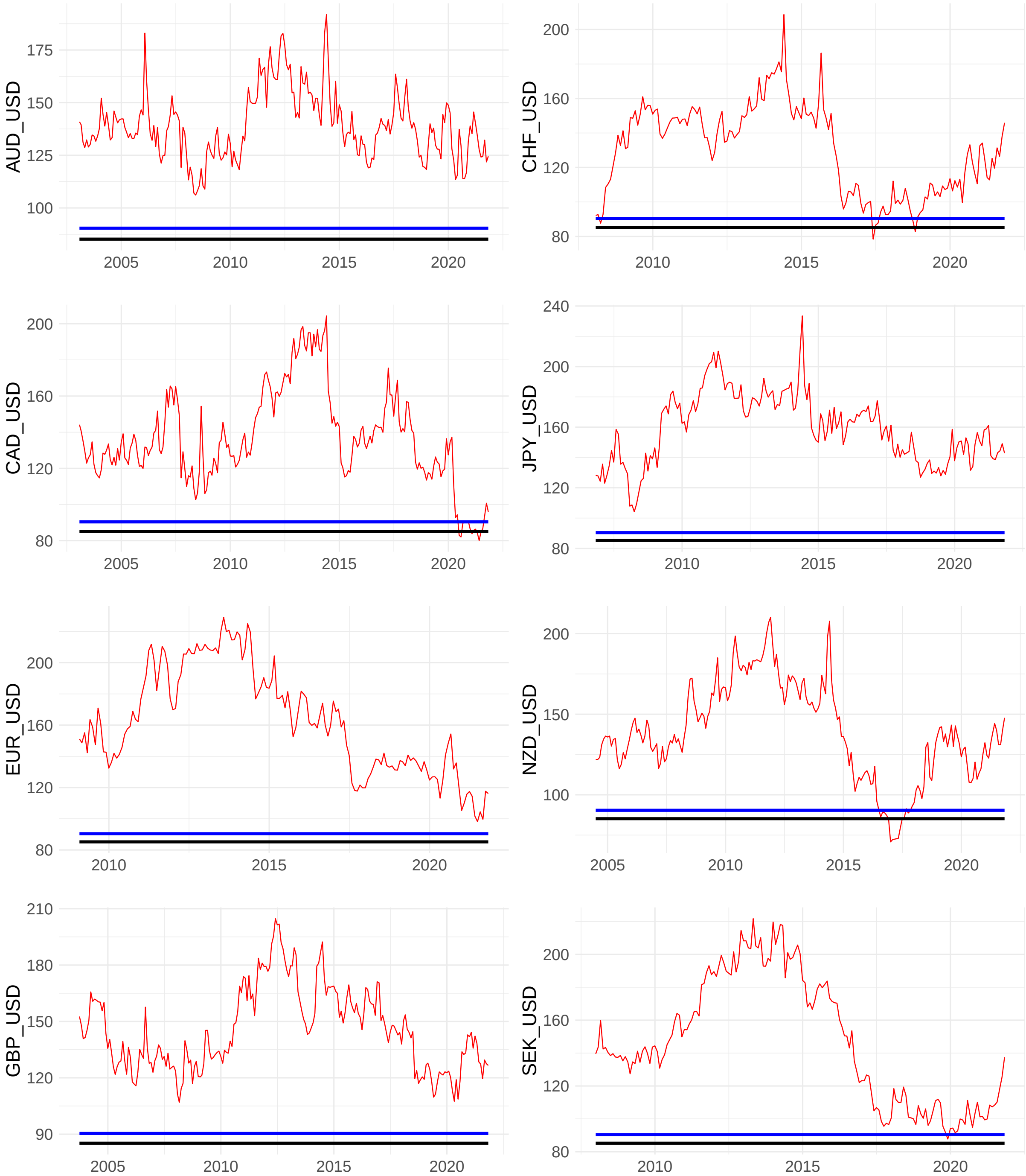
Note: The red line represents the Johansen trace test statistics, which indicates whether there is at least one cointegration vector. The black line represents 10 percent test statistics. The blue line represents 5 percent test statistics. Four lags were used for the estimation. The variables used are nominal exchange rates, US loans to non-financial corporations, US price level and loans to corporations of other countries, the price level of other countries given the chosen currency pair.
Source: Author's calculations, BoC, BoJ, Datastream, ECB DW, FRED, Eurostat, RBA, RBNZ, SCB, SNB.

Figure C2: Johansen Trace Test (Including Price Levels)



Note: The red line represents the Johansen trace test statistics, which indicates whether there is at least one cointegration vector. The black line represents 10 percent test statistics. The blue line represents 5 percent test statistics. Four lags were used for the estimation. The variables used are nominal exchange rates, US loans to non-financial corporations, US price level and loans to corporations of other countries, the price level of other countries given the chosen currency pair.
Source: Author's calculations, BoC, BoJ, Datastream, ECB DW, FRED, Eurostat, RBA, RBNZ, SCB, SNB.

Figure C3: Johansen Trace Test (Including Unemployment Rates)



Note: The red line represents the Johansen trace test statistics, which indicate whether there is at least one cointegration vector. The black line represents 10 percent test statistics. The blue line represents 5 percent test statistics. Four lags were used for estimation. The variables used are nominal exchange rates, US loans to non-financial corporations, the US unemployment rate and loans to corporations of other countries, the unemployment rate of other countries given the chosen currency pair.
Source: Author's calculations, BoC, BoJ, Datastream, ECB DW, FRED, Eurostat, RBA, RBNZ, SCB, SNB.

Table C1: AAF Test P-Values (Median Values over the Sample)

	M1	M3	M6	M9	M12	M24	M36
AUD_USD	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CAD_USD	0.01	0.01	0.01	0.01	0.01	0.04	0.01
CHF_USD	0.01	0.01	0.01	0.01	0.02	0.14	0.39
EUR_USD	0.01	0.01	0.01	0.02	0.05	0.14	0.20
GBP_USD	0.01	0.01	0.01	0.01	0.02	0.10	0.07
JPY_USD	0.01	0.01	0.06	0.13	0.34	0.62	0.75
NZD_USD	0.01	0.01	0.01	0.02	0.02	0.10	0.03
SEK_USD	0.01	0.01	0.01	0.01	0.01	0.04	0.23

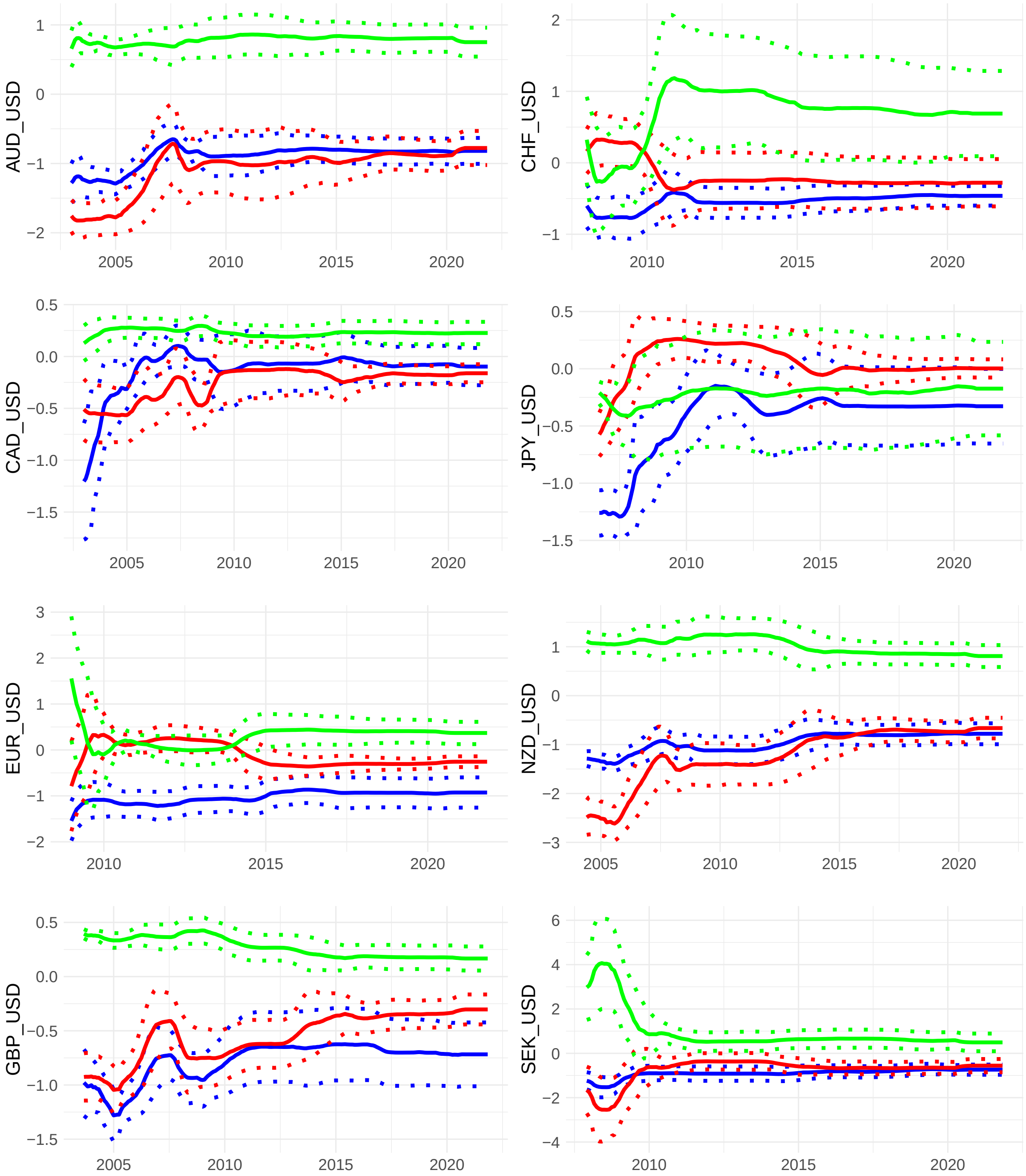
Note: ADF tests the null hypothesis that a unit root is present. The number of lags was selected to minimize the AIC. P-value 0.01 means equal or smaller than 0.01. Explanatory variables in regression are US loans to non-financial corporations and loans to corporations of other countries given the chosen currency pair. The dependent variable is the h step forward difference of the given currency pair. The individual columns (Mx) denote the results for the x month ahead forecast.

Table C2: KPSS Test P-Values (Median Values over the Sample)

	M1	M3	M6	M9	M12	M24	M36
AUD_USD	0.10	0.10	0.10	0.10	0.10	0.10	0.10
CAD_USD	0.10	0.10	0.10	0.10	0.10	0.10	0.10
CHF_USD	0.10	0.10	0.10	0.10	0.10	0.10	0.05
EUR_USD	0.10	0.10	0.10	0.10	0.10	0.05	0.08
GBP_USD	0.10	0.10	0.10	0.10	0.10	0.10	0.10
JPY_USD	0.10	0.10	0.10	0.10	0.10	0.05	0.02
NZD_USD	0.10	0.10	0.10	0.10	0.10	0.10	0.10
SEK_USD	0.10	0.10	0.10	0.10	0.10	0.09	0.09

Note: KPSS tests the null hypothesis that time series are stationary. The number of lags was selected to minimize the AIC. A P-value of 0.10 means equal or greater than 0.10. US loans to non-financial corporations and loans to corporations of other countries given the chosen currency pair are the explanatory variables in regression. The dependent variable is the h step forward difference of the given currency pair. The individual columns denote the results for the x-month-ahead forecast.

Figure C4: Regression Coefficient Stability



Note: The graph shows the coefficients for the twelve-month-ahead forecast estimated using a recursive approach. The blue line represents the exchange rate coefficient. The red line represents the coefficient for USD loans, and the green line represents the coefficient for other loans in the given currency pair. The dashed lines represent 95% confidence intervals using Newey-West robust standard errors with 16 lags.
Source: Author's calculations, BoC, BoJ, Datastream, ECB DW, FRED, Eurostat, RBA, RBNZ, SCB, SNB.

Table C3: Out-of-Sample Forecast Evaluation (Base Specification, Two Step Estimation)

AUD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.01	1.01	1.01	1.01	1.02	1.01	0.98
MAFE_M/MAFE_RW	1.00	1.04	1.04	1.04	1.03	0.98	0.96
R2	0.02	0.07	0.14	0.22	0.25	0.28	0.29
DMW	0.70	0.56	0.54	0.52	0.54	0.51	0.47
CW	0.05	0.02	0.02	0.02	0.02	0.00	0.02
N	225	223	220	217	214	202	190
CAD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.01	1.01	1.01	1.01	1.02	1.09	1.11
MAFE_M/MAFE_RW	1.00	1.01	1.02	1.03	1.01	1.02	1.06
R2	0.02	0.00	0.00	0.00	0.01	0.01	0.03
DMW	0.99	0.78	0.69	0.61	0.62	0.74	0.68
CW	0.96	0.61	0.44	0.32	0.29	0.37	0.34
N	225	223	220	217	214	202	190
CHF/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.01	1.03	1.00	0.97	0.93	1.00	1.08
MAFE_M/MAFE_RW	1.00	1.00	1.02	1.02	0.99	1.05	1.09
R2	0.00	0.02	0.11	0.22	0.30	0.25	0.24
DMW	0.70	0.73	0.49	0.39	0.34	0.50	0.56
CW	0.20	0.11	0.05	0.06	0.06	0.11	0.15
N	165	163	160	157	154	142	130
EUR/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.08	1.18	1.26	1.25	1.20	1.19	1.09
MAFE_M/MAFE_RW	1.03	1.06	1.10	1.10	1.08	1.05	1.06
R2	0.02	0.02	0.00	0.01	0.04	0.03	0.01
DMW	1.00	0.97	0.94	0.91	0.87	0.87	0.73
CW	0.90	0.86	0.70	0.47	0.33	0.57	0.70
N	153	151	148	145	142	130	118
GBP/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.02	1.02	1.02	1.02	1.02	1.03	0.98
MAFE_M/MAFE_RW	1.01	1.03	1.01	1.03	1.06	1.09	1.03
R2	0.00	0.01	0.05	0.09	0.13	0.33	0.48
DMW	0.94	0.71	0.63	0.56	0.54	0.55	0.46
CW	0.51	0.22	0.09	0.08	0.08	0.07	0.05
N	217	215	212	209	206	194	182
JPY/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.03	1.05	1.06	1.06	1.07	1.03	0.94
MAFE_M/MAFE_RW	1.01	1.02	1.03	1.03	1.03	0.98	0.92
R2	0.02	0.02	0.03	0.03	0.04	0.00	0.23
DMW	0.98	0.96	0.93	0.86	0.85	0.58	0.40
CW	0.93	0.89	0.85	0.79	0.78	0.44	0.24
N	180	178	175	172	169	157	145
NZD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.01	1.03	1.03	1.03	1.06	1.20	1.08
MAFE_M/MAFE_RW	1.02	1.04	1.06	1.06	1.06	1.08	1.00
R2	0.01	0.05	0.11	0.18	0.24	0.31	0.34
DMW	0.77	0.70	0.60	0.56	0.60	0.84	0.61
CW	0.06	0.03	0.04	0.04	0.05	0.01	0.00
N	208	206	203	200	197	185	173
SEK/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.05	1.11	1.16	1.12	1.11	1.17	1.14
MAFE_M/MAFE_RW	1.03	1.06	1.09	1.08	1.10	1.11	1.12
R2	0.00	0.01	0.05	0.18	0.29	0.40	0.38
DMW	0.98	0.94	0.94	0.91	0.84	0.99	1.00
CW	0.77	0.50	0.24	0.06	0.04	0.09	0.24
N	166	164	161	158	155	143	131

Note: The explanatory variables are US loans to non-financial corporations and loans to corporations of other countries given the chosen currency pair. The dependent variable is the h step forward difference of the given currency pair. The individual columns (Mx) denote the results for the x-month-ahead forecast. RMSFE_M/RMSFE_RW denote the ratio of the root mean squared forecast error of the model and the random walk benchmark. MAFE_M/MAFE_RW is the ratio of the root mean absolute forecast error of the model and the random walk benchmark. R2 is calculated as the squared correlation coefficient of the prediction and the actual realization of the exchange rate. DMW and CW denote the p-values of the Diebold Mariano and Clark-West statistics. N denotes the number of estimated forecasts. A *recursive* window approach was used for the estimation.

Table C4: Out-of-Sample Forecast Evaluation (Base Specification, Rolling Window)

AUD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.04	0.97	0.84	0.72	0.64	0.52	0.62
MAFE_M/MAFE_RW	1.02	1.02	0.95	0.87	0.81	0.70	0.76
R2	0.00	0.12	0.35	0.53	0.63	0.74	0.63
DMW	0.95	0.28	0.09	0.05	0.01	0.00	0.01
CW	0.20	0.00	0.00	0.00	0.00	0.00	0.00
N	225	223	220	217	214	202	190
CAD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.06	1.04	0.97	0.86	0.78	0.61	0.51
MAFE_M/MAFE_RW	1.03	1.02	1.00	0.92	0.85	0.78	0.73
R2	0.00	0.03	0.10	0.27	0.40	0.64	0.74
DMW	1.00	0.90	0.27	0.01	0.00	0.01	0.01
CW	0.83	0.05	0.01	0.00	0.00	0.00	0.00
N	225	223	220	217	214	202	190
CHF/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.04	1.02	0.97	0.92	0.80	0.67	0.51
MAFE_M/MAFE_RW	1.03	1.00	0.97	0.95	0.89	0.79	0.72
R2	0.00	0.04	0.14	0.24	0.40	0.58	0.72
DMW	0.96	0.64	0.38	0.15	0.00	0.04	0.17
CW	0.42	0.05	0.01	0.00	0.00	0.00	0.04
N	165	163	160	157	154	142	130
EUR/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.04	0.97	0.89	0.82	0.76	0.63	0.72
MAFE_M/MAFE_RW	1.02	0.99	0.97	0.94	0.90	0.76	0.88
R2	0.00	0.10	0.28	0.42	0.51	0.61	0.36
DMW	0.97	0.29	0.09	0.04	0.04	0.03	0.12
CW	0.52	0.00	0.00	0.00	0.00	0.01	0.03
N	153	151	148	145	142	130	118
GBP/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.07	1.04	0.99	0.93	0.84	0.59	0.61
MAFE_M/MAFE_RW	1.03	1.03	1.00	0.98	0.94	0.79	0.79
R2	0.00	0.04	0.13	0.24	0.38	0.72	0.61
DMW	1.00	0.77	0.46	0.31	0.19	0.05	0.00
CW	0.38	0.01	0.00	0.00	0.00	0.00	0.00
N	216	215	212	209	206	194	182
JPY/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.09	1.11	1.05	0.95	0.89	0.58	0.43
MAFE_M/MAFE_RW	1.04	1.05	1.01	0.98	0.94	0.75	0.64
R2	0.02	0.00	0.03	0.14	0.22	0.71	0.86
DMW	1.00	0.97	0.73	0.28	0.11	0.03	0.03
CW	0.97	0.64	0.08	0.01	0.00	0.00	0.00
N	180	178	175	172	169	157	145
NZD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.05	1.03	0.92	0.83	0.79	0.64	0.72
MAFE_M/MAFE_RW	1.03	1.04	1.00	0.94	0.91	0.79	0.86
R2	0.00	0.05	0.24	0.41	0.48	0.61	0.50
DMW	1.00	0.72	0.29	0.22	0.18	0.01	0.01
CW	0.50	0.00	0.00	0.01	0.01	0.00	0.00
N	208	206	203	200	197	185	173
SEK/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.07	1.01	0.91	0.81	0.74	0.54	0.64
MAFE_M/MAFE_RW	1.02	1.02	0.97	0.93	0.89	0.72	0.76
R2	0.02	0.03	0.19	0.38	0.50	0.69	0.51
DMW	1.00	0.60	0.07	0.04	0.03	0.01	0.06
CW	0.95	0.05	0.00	0.00	0.00	0.00	0.01
N	166	164	161	158	155	143	131

Note: The explanatory variables are US loans to non-financial corporations and loans to corporations of other countries given the chosen currency pair. The dependent variable is the h step forward difference of the given currency pair. The individual columns (Mx) denote the results for the x-month-ahead forecast. RMSFE_M/RMSFE_RW denote the ratio of the root mean squared forecast error of the model and the random walk benchmark. MAFE_M/MAFE_RW is the ratio of the root mean absolute forecast error of the model and the random walk benchmark. R2 is calculated as the squared correlation coefficient of the prediction and the actual realization of the exchange rate. DMW and CW denote the p-values of the Diebold Mariano and Clark-West statistics. N denotes the number of estimated forecasts. A *rolling* window approach was used for the estimation.

Table C5: Out-of-Sample Forecast Evaluation (Including Unemployment Rates)

AUD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.01	0.94	0.83	0.73	0.67	0.56	0.59
MAFE_M/MAFE_RW	1.00	0.98	0.93	0.87	0.82	0.73	0.76
R2	0.02	0.14	0.35	0.50	0.58	0.70	0.73
DMW	0.61	0.12	0.03	0.01	0.01	0.00	0.00
CW	0.05	0.00	0.00	0.00	0.00	0.01	0.00
N	225	223	220	217	214	202	190
CAD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.04	1.00	0.97	0.90	0.85	0.66	0.55
MAFE_M/MAFE_RW	1.02	1.00	0.96	0.93	0.90	0.83	0.74
R2	0.00	0.04	0.11	0.21	0.31	0.56	0.74
DMW	0.98	0.54	0.26	0.03	0.03	0.03	0.01
CW	0.54	0.01	0.00	0.00	0.00	0.00	0.00
N	225	223	220	217	214	202	190
CHF/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.03	0.99	0.94	0.92	0.85	0.64	0.69
MAFE_M/MAFE_RW	1.01	0.99	0.96	0.97	0.92	0.81	0.86
R2	0.00	0.04	0.13	0.16	0.26	0.66	0.53
DMW	0.95	0.30	0.06	0.09	0.03	0.14	0.27
CW	0.70	0.04	0.00	0.00	0.00	0.03	0.10
N	165	163	160	157	154	142	130
EUR/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.06	1.04	0.97	0.86	0.77	0.65	0.56
MAFE_M/MAFE_RW	1.03	1.01	0.99	0.94	0.89	0.80	0.73
R2	0.01	0.01	0.14	0.33	0.46	0.63	0.62
DMW	0.99	0.78	0.34	0.16	0.08	0.07	0.06
CW	0.90	0.17	0.00	0.00	0.00	0.01	0.04
N	153	151	148	145	142	130	118
GBP/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.05	1.01	0.95	0.88	0.82	0.60	0.57
MAFE_M/MAFE_RW	1.03	1.02	0.97	0.95	0.93	0.80	0.78
R2	0.00	0.04	0.15	0.28	0.39	0.63	0.60
DMW	0.99	0.60	0.31	0.27	0.22	0.08	0.00
CW	0.30	0.01	0.00	0.00	0.00	0.01	0.01
N	216	215	212	209	206	194	182
JPY/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.08	1.06	1.04	1.02	0.99	0.80	0.67
MAFE_M/MAFE_RW	1.05	1.06	1.07	1.06	1.04	0.86	0.81
R2	0.01	0.02	0.06	0.09	0.12	0.40	0.70
DMW	1.00	0.85	0.71	0.57	0.46	0.17	0.14
CW	0.85	0.15	0.02	0.01	0.01	0.01	0.00
N	180	178	175	172	169	157	145
NZD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.05	1.04	0.95	0.86	0.81	0.69	0.69
MAFE_M/MAFE_RW	1.03	1.04	1.03	0.97	0.94	0.81	0.82
R2	0.01	0.08	0.25	0.41	0.53	0.63	0.55
DMW	0.96	0.73	0.35	0.23	0.18	0.03	0.00
CW	0.20	0.00	0.00	0.00	0.00	0.00	0.00
N	208	206	203	200	197	185	173
SEK/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.07	1.02	0.92	0.84	0.77	0.67	0.70
MAFE_M/MAFE_RW	1.02	1.00	0.98	0.94	0.90	0.81	0.85
R2	0.01	0.03	0.32	0.52	0.58	0.54	0.40
DMW	0.92	0.69	0.21	0.12	0.06	0.01	0.10
CW	0.73	0.16	0.02	0.01	0.01	0.00	0.00
N	166	164	161	158	155	143	131

Note: The explanatory variables are US loans to non-financial corporations, the US unemployment rate, and loans to corporations and the unemployment rates of other countries given the chosen currency pair. The dependent variable is the h step forward difference of the given currency pair. The individual columns (Mx) denote the results for the x-month-ahead forecast. RMSFE_M/RMSFE_RW denote the ratio of the root mean squared forecast error of the model and the random walk benchmark. MAFE_M/MAFE_RW is the ratio of the root mean absolute forecast error of the model and the random walk benchmark. R2 is calculated as the squared correlation coefficient of the prediction and the actual realization of the exchange rate. DMW and CW denote the p-values of the Diebold Mariano and Clark-West statistics. N denotes the number of estimated forecasts. A *recursive* window approach was used for the estimation.

Table C6: Out-of-Sample Forecast Evaluation (Including Price Levels)

AUD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.01	0.96	0.86	0.80	0.74	0.60	0.63
MAFE_M/MAFE_RW	1.00	0.99	0.93	0.91	0.87	0.77	0.77
R2	0.01	0.11	0.29	0.43	0.51	0.64	0.70
DMW	0.74	0.16	0.08	0.06	0.04	0.01	0.00
CW	0.15	0.00	0.00	0.00	0.00	0.00	0.00
N	225	223	220	217	214	202	190
CAD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.03	1.03	1.00	0.96	0.92	0.73	0.57
MAFE_M/MAFE_RW	1.02	1.01	0.99	0.97	0.94	0.83	0.76
R2	0.01	0.01	0.05	0.12	0.18	0.47	0.70
DMW	0.99	0.80	0.48	0.25	0.14	0.07	0.02
CW	0.88	0.34	0.10	0.03	0.01	0.00	0.00
N	225	223	220	217	214	202	190
CHF/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.04	1.03	1.00	0.97	0.91	0.87	0.66
MAFE_M/MAFE_RW	1.02	1.01	1.04	1.06	1.04	0.96	0.85
R2	0.01	0.01	0.12	0.26	0.43	0.24	0.64
DMW	0.98	0.84	0.51	0.43	0.37	0.33	0.27
CW	0.64	0.11	0.01	0.02	0.03	0.05	0.10
N	165	163	160	157	154	142	130
EUR/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.03	0.99	0.96	0.89	0.82	0.65	0.59
MAFE_M/MAFE_RW	1.01	0.97	0.95	0.93	0.90	0.81	0.78
R2	0.00	0.06	0.17	0.29	0.39	0.58	0.55
DMW	0.90	0.44	0.27	0.11	0.03	0.06	0.07
CW	0.45	0.04	0.01	0.00	0.00	0.00	0.03
N	153	151	148	145	142	130	118
GBP/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.04	1.00	0.94	0.89	0.83	0.58	0.61
MAFE_M/MAFE_RW	1.02	1.02	0.97	0.96	0.93	0.79	0.75
R2	0.00	0.04	0.16	0.26	0.35	0.67	0.64
DMW	0.98	0.51	0.30	0.24	0.18	0.08	0.00
CW	0.44	0.01	0.01	0.00	0.00	0.01	0.00
N	216	215	212	209	206	194	182
JPY/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.08	1.08	1.08	1.05	1.02	0.82	0.57
MAFE_M/MAFE_RW	1.03	1.03	1.03	1.03	0.99	0.86	0.77
R2	0.04	0.01	0.00	0.02	0.03	0.45	0.79
DMW	1.00	0.96	0.87	0.75	0.58	0.13	0.08
CW	1.00	0.77	0.40	0.18	0.16	0.01	0.00
N	180	178	175	172	169	157	145
NZD/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.02	1.00	0.90	0.83	0.81	0.79	0.83
MAFE_M/MAFE_RW	1.01	1.03	1.01	0.96	0.94	0.88	0.91
R2	0.02	0.13	0.32	0.44	0.51	0.60	0.48
DMW	0.78	0.48	0.28	0.22	0.18	0.03	0.19
CW	0.08	0.00	0.00	0.00	0.00	0.00	0.00
N	208	206	203	200	197	185	173
SEK/USD	M1	M3	M6	M9	M12	M24	M36
RMSFE_M/RMSFE_RW	1.04	1.01	0.94	0.86	0.81	0.72	0.70
MAFE_M/MAFE_RW	1.01	1.00	0.97	0.94	0.91	0.84	0.83
R2	0.02	0.03	0.23	0.39	0.48	0.56	0.47
DMW	0.97	0.55	0.17	0.11	0.06	0.02	0.03
CW	0.91	0.17	0.02	0.01	0.01	0.01	0.00
N	166	164.	161	158	155	143	131

Note: The explanatory variables are US loans to non-financial corporations, the US price level, and loans to corporations and the price level of other countries given the chosen currency pair. The dependent variable is the h step forward difference of the given currency pair. The individual columns (Mx) denote the results for the x-month-ahead forecast. RMSFE_M/RMSFE_RW denote the ratio of the root mean squared forecast error of the model and the random walk benchmark. MAFE_M/MAFE_RW is the ratio of the root mean absolute forecast error of the model and the random walk benchmark. R2 is calculated as the squared correlation coefficient of the prediction and the actual realization of the exchange rate. DMW and CW denote the p-values of the Diebold Mariano and Clark-West statistics. N denotes the number of estimated forecasts. A *recursive* window approach was used for the estimation.

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