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Currency Valuation

A Medium-Term Horizon View

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ABSTRACT:

This thesis studies the medium-term horizon predictability of nominal exchange rate changes using a currency value signal. The currency value is derived from different purchasing power parity indicators. The goal of the thesis is to extend the prevailing currency value signal's short-term predictive content of excess currency returns, to medium-term horizon nominal exchange rate changes context.

Previous studies have examined the short-term predictability power of currency value over future excess currency returns. The literature has found that currency value strategies can generate abnormal returns on a short-term horizon, from one month to one quarter. Recently, studies about currency value have been employing purchasing power parity indicators to account for the currency value. To be precise, the five-year change in RER has emerged as a generally used indicator of currency value in the literature. The study contributes to the existing literature by answering the main research question of whether it is possible to predict future medium-term nominal exchange rate changes using currency value signals. In addition, the study accounts for the cross-sectional differences in the selected macro fundamentals to get a clearer measure of currency value which is not dependable on fundamentals of the economies.

The thesis starts the examination with regression analysis and further moves on to strengthen the results using portfolio sorts. Therefore, the regression analysis is used to find a positive relationship between the currency value indicator and subsequent nominal exchange rate changes. Then, the macro fundamentals are included to see if the predictability increases. After that, predictability is evaluated for different currency groups. Next, the portfolio sorts start from the short-term assessment to see if the results here are in line with the previous studies. Continuing to the hitherto unexplored area, the overlapping holding period portfolios are used to evaluate the medium-term horizon predictability. Lastly, the additional results provide a wide range view of the real exchange rate dynamics and the current state of the studied signal.

The results show that by accounting for the macro fundamentals, it is possible to enhance the currency value signal's predictable power for both short-term and medium-term horizons. Hence, the expected inflation differentials emerge as the most influential macro factor to account for when predicting the nominal exchange rate changes. In addition, the study finds that safe haven and emerging market currency groups have dissimilar expected future changes in the nominal exchange rates compared to the base group. Further on, the overlapping holding period portfolio sorts show that the unadjusted currency value signal is unable to beat a random walk, characterized by an equal weight market portfolio of sample currencies. Nonetheless, when adjusting the currency value signal, the performance increases significantly compared to the unadjusted signal. The additional results find that currently, the five-year change in RER power to predict the subsequent nominal exchange rate changes is poor.

KEYWORDS: currency value, value factor, purchasing power parity, real exchange rate, nominal exchange rate, asset pricing

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TIIVISTELMÄ:

Tämä tutkimus tutkii nimellisten valuuttakurssimuutosten keskipitkän aikavälin ennustettavuutta valuutta arvosignaalin avulla. Valuutan arvo mittari on johdettu eri ostovoimapariteetti indikaattoreista. Tutkimuksen tavoitteena on laajentaa vallitsevan valuutta arvosignaalin lyhyen aikavälin ennustesisältöä koskemaan keskipitkän aikavälin valuuttakurssimuutoksia.

Aiemmat tutkimukset ovat tutkineet valuutan arvofaktorin lyhyen aikavälin ennustamiskykyä kokonaisvaluuttatuoton ennustajana. Kirjallisuudessa on havaittu, että valuutta-arvostrategiat voivat tuottaa epänormaaleja tuottoja lyhyellä aikavälillä, kuukaudesta yhteen kvartaaliin. Viime aikoina valuutta-arvoa koskevissa tutkimuksissa on käytetty ostovoimapariteetti indikaattoreita valuutan arvon indikaattorina. Tarkemmin sanottuna viiden vuoden muutos reaalisessa valuuttakurssissa on noussut yleisesti käytetyksi valuutan arvon indikaattoriksi kirjallisuudessa. Tutkimus täydentää olemassa olevaa kirjallisuutta vastaamalla pääasialliseen tutkimuskysymykseen, onko mahdollista ennustaa tulevaisuuden keskipitkän aikavälin valuuttakurssimuutoksia valuutta-arvo signaaleilla. Lisäksi tutkimuksessa huomioidaan valittujen makrofundamenttien poikkileikkauserot, jotta valuutta-arvosta saadaan selkeämpi mitta, joka ei ole riippuvainen talouksien perustekijöistä.

Tutkimus aloittaa tarkastelun regressioanalyysillä ja jatkaa tulosten vahvistamiseen portfoliolajitteluilla. Regressioanalyysiä käytetään löytämään positiivinen suhde valuutan arvon indikaattorin ja sitä seuraavien nimellisten valuuttakurssimuutosten välillä. Sitten makrofundamentit otetaan mukaan tarkasteluun, ja tutkitaan, paraneeko ennustettavuus. Tämän jälkeen ennustettavuutta arvioidaan eri valuuttaryhmille. Seuraavaksi portfoliolajittelut alkavat ensin lyhyen aikavälin ennustettavuuden arvioinnista, jotta nähdään, ovatko tulokset linjassa aikaisempien tutkimusten kanssa. Sen jälkeen jatketaan toistaiseksi tutkimattomalle alueelle, päällekkäisten omistusjaksojen portfolioiden avulla arvioidaan keskipitkän aikavälin ennustettavuutta. Lopuksi lisätulokset tarjoavat laajan katsauksen reaalisen valuuttakurssin dynamiikasta ja tutkitun signaalin nykytilasta.

Tulokset osoittavat, että ottamalla huomioon makronfundamentit, on mahdollista parantaa valuutta-arvosignaalin ennustavaa tehoa sekä lyhyellä että keskipitkällä aikavälillä. Odotetut inflaatioerot nousevat vaikuttavimmaksi makrotekijäksi, joka on tarpeellista ottaa huomioon ennustettaessa nimellisten valuuttakurssien muutoksia. Lisäksi tutkimuksessa havaitaan, että turvasatama- ja kehittyvien markkinoiden valuuttaryhmillä on erilaiset tuotto-odotukset nimellisvaluuttakursseissa perusryhmään verrattuna. Päällekkäiset omistusjakson portfoliot osoittavat, että ei-mukautettu valuutta-arvosignaali ei pysty päihittämään markkinaportfoliota, joka on koostettu otantaan kuuluvista valuutoista yhtäläisillä painoilla. Siitä huolimatta valuutta-arvosignaalia mukautettaessa makrofundamenteilla suorituskyky paranee merkittävästi ei-mukautettuun signaaliin verrattuna. Lisätulokset osoittavat, että tällä hetkellä viiden vuoden muutos reaalisessa valuuttakurssissa on heikko estimaattori tulevien nimellisten valuuttakurssimuutosten ennustamisessa niin lyhyellä kuin keskipitkällä aikavälillä.

AVAINSANAT: valuutan arvo, arvo faktori, ostovoimapariteetti, reaalinen valuuttakurssi, nimellinen valuuttakurssi, omaisuuslajien hinnoittelu

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1 Introduction

Purchasing power parity (PPP) provides the main backbone for the currency valuation. In essence, PPP is a theoretical proposition asserting that tradable goods between economies should sell at the same prices when turned into a common currency. While the purchasing power parity is a theoretical proposition, the real exchange rate (RER) can be used to measure the PPP condition. Thereby, RER has been widely used in the previous literature to assess the currency value (Asness et al., 2013; Menkhoff et al., 2017). For instance, according to Menkhoff et al. (2015), the RER is broadly adopted by different parties operating in the international finance field, such as policy makers and market participants. In particular, the future currency returns are of interest to global multi-asset investors. Hence, the implications for future expected returns across asset classes are affected by the expected currency returns. Therefore, the strategic allocation between over and undervalued currencies is important to consider.

Currency value can refer to any indicator that can be seen to measure currency valuation. Starting from Frankel's (1979) real interest rate model to the more recent innovation of a five-year change in RER indicator developed by Asness et al. (2013), the bottom line is the notion of quantifiable fundamental misalignment of the currency. The notion of over or undervaluation alone only tells how much the currency should move in one direction to balance the prevailing situation. However, in practice, over or undervaluation can be very persistent. For example, Rogoff (1996) states that the “PPP puzzle” stems from the fact that the misalignments from the equilibrium level of RERs are absorbed very slowly. As a result, RERs have been seen to be inaccurate measures of PPP in the short-term, whilst in the long term, RERs are believed to converge toward the PPP. The conversion, or mean reversion, toward the PPP equilibrium, is a key concept in this study also. Hence, the currency value based on RERs relies strongly upon the notion of mean reverting exchange rates, which counterbalance the RERs in the long-term.

1.1 Purpose of the study

The main motivation of this study is to examine nominal exchange rate predictability on a medium-term horizon by applying different PPP indicators. In addition, the extent of predictability is examined and how long does it take for an indicator to revert to the equilibrium or long-run mean value. Then, the predictability is examined for different currency groups to see whether the predictability is different across the currency groups. Special caution should be allocated to the fact that determining the right equilibrium level can be difficult to assess, and secondly, there is no universal model to obtain the equilibrium. Importantly, Taylor and Taylor (2004) puzzle the reversion phenomenon and concern if the appropriate questions are instead what the initial deviation was and to which level the RER is reverting now. For instance, the long-rung mean value of RER has been used to approximate the equilibrium level between economies.

The contribution of the thesis is to evaluate the nominal exchange rate predictability in the five-year horizon using currency value indicators obtained from the RER. Recent studies about currency value have been emphasizing the short-term predictability power of the signals, nonetheless, medium-term predictability has been covered only hollow manner. Therefore, the main emphasize of the thesis is to evaluate the medium-term horizon predictability more closely. Especially, the medium-term horizon is of interest to global multi-asset investors. Swinkels and van der Welle (2023, p. 22) outline in Robeco's five-year expected returns outlook that when considering the local-currency emerging debt valuation levels in the medium-term, the local currencies' valuations cannot be forgotten. Hence, currency appreciation or depreciation affects the expected investment outcome through the exposure of a currency. The authors continue (p. 31) that investors can hedge the currency exposure, however, this comes with a cost which is dependable on the interest rate differences between the economies. Thus, the issue left to solve is how fast the over or undervaluation of a currency will vanish, to decide the optimal currency exposure and potential hedge.

The predictability of plain currency value indicators is tried to increase by accounting for the economies' cross-sectional differences in selected macro fundamentals. The medium-term horizon predictability is studied using various regression models and overlapping holding period portfolios. To the author's knowledge, the thesis is the first to combine overlapping holding period portfolios with currency value strategies to account for the medium-term predictability. In addition, the thesis concerns whether the model estimated is universal for all currencies and whether the predictability's convergence speed is the same for all currencies.

The thesis follows previous currency value literature by examining the RER level and five-year changes in RER as currency value indicators. Generally used portfolio construction of currency value portfolios is used in the thesis to evaluate the signals' predictable power. The main study the thesis follows is the Currency Value paper by Menkhoff et al. (2017), in which the authors conducted a similar predictive regression analysis of excess currency returns on the five-year change in RER and selected macro fundamentals. Later on, the authors construct different currency value portfolios to examine the predictable power in an out-of-sample manner. However, the key distinction is that the thesis focuses on the nominal exchange rate changes in the medium term rather than the excess currency returns in the short term.

The thesis is different from earlier literature by examining the medium-term horizon predictability and conducting a subsample analysis of the predictable power of different currency groups. Recent previous literature has focused heavily on the G10 currency group or a group of developed economies (Ca' Zorzi et al., 2022; Dahlquist and Pénasse, 2022; Nakagawa & Sakemoto, 2023). By including the currencies from both developing and developed countries, the thesis aims to yield more reliable and robust results. Besides, the sample of currencies is akin to the sample selection in the Currency Value paper by Menkhoff et al. (2017). The thesis takes a different stance of evaluating the predictability over time, hence observing the strongness or weakness of the currency value signal currently. A similar stance has been taken in the recent paper by Hutchinson et al. (2022), who show that the current state of currency factor premium is zero.

1.2 Hypotheses

This section of the study covers the examined research questions and related hypotheses. The first research question relates to nominal exchange rate predictability in the medium-term horizon. Consequently, how well PPP indicators can forecast the subsequent 20 quarters' horizon nominal exchange rate change? The variable of interest is the five-year change in RER, denoted as $\Delta^{(5y)}q_{j,t}$, and τ_{t+1} denotes time-fixed effects. The corresponding hypotheses are stated as follows:

Regression model: $R_{j,\prod_{i=1}^{n=20}(1+R_i)-1} = \alpha + \beta\Delta^{(5y)}q_{j,t} + \tau_{t+1} + \upsilon_{j,t+1}$

H0: $\beta_1 = 0$

H1: $\beta_1 \neq 0$

Similarly, related to the first research question, the thesis concerns whether predictability can be enhanced and extended by including additional macro fundamental factors as control variables in the regression. The key idea is that after including the macro fundamentals in the regression as control variables, the overall predictability is enhanced. Hence, the hypothesis includes a restricted model including only a five-year change in RER and an unrestricted model including macro fundamentals as control variables. The control variables X denotes the control variables. The inference is based on heteroscedasticity robust F-test. In total, there are five different macro fundamentals included, the Harrod-Balassa-Samuelson effect (HBS), output gaps (OG), net foreign assets (NFA), real interest rate differentials (RDIFF), and expected inflation differentials ($E\pi$). All the macro fundamentals will be explained more thoroughly as the study progresses. The restricted and unrestricted model and hypotheses are stated as follows:

Restricted regression model:

$$R_{j,\prod_{i=1}^{n=20}(1+R_i)-1} = \alpha + \beta \Delta^{(5y)} q_{j,t} + \tau_{t+1} + \upsilon_{j,t+1}$$

Unrestricted regression model:

$$R_{j,\prod_{i=1}^{n=20}(1+R_i)-1} = \alpha + \beta \Delta^{(5y)} q_{j,t} + \gamma X_{j,t} + \tau_{t+1}$$
$$+\upsilon_{j,t+1}$$

H0: $\gamma_j = 0 \; \forall \; j = HBS, OG, NFA, RDIFF, E\pi$

H1: $\gamma_j \neq 0 \; \forall \; j = HBS, OG, NFA, RDIFF, E\pi$

Previous studies have found a positive and statistically significant relationship between lagged RER and currency excess returns (Asness et al., 2013; Kroencke et al., 2014; Menkhoff et al., 2017; Nakagawa & Sakemoto, 2023). While the previous studies have focused heavily on the excess currency return predictability in a short-term horizon, for instance, one month to one quarter, the thesis focuses on nominal exchange rate change predictability and medium-term horizon. The alternative hypothesis states that the thesis expects the RER to work as an explainable factor of the nominal exchange rate changes in the medium-term horizon. The alternative hypothesis is motivated by the earlier findings that the nominal exchange rate changes counterbalance the fluctuations in the RER rather than the price differentials (Ca' Zorzi et al., 2022). The alternative hypothesis related to the second research question denotes that including the macro-fundamental factors, the overall predictable power is expected to grow (Menkhoff et al., 2017).

The third research question is related to different types of currencies. To be precise, do different currency categories, such as safe haven or commodity currencies, have abnormal expected return characteristics based on the PPP indicator and is there a detectable equilibrium? The third research question examines a period-by-period long-horizon regression model and a cumulative change model which requires estimating one regression equation. By using both regression approaches, the thesis reaches a more robust view of the overall differences in predictability between different currency groups. The model and corresponding hypotheses are stated as follows:

Regression models:

$$R_{j,t+h} = \alpha_h + \beta_h \Delta^{(5y)} q_{j,t} + \gamma_h X_{j,t} + \delta_h R_{j,t} + \theta_h D_{j,t} + \beta_h (D_{j,t} * \Delta^{(5y)} q_{j,t}) + \tau_{t+1} + \upsilon_{j,t+h}$$

$$R_{j,\prod_{i=1}^{n=20}(1+R_i)-1} = \alpha + \beta \mathit{\Delta}^{(5y)} q_{j,t} + \gamma X_{j,t} + \theta D_{j,t} + \beta (D_{j,t} * \Delta^{(5y)} q_{j,t}) + \tau_{t+1} + \upsilon_{j,t+h}$$

Related hypotheses:

3A:

H0: $\beta_{Base\ currencies} = \beta_{Commodity}$

H1: $\beta_{Base\ currencies} \neq \beta_{Commodity}$

3B:

H0: $\theta_{Base\ currencies} = \theta_{commodity}$

H1: $\theta_{Base\ currencies} \neq \theta_{commodity}$

The alternative hypotheses state that safe haven, commodity, and emerging market currencies have different underlying characteristics driving the PPP indicator’s predictive characteristics. In addition, the impact of a currency belonging to a specific group has a meaningful implication for the five-year change in the nominal exchange rate change. Dahlquist & Pénasse (2022) find no evidence supporting the differences in currency excess returns predictability, based on RER and nominal interest rate differential, between different types of currencies. However, the authors examine the G10 currencies using individual time-series regressions and observe the predictability characteristics in that way. The thesis extends the different currency groups' predictability by applying the interaction term between the PPP indicator and currency group dummy variable in the regression model.

1.3 Structure of the study

The rest of the thesis is categorized as follows: First, the theoretical framework is presented, covering PPP theory as well as challenges, and the RER framework. Then, previous literature is presented. Next, the data and methodological design of the study are presented. Afterward, the main results of the study are presented, and a chapter about additional results. Lastly, the conclusions are drawn based on the results.

2 Theoretical framework

This chapter introduces the theoretical framework used in this thesis. First, the PPP theory is presented. Next, the chapter covers the reasons behind the disparities in the PPP condition. Lastly, the chapter introduces RER which is used to measure PPP, and in that way, works as a backbone currency value indicator in the thesis.

2.1 Purchasing power parity

According to Dornbusch (1985) most commonly used, PPP is a theory of exchange rate configuration. PPP holds the assumption that the observed exchange rate fluctuations are due to the price level changes in countries. Or as Brealey et al. (2020) put it, fundamentally PPP indicates that the future price change of goods between countries will be offset by the changes in nominal exchange rates. The relationship can be rearranged as a new equation in which the expected spot rate depends on the product of the current spot rate and expected inflation differentials. Specifically, $E(s) = s_t * \frac{1+\pi_{foreign}}{1+\pi_{domestic}}$. Rearranged equation gardens the future expected spot rate in a simple form, hence, the only approximation that needs to be carried out is to forecast inflation.

The theory of PPP holds two subvariants, absolute and relative. The absolute version also called the strong version, defines the law of one price (LOOP) in a frictionless and integrated market. If LOOP holds, then the exchange rate between two countries can be expressed as P/P^* in which P represents the domestic price level and P^* foreign price level. The price levels can be baskets of goods if the goods weighing and basket constitution are homogeneous between countries. Importantly, the outcome of absolute PPP condition is that no matter what the real economy or monetary disturbances in the nation are, the ongoing costless arbitrage will eliminate the disparities between baskets of goods and the equilibrium between countries takes a form $\frac{P}{e * P^*} = 1$, where e stands for the exchange rate (Dornbusch, 1985).

Absolute PPP stands out as a theoretical framework. Empirically, the proposition of the absolute form of PPP faces challenges. For example, in real life, different obstacles are preventing the absolute PPP from happening. For instance, transportation costs, tariffs, and quotas among others are everyday phenomena. Nevertheless, the imperfection of absolute PPP is not devastating, as it could straightforwardly imply that moving homogeneous goods or commodities from one place to another instantaneously and costless is not happening. In addition, there are costs related to information and impediments to trade preventing spatial price equalization. However, the impediments to trade do not imply that the common currency prices across goods in different places must be equalized in the first place (Dornbusch, 1985).

The relative form of PPP modifies the PPP proposition to incorporate barriers or obstacles into the equation. Therefore, the PPP gets the formation of $e = \theta P/P^*$ in which the θ stands for a constant, depicting the trade barriers. As a result, when the barriers are included, the increasing domestic price level compared to the foreign price level leads to an equal amount of depreciation of the home currency as $\hat{e} = \hat{P} - \widehat{P^*}$ and ^ refers to percentage change (Dornbusch, 1985).

The original absolute PPP condition meant to hold for a general basket of identical goods measured in various currencies. Consequently, the relative PPP is hardly a way of purging the transport costs or tariffs into the PPP equation. However, in practice, the PPP is usually derived using the Consumer Price Index (CPI), Wholesale Price Index (WPI), or Gross Domestic deflators. Usage of price indices leads to a violation of the LOOP condition because the indices between countries are not perfectly identical. Identicality is a problem, especially for non-tradable goods. Therefore, when the indices' compositions are not the same, the LOOP condition cannot serve anymore as a justification for PPP (Dornbusch, 1985).

Dornbusch (1985) argues that PPP as a theory of an equilibrium condition must hold an adjustment mechanism. For identical goods the solution is spatial arbitrage, meaning exploiting the price differences in different geographical locations. But for non-identical goods, the situation is another. Above all, substitutable goods play a crucial role in world trade, and through substitutability, the exchange rate-adjusted prices are thought to align internationally. However, one caveat lays in the causation relationship between prices and exchange rates. For instance, exchange rates may adjust to prices, but the exchange rate depreciation can be seen as a source of inflation, too.

Engel (1999) examines the non-tradable component with different estimators. First, the author incorporates the non-tradable component into the RER. The foreign country price index can be defined as follows:

$$P_t^* = (1 - \beta) * p_t^{T*} + \beta * p_t^{N*} \tag{1}$$

Where P^* stands for the log foreign price index and the superscripts *T* and *N* denote the tradable and non-tradable price log indices, respectively. β is the non-traded goods piece in the overall index. The above equation 1 implies that the overall price index is constructed from two compelling parts, namely tradable and non-tradable components.

2.1.1 Disparities

Deviations from the PPP can be separated into structural and transitory. The structural deviations refer to systematic changes in the underlying equilibrium dynamics. For example, structural deviation can occur as a response to a persistent change in relative price level. On the other hand, transitory deviations are largely due to dissimilar adjusting speeds in goods and assets markets. Notably, the deviations indicate that even the weak form of PPP is unable to meet the parity closely. Furthermore, primary reasons for the structural and transitory disparities can be categorized into three compelling parts.

First, habits in trade can change the underlying terms of trade. Second, when the economy grows in terms of GDP, the effect can be seen in the relative prices of domestic goods as well as in the globally traded goods. Lastly, inflexible wages and prices affect real price ratios and PPP violations when there are fluctuations in monetary and exchange rates (Dornbusch, 1985).

One potential explanation for the structural deviations is the theoretical framework of Ricardo-Harrod-Balassa (RHB), or Harrod-Balassa-Samuelson (HBS), effects. The theory framework begins to examine the domestic economy that produces two types of goods, home goods and global goods. Overall, the theory assumes that markets are competitive and there are constant returns available. These two assumptions further suggest that the prices for goods are driven by the unit labor costs. In addition, the relative consumer price level between domestic and foreign economies, measured in general currency, can be stated as P/eP^{*}. Now, considering the domestic global goods sector, productivity is growing, and wages are increasing in those particular sectors as well. Then, the home goods sector's productivity stays rather flat but the workers in these sectors demand wage increases also because the economy-wide wages must be equalized. However, there is a fundamental difference between increasing the wage in the global and home goods sector. Consequently, since productivity increases in the global goods sector, the wage increases do not affect the economy's relative price level. On the other hand, the home goods sector increases wages without productivity gains which leads to higher workforce costs and increased product prices. The outcome is a higher overall price level of an economy. Since the LOOP condition holds among the global goods and by assumption, the nominal exchange rate has not been changed to match the price level increase, the currency of the economy appears overvalued now. Finally, the domestic and foreign nations' productivity in the global goods sector can have a competitive advantage. Systematic variations in the competitive advantages alter the RER level. Hence, growing demand for a country's global goods tends to shift the PPP level higher (Dornbusch, 1985; Lothian & Taylor, 2008). The thesis measures the HBS effect using real GDP per capita.

Dornbusch (1985) argues that transitory disparities in PPP equilibrium can often be relatively persistent and large. Transitory deviations may occur due to different natures of wages and nominal exchange rates. Furthermore, while exchange rates act more like asset prices, the wages are stickier and often set for long horizons at once. The gap between wages and exchange rate settling leaves room for prices to deviate from the PPP. Nevertheless, the sources for transitory disparities cover a wide range of other factors besides the price stickiness. Now, the assessment shifts more toward the economic factors that can explain the short and medium-horizon disparities in the PPP.

According to Jahan and Mahmud (2013) The business cycle of an economy can be measured with output gaps. Moreover, the output gaps approximate whether the economy's output, for instance real GDP, is above or below the long-run potential real GDP. Thus, a positive output gap indicates that the economy is currently producing more than the long-run potential real GDP suggests but also, that demand for goods is at a high level. Besides, the positive output gap can indicate a heating economy, potentially leading to higher inflation in the future. Therefore, the output gaps work as a tool for central banks to assess the labor and monetary policy targets. To reconcile, the unemployment rate of zero means that the output gap is zero. Further, central banks often have an inflation targeting agenda and the output gap is an important indicator of inflationary pressures in the economy.

Menkhoff et al. (2017) argue that output gaps are essential driver of RERs because of the underlying relationship to central banks' actions, for instance as outlined above. The thesis measures the output gaps similarly as Cooper and Priestley (2009). Therefore, the procedure for approximating the output gaps includes running a recursive expanding window regressions in which the production, here real GDP per capita, is regressed on linear and quadratic time trends. The equation below specifies the output gap measurement:

$$y_t = a + b * t + c * t^2 + v_t \tag{2}$$

In the above equation, t is the time trend, t^2 is a quadratic time trend, and the v_t represents the error term, which is the estimation of the current output gap.

Previous literature has found that global imbalances in asset positions of the countries affect the RER. In a nutshell, economies having large net liabilities to foreign countries tend to preserve a weaker RER. This weakness is associated with the risk premiums the country must obtain but also for domestic low-price levels of non-traded goods (Menkhoff et al., 2017). Besides, Lane and Milesi-Ferretti (2004) study the co-movement between RERs and net foreign assets (NFA) of economies. The authors reach a conclusion suggesting that debtor countries have more depreciated RERs, and the main channel through the co-movement happens is the relative price differences of the non-tradable goods. The long-run relation between RERs and NFAs, called transfer effect, depends on economy's characteristics such as the size of an economy and foreign exchange restrictions. Thus, the thesis uses NFAs to account for the changes in global imbalances which might influence RERs.

2.2 Real exchange rate

The RER is an essential piece of the thesis's empirical examination. For instance, according to Taylor and Taylor (2004) RER as a currency value has been argued to capture the disparities from the PPP. However, the authors continue to be concerned about what is the appropriate equilibrium level of PPP. Despite the concerns, in the spirit of Menkhoff et al. (2017), the thesis defines the RER as follows:

$$Q_t = \frac{P_t}{S_t * P_t^*}$$

(3)

Where Q refers to RER, S refers to the nominal exchange rate quoted as US dollar per unit of foreign currency, P refers to the domestic price level, in this case, US, and p^* refers to the foreign price level. Price levels are measured as CPIs. The higher Q, the stronger the United States dollar.

Another way to construct the RER is to use another price measurement instead of CPI. For instance, Koedijk and Schotman (1990) use the wholesale price index (WPI) as an approximation of the tradable goods in the overall CPI. Burstein et al. (2006) refer to the non-tradable goods problem as a distribution cost issue and consider the Producer Price Index (PPI) as a relevant proxy of non-tradable goods. However, the caveat with PPI is that it does not include imports and exports. Notwithstanding, Engel (1999) constructs tradable and non-tradable price indices using PPI and CPI, respectively. Therefore, the thesis constructs an RER using the PPI as an approximation of a better tradable price index for robustness check alongside the CPI-based RER used in the main analysis.

2.2.1 Present value formula of the real exchange rate

Engel and West (2005) and Froot and Ramadorai (2005) develop a present-value formulation of the RER. This present value formation allows an investment-like approach in which the RER is effectively driven by three distinctive terms.

The currency excess return is measured as follows:

$$rx_{t+1} = -(q_{t+1} - q_t) + (ri_t^* - ri_t)$$

(4)

Where q is used to depict the log of the RER and ri and ri^* are domestic and foreign real interest rates, respectively (Menkhoff et al., 2017). Then rearranging the equation 2:

$$q_t = rx_{t+1} - (ri_t^* - ri_t) + q_{t+1} \tag{5}$$

Now, the current RER depends on the subsequent excess returns, real interest differential, and expected RER. Menkhoff et al. (2017) iterate forward the equation take conditional expectations of equation 5 and obtain a final model. Above all, the RER depends on expected currency excess returns or expected currency risk premiums, real interest rate differentials, and long-term expected RER.

$$q_t = \sum_{h=1}^{\infty} [E_t[rx_{t+h}] - E_t[ri_{t+h-1}^* - ri_{t+h-1}] + E_t[q_{t+\infty}]] \tag{6}$$

Most notably, the relationship between currency risk premiums and current RER should be clearer, when controlling for the forces affecting the real interest rate differential and long-term RER. Therefore, the focus is shifted to assessing the macro-fundamental factors that are important for real interest rates and long-term RER determination. This thesis follows Menkhoff et al. (2017) by identifying the HBS effect, output gaps, and net foreign assets as drivers of the real interest rate differentials and long-run value of RER.

3 Literature review

This chapter includes a previous literature review about important topics for the thesis. In addition, understanding the previous literature is of great interest since it builds a basic understanding of the topic and reviews the main contributions done so far. The chapter is organized as follows. First, the chapter covers the studies about currency value indicators. Then, the currency value premium is reviewed. Also, phenomena about different currency types are encompassed. Next, the relationship between RER and macro-fundamentals is covered. Lastly, the mean reversion of the purchasing power parities is revised.

3.1 Currency value indicators

Currency value can be measured with different metrics. According to De Zwart et al. (2009), certain types of currency investors, namely fundamentalists, believe that the fundamental value of a currency is connected to the macro-fundamental factors. For example, Gross Domestic Product (GDP) change, inflation, output gaps, and trade balances, out of many, may influence the nominal exchange rate.

Frankel (1979) names two appealing concepts to understand the currency exchange rate from an asset view. In particular, the asset view explanation for the exchange rate is to move to settle the international demand for publicly traded assets. The first of the two approaches, called Frenkel-Bilson, is to assume that the prices in the economies are flexible. Then, what happens is that the nominal interest rate moves in response to the expected price changes. Further, when the interest rate is anticipated to rise against the foreign counterpart, it is due to the home currency's expected value decrease via depreciation and inflation. The lower demand for the home currency relative to the foreign currency starts the depreciation spiral immediately. The outcome is that the price of foreign currency becomes more expensive. Lastly, the relationship between the nominal interest rate differential and the exchange rate is positive. The other theory, called

Dornbusch, starts with an assumption that in the short run, prices are sticky, however, in the long run, the stickiness assumption can be eased. The keynote relates to a contraction in the domestic money supply compared to the demand that should spark a fall in prices but due to sticky prices, the mechanism does not work. Moreover, the nominal interest rates are moving because of the tightening monetary policy changes. A higher interest rate compared to a foreign one attracts foreign capital inflows to domestic assets. Then, inflows increase the demand for the domestic currency which appreciates immediately. As a consequence, the price of foreign currency gets cheaper, and overall, the relationship between the nominal interest rate differential and the exchange rate is negative.

Frankel (1979) combines the Frenkel-Bilson and Dornbusch approaches to a real interest rate model capturing the currency value. The model allows sticky prices but also confesses that there is a long-run mild inflation. Now, the exchange rate is positively related to long-run inflation but inversely to the nominal interest rate differential. The bottom line is that the exchange rate differs from the equilibrium level proportionally to the real interest rate differential. Thus, the real interest rate differential is a useful concept to assess the exchange rate valuation because if the real interest rate differentials between countries are not equal, there may be under or over-valuation, respectively.

De Zwart et al. (2009) use two compelling macroeconomic factors to account for the fundamental value of a currency. GDP changes and the real interest rate differential are employed. The first measure of the currency value, GDP change, is used because the higher GDP growth attains investors attraction. As a result, the capital inflows to the country increase leading to growing demand for the country's currency which leads to appreciation in the value of currency. The second factor, the real interest rate differential signals the undervaluation of the foreign currency if the economy's real interest rate differential is higher than the domestic one.

Asness et al. (2013) put forward a new era of currency value indicators. In the article, the authors define the value signal for a currency based on a five-year change in the PPP. The original idea of using the PPP as a currency value indicator is not new. However, the problem with using an absolute PPP is that the equilibrium PPP is hard to identify. There can be structural and transitory deviations from the PPP. Especially, the earlier mentioned HBS effect can change the observed equilibrium level from one to anything. To tackle the equilibrium identifying issue, researchers can use the relative change of the PPP indicator. In this way, the movement can be separated from the underlying equilibrium.

Kroencke et al. (2014) and Nakagawa and Sakemoto (2023) examine different currency investment strategies at a portfolio level by allocating weights between the strategies. One of the currency strategies is called fundamental currency value which relies on mean-reversal exchange rates in the long run. Consequently, both articles define the value signal as the cumulative five-year change of the RER. Kroencke et al. (2014) evenly coin the strategy as a long-term reversal or contrarian strategy. Furthermore, fundamental currency value is therefore inevitably linked to the PPP condition.

Ranganathan et al. (2023, forthcoming) study integrated currency portfolio combinations. The authors developed an optimal strategy that involved the pronouncing of cross-sectional currency factors. One of the currency factors that the study uses is the value factor. Nonetheless, the currency value factor is not generally determined and that is why the article needs to approximate the fundamental value of a currency. Furthermore, the authors define the currency value factor based on the PPP condition. Specifically, the RER can be used to assess the over or undervaluation of a currency relative to another. The author decides to use a five-year change in the PPP indicator.

Overall, the indicator of a fundamental currency value measured by the five-year change in RER shares great similarities with De Bondt and Thaler (1985) and De Bondt and Thaler (1987) long-term reversal factor in the US stock market. The authors examine in the previously mentioned two articles a stock market investment strategy that sorts stocks based on the five-year previous returns. Going forward, the loser stocks, based on the five-year previous returns, tend to outperform past winners. In effect, the so-called loser's outperformance is long-lasting, hence even after five years the losers outgain the winners. The articles' sharing conclusion is that investors tend to overreact to short-term news and announcements, consistent with the behavioral assumptions of investors' reactions.

Ca' Zorzi et al. (2022) evaluate the predictive power of equilibrium exchange rate models over future RERs as well as nominal exchange rates. The authors use the initial misalignment from the equilibrium model as an explanatory variable. Interestingly, this is a somewhat different approach compared to the relative RER value indicator. As a result, the authors find that the deviations from the long-run mean value of RER successfully forecast both future nominal exchange rate changes and RERs.

Table 1. Currency value indicators.

The table below presents the latest studies and the usage of currency value indicators.

Indicator	**Previous literature**
Relative PPP (Change in RER)	Asness et al. (2012), Kroencke et al. (2014), Menkhoff et al. (2017), Baltussen et al. (2021), Nakagawa & Sakemoto (2023), Ranganathan et al. (2023, forthcoming)
Absolute PPP (RER level)	Menkhoff et al. (2015), Baltussen et al. (2021), Ca' Zorzi et al. (2022), Dahlquist and Pénasse (2022)
Real GDP growth differentials	De zwart et al. (2009)
Real interest rate differentials	Frankel (1979), De zwart et al. (2009)

3.2 Currency value premium

Menkhoff et al. (2017) examine the currency valuation and currency risk premiums with the RER indicator. Further, the authors are interested to know if the RER can predict future currency returns, and if proven so, to what extent the predictability can be separated to concern future fundamentals and potential currency risk premiums. Lastly, the study examines the value indicator's translatability into investment decisions. The study applies the formation of present value representation of RERs to examine the underlying factors affecting the currency risk premium and forecasting ability of RERs. Consequently, the formula depicts the RER because of real interest rate differential, expected currency returns, currency risk premiums, and lastly the long-term expected RER. The authors assume the expected long-term RER to reach the unity level, so the term gets a value of 0. This assumption of unity comes with a caveat because it does not allow finite discrepancies between countries' equilibrium PPP levels. The contribution of the study is to adjust the RER for the macro-fundamentals which are connected to the real interest rate differential and the long-term expected RER. Therefore, the macro-economic factors of interest are the HBS effect, which is depicted using real GDP per capita, export quality of a country, net foreign assets, which tries to capture the net foreign wealth of a country, and finally output gaps.

Menkhoff et al. (2017) can amplify the predictability of RER as a future excess currency returns predictor using selected macro-fundamental factors as control variables. Hence, the macro-fundamental factors capture the expectations related to the future real interest rate differential. In this manner, the relationship between the currency risk premium and RER is better isolated in the regression. The authors use a panel regression with time-fixed effects and the data spans from 1976 Q1 to 2014 Q1. In addition, the sample consists of 22 currencies quoted against the US dollar. The regression model regresses excess currency returns on lagged five-year change in the RER and control variables. Further, the benchmark regression result uses the lagged five-year log RER change as an independent variable.

Menkhoff et al. (2017) continue the predictability of currency value premium examination further with a long-run regression model. The model regresses future excess returns on lagged five-year RER change and control variables, now including the lagged dependent variable. The forecast horizon is from one quarter to 20 quarters. The slope coefficient of interest is the lagged five-year log RER change, and this slope represents the impulse response function of currency excess returns to lagged five-year RER change. At the same time, the model holds the macro-fundamental factors constant. By definition, this type of model is known as local projections, developed by Jorda (2005). Similarly, the authors obtain results indicating more persistent predictability when macro-fundamentals are controlled. Consequently, the resulting predictability with controlled macro-fundamentals extends to approximately two years compared to one year obtained without additional control variables.

Menkhoff et al. (2017) extend the predictability relationship eventually onto the currency portfolio level. Furthermore, the unadjusted RER signal is used to divide currencies into different bins according to the cross-sectional distribution of the signal. Results from the portfolio sorts are economically significant, with Sharpe ratios ranging from 0.44 to 0.51. Yet, the largest finding comes when the authors use cross-sectional regressions to purge the impact of macro fundamentals out of the RER signal. As a result, the regression residual represents residual currency value when macro fundamentals are controlled. After the regressions, portfolios are formed based on the overall, fitted, and residual signals. The residual signal substantially outperforms the other two signals. However, the outperformance is rather driven by lower volatility and drawdown control than higher returns.

Dahlquist and Pénasse (2022) examine the relationship between currency risk premium, real interest differential, and RER. Likewise, Menkhoff et al. (2017), the authors use the present value formula of RERs. Albeit the authors reframe the present value formula by allowing the risk premium to depend on a latent component, namely missing risk premium. The sample consists of G10 currencies quoted against the US dollar spanning from

January 1976 to May 2020 monthly. The examination starts with predictable regressions where currency excess return is explained by interest rate differential and current RER level. Results show that higher interest-bearing currencies tend to have higher subsequent returns. Above all, the following state-space model estimations suggest that the missing risk premium is largely responsible for the movements in the RER and unexpected currency returns. Notably, Balduzzi and Chiang (2020) come to the same conclusion that the currency risk premiums are largely accountable for the variation in the RERs. Additionally, the results of Dahlquist and Pénasse (2022) are cohesive when allowing the long-term exchange rate to be constant or time-varying.

Table 2. Previous studies of the currency value premium.

The table below presents the studies that have examined the currency value premium. The first column denotes the author/s and studies signal. The second column presents the t-statistics related to the observed currency value premium. The third column presents the risk-adjusted return, denoted as Sharpe ratio, that the study finds. The last column presents the sample period that the study use.

Author/s and indicator	**t-stat**	**Sharpe**	**Sample period**
de Zwart et al. (2009) Relative GDP growth rates	4.49	1.39	199701 - 200706
de Zwart et al. (2009) Real Interest Rate Differentials	3.32	1.02	199701 - 200706
Asness et al. (2013) Five-year change in RER	1.89	0.34	197911 - 201107
Menkhoff et al. (2017) Five-year change in RER	2.71	0.44	197603 - 201403
Baltussen et al. (2021) Combination of relative and absolute PPP	1.03	0.09	180001 - 201612

3.2.1 Currency characteristics

Lee (2017) identifies safe-haven currency as being an extremely popular choice to allocate investments during a market turmoil. The idea behind the popularity is that safe haven currencies are assumed to correlate negatively with risky assets. In addition, the safe haven currencies can provide a hedge for the investors also during the normal market conditions.

According to Bork et al. (2022), commodity currency refers to a currency that is issued by a government that has a major exposure to the commodity export sector. Furthermore, the co-movement between currency exchange rate and commodity price index is notable. Specifically, the commodity currency hypothesis states that the commodity export prices are forecasted by the exchange rates for those countries that have high exposure to the export sector.

Chen et al. (2010) find that commodity currency exchange rates have predictable power over global commodity prices. The authors define Australian, Canadian, and New Zealand dollars as well as the South African rand and Chilean peso as potential commodity currencies since these nations get income between one-fourth and over one-half from commodity exports. Consequently, there seems to be an inverse relationship also, however, a less robust one. The author's reasoning for the relationship's less robust inverse nature is that the currency exchange rates pose longer-term horizon information whilst the commodity prices are exposed to more short-term imbalances in demand and supply. The article suggests that the pricing takes place when market participants correctly anticipate the future commodity market shocks which are then translated into the exporters' currency exchange rates. The commodity markets can be quite inflexible and less organized as well as more regulated than exchange rates. Hence, the currency exchange rates appear to be the proper choice of future estimates over commodity price indices.

3.3 Purchasing power parity indicators and macro-fundamentals

Previous studies have been arguing that macro-fundamentals provide only a little explanation of the RER fluctuations. According to Meese and Rogoff (1988), real interest rate differentials and RERs do not have a stable relationship. Moreover, the interest differentials seem to have no predictable power over the RERs. Nevertheless, the authors state that real shocks have a potentially great impact on the observed exchange rate volatility. In addition, Breitenbach et al. (2020) study the relationship of real interest rate differential and RER differential in countries with heterogenic inflation targets. The sample accounted for a large panel of countries, 12 who had adopted a similar inflation target, over time from 1993 to 2018. The authors conclude that the examination does not find clear evidence that the relationship is different from that of the countries with dissimilar inflation targets. Finally, the study suggests that real interest differentials are poor predictors of RERs.

Itskhoki and Mukhin (2021) argue that the nominal and RER go hand in hand and the driver for the fluctuations is shocks in financial markets. In addition, the authors tackle the Backus-Smith puzzle, meaning that the overall consumption and the RER have a go-parallel relationship. As a result, the findings confirm that the relationship between RER and consumption is negative. The reasoning for the outcome is that when the RER depreciates, global consumption shifts toward domestic goods. The effect is known as home bias.

Controversially, earlier literature has also been identifying important macro-fundamental factors that affect the observed RER level. Moreover, expectations about inflation and nominal interest rates play a crucial part in determining the level of the RER level through the nominal exchange rate. In the same manner, Devereux (1997) research the question of whether macro-economic factors affect the observed RER level. The author covers vast research on the topic and finds that price stickiness and nominal exchange rate fluctuations cover the majority of the RER volatility. Furthermore, Ugurlu and Razmi (2023) find statistically and economically significant results that RER undervaluation is associated with an increasing share of non-tradable sector output, import intensity of exports, and capital account openness. Contrarily, Menkhoff et al. (2017) argue that the higher quality of a nation’s exports will lead to stronger RERs. The author's reasoning behind this is the discrepancies between nations’ price levels differ because of the different quality of the traded goods. Lane and Milesi-Ferreti (2005) find that the net asset positions of a country have an impact on the observed RER level. As a result, the more positive the net asset position is, the stronger the RER.

Continuing, the productivity of a nation has implications for the observed level of the RER. According to Harrod (1933) and Samuelson (1964), nations that have higher productivity rates tend to experience stronger real effective exchange rates. Further, the exchange rate indicated by the PPP is too low for high productive countries persistently. For that reason, some previous studies about RERs have excessively focused on productivity differences between nations as an explainable factor of RER fluctuations of the equilibrium level and reversions back to the equilibrium (Sager, 2006; Lothian & Taylor, 2008; Chong et al., 2012; Boero et al., 2015).

3.4 Mean reversion of the purchasing power parities

Lothian and Taylor (2008) examine RERs' equilibrium level and the speed of convergence toward the indicated equilibrium. The article points out three different research problems. Specifically, the authors are interested in the real effects, denoted as the HBS effects, of the RER and convergence speed in a non-linear setting. Lastly, the RER variation is examined through changes in nominal exchange rates. The study's time series covers the years from 1820 to 2001. In addition, the sample consists of the United States, United Kingdom, and France, and rates under consideration are pound sterling-dollar and franc-pound sterling. The authors use exponential smooth transition autoregressive models for modeling correctly the non-linear relationships. The method allows a smoothing parameter to change across the time-series and to better adapt the non-linear relationships. The authors estimate the half-lives using data from Monte Carlo simulation. Also, the mean reversion is calculated using the RER equilibrium level conditional on average history and conditional on initial RER equilibrium. The mean reversion is much faster for larger shocks from 20% to 40%, compared to smaller shocks of 10% or less. Likewise, the thesis accounts for the non-linear mean reversion by constructing portfolios based on the five-year change in RERs' cross-sectional distribution. Implicitly sorting currencies according to this way allows extreme change currencies to be allocated to the same bins, tackling the fact that the currencies experienced the largest changes should appreciate or depreciate more in the short future horizon. Besides, the authors continue, using the equilibrium obtained from conditional initial history yields much faster reversion times. The resulting half-life with equilibrium level conditional on average initial history ranges from one to two years for shocks 40% and 1% respectively. Using the initial equilibrium level, the half-lives range for pound-sterling-dollar and franc-pound sterling from one to nine and six years for shocks 40% and 1% respectively. Consequently, the examination reveals significant non-linear adjustment in both RERs, however, the support for the HBS effect is twofold. Foremost, the estimation finds significant evidence about the HBS effect affecting the pound sterling-dollar but not to franc-pound sterling relationship. The period for calculating the half-lives for mean reversion is pound sterling-dollar 1973-2001 and franc-pound sterling 1973-1998. Concluding, the authors observe variation shifting from RERs to exchange rates and the variation is higher in fixed nominal exchange rate regimes.

Chong et al. (2012) examine the RER's reversion speed to the value indicated by PPP. Besides, the authors tackle questions of how much rapid shocks wave the RER of the equilibrium and how long it takes to settle back to the equilibrium level. Specifically, the authors are interested in whether the HBS effects have contribution to the half-lives of deviations from equilibrium. The authors' thesis is that by accounting for the non-tradable goods and persistent relative productivity differences between countries, the adjustment toward the equilibrium level of RERs can be understood better. As a result, the article's methodology is a novel approach combining local projection methods with the cointegration analysis. The local projection method is a way to approximate the response impulse functions. The advantage of this is that the macro-economic variables can be modeled in a dynamic setting for response to the shocks. The aim is to separate the long-term secular movements from the short-term movements. Further, cointegration analysis shows that the relative productivity is closely related to the long-term equilibrium of RERs.

Chong et al. (2012) can estimate the half-lives depending on the short-term and long-term dynamics, labeled as incorrect, as well as the half-lives depending solely on long-term dynamics, labeled correct. On top of that the half-lives are estimated including and excluding the HBS effects. The half-lives estimated from short-term and long-term dynamics correspond to what previous studies have been able to find, half-lives of approximately three. Further, including the HBS effect on short-term and long-term response combinations does not yield better estimates of the half-lives. Thus, the response to shock isolating the long-term movement and including the HBS effect yields faster reversions to the equilibrium. Precisely, the half-lives from correct estimates are about three to five quarters shorter than incorrect ones. The main conclusion of the paper is that productivity shocks have a major role in affecting the dynamics of RERs. Consequently, when authors take the HBS effects into account, the outcome is a much faster adjustment of RERs towards the equilibrium level. Precisely, the authors argue that the methodology, particular data or sample of counties, observation frequency, or the base explanator used do not draw a line between the results of the article and previous literature. Nonetheless, the largest contributor and main explanator of the shorter half-lives, three to five quarters, is due to correctly accounting for the HBS effects on the long-run equilibrium. The authors emphasize the importance of differentiating short-term frictions from long-term movements.

Rabe and Waddle (2020) take a different perspective on estimating the purchasing power parity mean reversions. Thus, the authors examine how the convergence speed itself has evolved throughout the decades. The author's methodology is dynamic common correlated effects. The datasets contain 61 counties from developing and developed countries over the years from 1960 to 2015. Furthermore, the authors find half-life decreasing throughout the sample period. Currently, the lowest point of approximately three years has been achieved as the half-life has been decreased about one-half to three years from the high. Article, arguments on behalf of the higher weight of tradable goods account for a piece of the changed convergence speed. Convergence speed relates also to the phenomenon of what goods the households are consuming. All in all, the authors suggest that the decreasing half-lives may be caused by the increase in CPI tradability and a fraction of trade.

4 Data and methodology

This chapter introduces the data and methodologies to test the hypotheses. First, data collection and sources are reviewed. Also, relevant descriptive statistics are presented. Secondly, the chapter presents the methodologies to thoroughly examine the research questions.

4.1 Data

The data is obtained from various providers. For instance, the International Monetary Fund's (IMF) Database (IFS) is used to retrieve end-of-period nominal exchange rates for selected countries. In addition, consumer price index figures come from IFS. The thesis examines a sample of currencies from developing and developed countries. Three-month T-bill rates for countries are loaded from the Fred and the Global Financial Database. GDP figures are obtained from the Organization for Economic Co-operation and Development (OECD). Lastly, NFA figures come from the External Wealth of Nations by Lane, Philip R., and Gian Maria Milesi-Ferretti (2022) and the IFS database. Lastly, expected inflation observations are obtained from the World Economic Outlook (WEO). Population figures are obtained from the World Bank. In some cases, to ensure a full set of data, the datastream is deployed.

The currency excess return, denoted as RX_t, is a combination of nominal exchange rate change and interest rate relationship between foreign and domestic rates. The thesis is interested only in the nominal exchange rate part. For that reason, the currency return is referred to as R_t in the subsequent sections.

$$R_{t+1} = \frac{S_{t+1}}{S_t} \tag{7}$$

Where S refers to the nominal exchange rate measured as the United States dollar per unit of foreign currency. Moreover, the currency returns is this study refer to returns obtained by US-based investor, who holds a foreign currency for a defined period and then converts the foreign currency back to dollars. Therefore, when the currency return is positive, the US-based investor would have made money by investing in a foreign currency.

RER is constructed as denoted in equation 3. In addition, the RERs are set to unity as of 1970Q1 for all sample countries. The HBS effect is approximated using real GDP per capita. Moreover, the real GDP per capita is constructed using constant 2010 exchange rates for all economies. OGs are constructed using the real GDP data series. Further, equation 2 quadratic trend-line regression is employed. NFAs are constructed using the international investment position data, excluding gold, and scaled by GDP. Real interest rate differentials (RDIFF) are constructed using ex-post inflation and nominal interest rates. The domestic, US, RDIFF figure is deducted from the foreign RDIFFs to obtain the final series. The expected inflation differentials are approximated using the previous 12 quarters' moving average until 1990. From the beginning of 1990, the WEO expected inflation is used as an approximation of future inflation.

Descriptive statistics are shown in Table 3**.** The columns from left to right refer to currency excess return, nominal exchange rate return, log RER, five-year log RER change, and inflation differentials. The specific sample of currencies is motivated by the earlier study by Menkhoff et al. (2017) about currency value.

Table 3. Descriptive statistics.

This table reports descriptive statistics for excess currency returns, nominal exchange rate returns, log RER, five-year log RER change, and inflation differentials. The figures are in percentage and annualized, except for the log RER, *q*. Quotations and differentials are against USD/US. The sample period is from 1976Q1 to 2023Q1.

Variable	**RX**		**ΔS**		**q**		**Δq**		**Δπ**	
Statistic	**μ**	**σ**	**μ**	**σ**	**μ**	**σ**	**μ**	**σ**	**μ**	**σ**
AU	1.73	10.86	-0.76	10.61	-0.14	0.17	5.05	45.31	0.80	2.15

CA	0.78	6.61	-0.39	6.54	0.10	0.12	11.87	31.62	-0.12	1.23
CH	0.88	12.04	2.92	11.92	-0.67	0.15	-14.32	48.75	-2.00	1.71
DE	0.55	11.12	1.40	11.05	-0.25	0.16	6.79	48.79	-1.27	1.72
ES	3.50	11.17	-3.11	11.39	-0.49	0.19	-22.38	64.16	1.92	2.86
FR	1.85	11.87	-0.30	11.70	-0.24	0.16	-7.04	52.38	-0.16	1.55
GB	1.18	10.24	-0.53	10.05	-0.23	0.13	4.39	38.11	0.71	1.94
HU	3.13	13.60	-3.72	11.51	-0.24	0.29	-14.09	47.46	5.62	5.71
ID	3.90	21.53	-5.71	17.96	0.57	0.44	36.93	73.43	5.08	6.11
IN	1.69	6.70	-4.42	6.91	0.48	0.25	25.43	35.32	3.53	3.85
IT	2.61	11.65	-3.13	11.62	-0.12	0.15	-1.80	48.05	1.65	2.38
JP	0.31	12.12	2.46	12.00	-0.66	0.21	-3.72	51.14	-2.23	1.79
KR	2.50	11.18	-1.59	9.54	0.08	0.13	4.98	39.65	1.50	2.60
MX	5.16	12.77	-13.30	17.16	0.05	0.17	14.00	47.43	15.77	12.65
NO	0.61	11.17	-0.72	10.99	-0.28	0.16	9.50	44.59	0.35	2.21
NZ	2.73	11.88	-0.45	11.08	-0.30	0.18	-5.39	49.86	1.49	2.63
SE	0.05	11.07	-1.20	11.00	0.03	0.23	24.80	50.83	0.32	2.25
SG	0.03	5.55	1.47	5.28	-0.20	0.11	0.49	32.35	-1.49	2.04
TH	2.33	10.24	-0.66	8.94	0.12	0.17	10.86	37.16	0.19	2.04
TR	12.85	21.98	-26.82	17.77	0.28	0.28	24.38	69.64	29.97	13.00
TW	1.19	7.49	0.71	7.18	-0.24	0.14	1.28	31.20	-1.04	2.36
ZA	0.15	15.58	-5.28	14.39	0.32	0.28	33.60	51.63	4.79	2.71

4.2 Methodology

The thesis moves on to test the PPP indicators and currency value relationship. To test the first research question, the thesis uses a panel regression with fixed time effects, similar to Menkhoff et al. (2017). Controlling for the macro-fundamentals, the thesis uses real GDP per capita (HBS), net foreign assets (NFA), and output gaps (OG) growth rates over the five previous years. Alongside, the real interest rate and expected inflation differentials, defined as foreign rate less domestic, are used in regression as a control variable. The regression model is as follows:

$$R_{j,t+1} = \alpha + \beta \Delta^{(5y)} q_{j,t} + \gamma X_{j,t} + \tau_{t+1} + \upsilon_{j,t+1} \tag{8}$$

Where $R_{j,t}$ refers to the currency returns on one subsequent period, the $\beta\Delta^{(5y)}q_{j,t}$ refers to lagged five-year RER change, $\gamma X_{j,t}$ refer to lagged control variables, τ_{t+1} is the time-fixed effect, and α and $\upsilon_{j,t+1}$ refer to constant and error terms, respectively. The variable of interest is the β coefficient and particularly the predictable power over the currency return. The thesis is interested in evaluating the medium-term horizon predictability, hence, the regressions are run for subsequent cumulative returns of five years.

$$R_{j,\prod_{i=1}^{n=20}(1+R_i)-1} = \alpha + \beta\Delta^{(5y)}q_{j,t} + \gamma X_{j,t} + \tau_{t+1} + \upsilon_{j,t+1} \tag{9}$$

Above regression equation 9, the $R_{j,\prod_{i=1}^{n=20}(1+R_i)-1}$ left-hand side refers to the cumulative five-year return and the other variables are similar as in equation 8.

Next, the thesis concerns the predictability of the long-run horizon regression model. The model is stated below:

$$R_{j,t+h} = \alpha_h + \beta_h\Delta^{(5y)}q_{j,t} + \gamma_h X_{j,t} + \delta_h R_{j,t} + \tau_{t+1} + \upsilon_{j,t+h} \tag{10}$$

h implies the forecast horizon in quarters. The same variables in the above equation have the same meaning as in equation 9**.** However, now the regression model includes lagged dependent variables as a control variable. This setting deficits the possible autocorrelation of the dependent variable. Another reason for this specific setting is that the β_h coefficient works as an impulse response function of excess currency returns to five-year changes in the RER whilst the control variables path is assumed to be constant. This forecasting method is known as local projections, and it has been developed by Jorda (2005). With this regression model, the thesis tries to capture the extendable predictability and convergence of RER over a specified horizon (Menkhoff et al., 2017). Including the change of lagged dependent variable aims to capture longer-term trend in the dependent variable. In addition, in dealing with volatile nominal exchange rates, the lagged dependent variable can anchor the current values to past values and provide stability to the regression equation. Lastly, Nominal exchange rates might pose an autoregressive process that can be captured with a lagged dependent variable.

The third research question, and related hypotheses, can be tackled with previous regression models but including an interaction effect term into the regression. Dahlquist and Pénasse (2022) are examining the safe haven currencies and commodity currencies separately alongside with currency portfolio. The beta coefficients for individual currencies are then compared to each other. However, the crucial distinction between Dahlquist and Pénasse (2022) is that the authors pool the data rather than introduce an interaction term. The regression equation is as follows:

$$R_{j,t+h} = \alpha_h + \beta_h \Delta^{(5y)} q_{j,t} + \gamma_h X_{j,t} + \delta_h R_{j,t} + \theta D_{j,t} + \beta_h (D_{j,t} * \Delta^{(5y)} q_{j,t}) + \tau_{t+1} + \upsilon_{j,t+h} \tag{11}$$

Where term $D_{j,t}$ represents a set of three distinctive dummy variables, namely safe haven, commodity, and emerging market currency. $D_{j,t} * \Delta^{(5y)} q_{j,t}$ term depicts the interaction term between RER and the dummy variable. Including the interaction term in the regression can reveal the different predictability dynamics and responses to the movements in the RER. The base case where the dummy variable and interaction term take a value of zero harvests the other type of currency characteristics. As a result of estimating equation 11, the study ends up estimating four different regression lines for each horizon corresponding to each of the currency groups. For instance, safe haven currency group have possibly different intercept α_h and slope coefficient of the β_h.

4.3 Portfolio construction

Next, the thesis concerns the RER signal in a direct portfolio setting. Hence, after confirming the predictable relationship between the RER signal and subsequent currency returns with regression analysis, the portfolio construction exercises work as an alternative way to assess the RER signal's predictable power purely out of sample manner. The portfolios are constructed in a long-short manner based on the cross-sectional value signals.

The currency value portfolios are formulated using three different portfolio construction methods. Therefore, the first construction method is to use linear portfolio (Linear) weights based on the RER signal. The currency's weight in the linear portfolio is stated as follows:

$$w_{j,t+1} = c_t * (x_{j,t} - \bar{x}) \tag{12}$$

Where the left-hand side term represents the weight at time t+1, $(x_{j,t} - \bar{x})$ term depicts the currency j's dispersion from the signal's cross-sectional mean across the currencies, and c_t is a scaling factor forcing the sum of portfolio weights to equal unity. More precisely, the c_t is formulated:

$$c_t = 1/\sum_j |x_{j,t} - \bar{x}| \tag{13}$$

In the above equation 13, the right-hand side divides 1 by the absolute sum of all the currency signals. As a result of the scaling factor, the weights in the linear portfolio will equal 0.5 for long positions and -0.5 for short positions. In addition, the currency which has a signal above the cross-sectional mean will receive a positive, long, weight, and oppositely, the currency with a value signal below the cross-sectional mean will receive a negative, short, weight (Menkhoff et al., 2017).

The second method to construct portfolios is rank-based weights (Rank). Moreover, this method, developed by Koijen et al. (2013) and popularized by Asness et al. (2013), ranks the value signals rather than taking pure signals as a weighing base. Thus, the rank portfolio weights do not emphasize extreme value signals, and hence, is a more conservative way to construct a portfolio. Below is the actual equation for calculating the portfolio weights in the rank portfolio:

$$w_{j,t+1} = c_t * (rank(x_{j,t}) - \sum_{j=1}^{N_t} rank(x_{j,t})/N_t)) \tag{14}$$

Where $rank(x_{j,t})$ is the currency j's rank number among the cross-section of signals, $\sum_{j=1}^{N_t} rank(x_{j,t})/N_t))$ depicts the average number of ranks, and c_t is a similar scaler as in the linear portfolio case but uses the ranks of the signals rather than the plain signal. In addition, the scaling factor is set to scale the weights in a manner that the portfolio is one dollar short and one dollar long (Menkhoff et al., 2017).

The third portfolio construction method is a high-minus-low (HML) portfolio. To begin with, three bins are formed based on the cross-sectional distribution of value signals. Consequently, a P1 holds five expensive currencies, a P3 bin holds the five cheapest currencies, and a neutral bin includes all the tweeners. Furthermore, the currencies are equally weighed inside the bins. Finally, The HML portfolio is obtained by going short on the expensive, P1, bin and going long on the cheap, P3, bin, essentially resulting in a P3 – P1.

To assess the statistical significance of the portfolio results, the thesis applies a performance test by Ledoit and Wolf (2008). Precisely, selected portfolios' risk-adjusted returns are compared against each other using the heteroskedasticity and autocorrelation robust covariance matrix estimator. The risk-adjusted return is specified as follows:

$$risk\ adjusted\ return = \frac{R_p}{\sigma_p} \tag{15}$$

Where R_p stands for the return of a portfolio and σ_p stands for the volatility of a portfolio. The difference from the traditional Sharpe ratio is that the returns are not excess returns. The reason is that the thesis is interested in predicting nominal exchange rates rather than excess currency returns, where the interest rate differentials between foreign and domestic economies would be present.

Secondly, the thesis assumes a null hypothesis that random walk theory is dominating in the currency markets, and hence forms a market portfolio by equally weighing all the available sample currencies in the portfolio at each point in time. The key idea is to observe how the alpha spreads between P3 and P1 portfolios evolve. However, benchmarks can be different when examining different currency value indicators, hence for an adjusted currency value strategy, the returns from the plain value signal are the appropriate benchmark. Hence, the question is then can the adjusted signal deliver abnormal returns over the plain five-year change in the RER signal. Then, after the benchmarks are selected, time-series regression is run and the resulting alphas are saved. In addition, to obtain robust alphas, the standard errors are estimated using the Newey and West (1987) robust standard errors using lags equal to $n^{(\frac{1}{4})}$, where *n* denotes the number of time-series observations. The alpha spread test will be used to assess the statistical significance of P3 – P1 alphas. Äijö and Tikkanen (2018) define the alpha spread test as follows:

$$t = \frac{\alpha_i - \alpha_j}{\sqrt{SE_{\alpha i}^2 + SE_{\alpha j}^2}}$$

(16)

Where α_i and α_j represents alphas of portfolio i and j, correspondingly. $SE_{\alpha i}^2$ and $SE_{\alpha j}^2$ are the standard errors of portfolios' alphas. The degree of freedom for the t-statistic is based on the following equation (Siirtola, 2021):

$$v = \frac{\left(SE_{\alpha i}^2 + SE_{\alpha j}^2\right)^2}{\frac{SE_{\alpha i}^4}{v_i} + \frac{SE_{\alpha j}^4}{v_j}}$$

(17)

Where the terms v_i and v_j denote the observations in the time-series regression, specifically *n-1.*

4.3.1 Overlapping holding periods

The thesis constructs an overlapping holding period portfolio to assess the medium-term horizon predictability further. As a result, portfolios are formed in a manner such that given any quarter *t* in the sample period, there will be a portfolio constructed at time *t* but also a series of portfolios constructed at *K* – 1 quarter ago, where *K* is the holding period. In essence, during the holding period of an individual portfolio, the initial currency weights are held fixed. However, every quarter the weights are revised for a portion equal to $\frac{1}{K}$ in the entire overlapping holding period portfolio (Jegadeesh and Titman, 1993). The 1 is an example of an overlapping holding period portfolio in which the holding period is two quarters. The picture indicates that quarter three is the first quarter when a return can be calculated for the entire overlapping holding period portfolio. Next, at the beginning of quarter four, individual portfolio 1 gets rebalanced, resulting in a turnover of 50% for the entire overlapping holding period portfolio, as indicated by $\frac{1}{K}$.

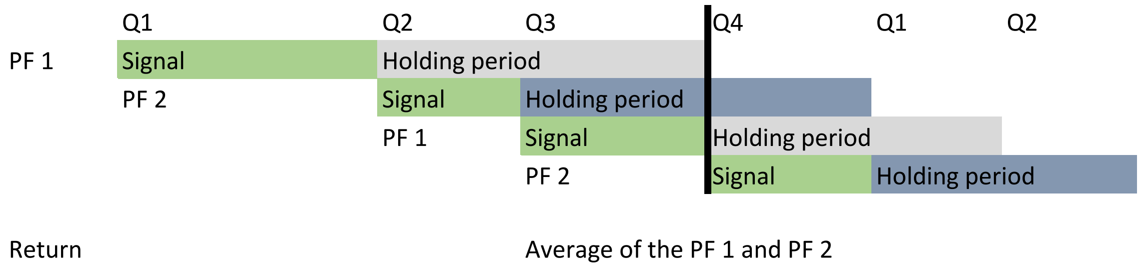

Figure 1. Overlapping holding period portfolio construction.

The figure above depicts the overlapping holding period portfolio construction method.

In addition, figure 1 marks that the entire overlapping holding period portfolio's return is calculated by averaging the cross-section of the individual portfolios.

4.3.2 Currency value and macro-fundamentals

The thesis concerns the impact of macro fundamentals on the currency value signal. One way to assess the impact of macro-fundamentals is by simply deducting the expected differentials from the signal. Alternatively, cross-sectional regressions can be used to strip the value signal into two compelling parts. More specifically, cross-sectional regressions are used to divide the value measure into known risk factors part and a residual term, coined as an adjusted signal. The cross-sectional regression is defined as follows:

$$\Delta^{(5y)} q_{j,t} = \alpha_t + \beta_t x_{j,t} + \varepsilon_{j,t}^{Q} \tag{18}$$

Where $\Delta^{(5y)} q_{j,t}$ refers to the five-year change in RER, α_t is an intercept, $\beta_t x_{j,t}$ term refers to macro-fundamentals, and $\varepsilon_{j,t}^{Q}$ refers to the residual currency value signal. Cross-sectional regression is run to each quarter separately and then collecting the resulting fitted value and residual value. Further, fitted and residual signals are used in the portfolio formation to see whether the macro-fundamentals play a part in the currency valuation. A similar adjustment of currency value signal is carried out by Menkhoff et al. (2017).

5 Results

This section of the thesis introduces the results from the empirical analysis. Beginning with the regression analysis results, the three hypotheses that the thesis concerns are covered. Afterward, the focus shifts to the nominal exchange rate predictability in a portfolio setting. Furthermore, the portfolio section covers the results from the direct application of currency value signals in investment decision-making. Lastly, the results from overlapping holding period portfolios are reviewed.

5.1 Regression results

The empirical examination starts with panel regressions including time-fixed effects. In essence, the panel regressions shed light on the predictable relationship between the RER signal and subsequent currency returns. The relationship is directly related to the first hypothesis of the thesis. However, the thesis is solely interested in the medium-term horizon, so the short-term predictability is to show and confirm the previous findings of the literature. Moreover, table 4 presents the results from a regression indicated in Equation 8. The inference is based on the standard errors clustered only by time because returns are seldom correlated (Menkhoff et al., 2017). The positive value of the five-year change in the RER coefficient indicates that there is a positive relationship between the RER signal and subsequent currency returns. Beginning from the first and second columns of Table 4, the regression specification excludes and includes expected inflation expectations as a control variable, respectively. The first specification shows that without expected inflation differentials as a control variable, the result for the predictive slope coefficient of five-year change in RER is slightly positive. When including the expected inflation differentials as a control variable, the value of the RER slope coefficient amplifies but statistical significance is not present yet.

Table 4. Short-term nominal exchange rate predictability.

The below table presents the results for panel regressions with time-fixed effects of nominal exchange rate change on lagged five-year change in RER and additional control variables. Additional control variables include expected inflation differentials ($\beta E\pi_{j,t}$), Real interest rate differentials (β_{RDIFF}), real per capita change (β_{HBS}), output gap change (β_{OG}), and net foreign assets change (β_{NFA}). T-statistics are based on clustered standard errors, clustered by time. *, **, *** indicate statistical significance of the slope coefficient at 10%, 5%, and 1% significance level, respectively. The sample period is from 1976Q1 to 2023Q1.

Short-term predictability: subsequent one quarter return							
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**
α	**-0.007*** **	**-0.003*** **	**-0.001** **	-0.001	**-0.001* **	-0.001	-0.001
$\beta\Delta^{(5y)}q$	0.009	0.015	**0.022** **	**0.023** **	**0.023** **	**0.022** **	**0.023** **
$\beta E\pi$		**-0.189*** **	**-0.145*** **	**-0.144*** **	**-0.143*** **	**-0.144*** **	**-0.143*** **
β_{RDIFF}			-0.228	-0.230	-0.231	-0.231	-0.235
β_{HBS}				0.001			-0.001
β_{OG}					0.012		0.014
β_{NFA}						0.000	0.000
R-squared	0.001	0.117	0.075	0.078	0.078	0.076	0.078
Number of observations	3845	3845	3250	3155	3155	3246	3151

By including different macro fundamental factors in the regression as control variables, the slope coefficient increases, hence accounting for better predictability of the RER signal. Further, when including the RDIFF alongside the expected inflation differentials in the regression, the value of the RER slope coefficient becomes statistically significant. Thus, the statistical significance for value signal slope increases from a base case, of 0.83 to 2.1 when adding expected inflation differentials and RDIFF as additional control variables. Likewise, the RER slope coefficient increases from 0.009 to 0.022, an increase of 172%. One percent increase in five-year change in RER leads to an approximately 0.022% increase in the expected nominal exchange rate change in the following quarter. Interestingly, the RDIFF slope coefficient is negative, indicating that an increase in the RDIFF results in a subsequent decrease in the nominal exchange rate. Changing a five-year change in the RER slope coefficient to a quarterly basis results in an approximately 0.44 (0.022*20). From the descriptive statistics table, the average standard deviation of a five-year change in RER is approximately 47% annually. Hence, turning the 47% into quarterly yields 23.5%, now economic significance can be interpreted as follows: 0.44%*23.5%=0.103% leading to observe that one standard deviation higher five-year change in RER quarterly results in an increase in the expected subsequent quarter nominal exchange rate change of 0.103% relative to other currencies. Notwithstanding, adding the rest macro fundamentals one by one to the regression has only a marginal increasing effect on the RER slope coefficient and the statistical significance. Besides, the HBS, OG, and NFA enter the regressions with statistically insignificant coefficients. Therefore, the RDIFF and expected inflation differentials combined can boost the RER signal predictability substantially. The result is reasonable in the sense that earlier, the thesis observed that the basic implication of the PPP condition is bound to the expected inflation differences and the resulting movement in the nominal exchange rate. Interestingly, the slope coefficient for expected inflation differentials changes when other macro fundamental variables are included in the regression. Thus, looking at the second regression specification, the expected inflation differentials' slope coefficient is -0.189, suggesting that the expected inflation differentials have an almost one-on-one relationship with subsequent nominal exchange rate changes. Hence, a -0.25 slope coefficient would imply a relationship where a 1% increase in the annual expected inflation differential results in a -0.25% decrease in the subsequent one-quarter nominal exchange rate change. Annualizing the -0.25% result leads to -1%, meaning that the increase in the expected inflation differential is fully reflected in the subsequent nominal exchange rate change, as the theory of PPP suggests.

Table 5. Medium-term nominal exchange rate predictability.

The below table presents the results for panel regressions with time-fixed effects of nominal exchange rate change on lagged five-year change in RER and additional control variables. Additional control variables include expected inflation differentials ($\beta E\pi_{j,t}$), Real interest rate differentials (β_{RDIFF}), real per capita change (β_{HBS}), output gap change (β_{OG}), and net foreign assets change (β_{NFA}). T-statistics are based on heteroscedasticity and autocorrelation robust standard errors. *, **, *** indicate statistical significance of the slope coefficient at 10%, 5%, and 1% significance level, respectively. The sample period is from 1976Q1 to 2023Q1.

Medium-term predictability: subsequent 20-quarter return							
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**
α	**-0.097*** **	**-0.052*** **	**-0.021*** **	**-0.014*** **	**-0.016*** **	**-0.026*** **	**-0.017*** **
$\beta\Delta^{(5y)}q$	0.060	**0.102** **	**0.175*** **	**0.199*** **	**0.202*** **	**0.176*** **	**0.198*** **
$\beta E\pi$		**-1.568*** **	**-1.217*** **	**-1.234*** **	**-1.224*** **	**-1.208*** **	**-1.221*** **
β_{RDIFF}			-0.378	-0.297	-0.332	-0.379	-0.327
β_{HBS}				-0.032			-0.059

β_{OG}					0.061		0.087
β_{NFA}						**0.038****	**0.036***
R-squared	0.002	0.352	0.258	0.274	0.274	0.260	0.277
Number of observations	3427	3427	2832	2737	2737	2828	2733

Table 5 presents the results from a regression presented in equation 9. Now, the examination shifts to account for the relationship between the value signal and subsequent five-year currency returns. The inference is based on heteroscedasticity and autocorrelation robust standard errors. Again, the base case scenario does not include any control variables. As a result, the first columns in Table 5 correspond to the base scenario, indicating that the predictive slope coefficient for a five-year change in RER is not statistically significant. The finding leads the thesis to accept the first null hypothesis that there is no predictable power of five-year change in the RER over medium-term horizon nominal exchange rate changes. Including the expected inflation differentials as a control variable leads to a statistically significant five-year change in the RER coefficient at a 5% significance level and the slope coefficient increases from 0.06 to 0.10. Therefore, the result confirms the usefulness of the RER signal as a medium-term nominal exchange rate predictor, but the expected inflation differentials must be controlled. But also, the result indicates the importance of expected inflation differentials in the nominal exchange rate change configuration. Thus, the slope coefficient of -1.57 for expected inflation differentials can be interpreted as a one percent increase in the annual expected inflation differentials leading to a 1.57% depreciation in a five-year nominal exchange rate change. Continuing by adding the rest macro fundamentals one by one increases the statistical significance and simultaneously increases the slope coefficient. Hence, including RDIFF as a control variable increases the five-year change in RER slope coefficient from 0.10 to 0.17 and meanwhile, the statistical significance increases showing a significant result on a 1% significance level. Incorporating the rest of the macro fundamentals HBS, OG, and NFA into the equation provides a slight increase in the five-year change in the RER slope coefficient while the statistical significance remains under the 1% level. In addition, the NFA has a statistically significant slope coefficient at a 5% significance level, indicating that a 1% percent increase in the NFAs' change over five years results in a 0.036% increase in the subsequent five-year nominal exchange rate change.

The second research question relates to the enhanced predictive power of a five-year RER when macro fundamentals are included in the regression. Comparing the increase in the overall predictability, the thesis treats the baseline model as a restricted model, and all macro fundamentals included as an unrestricted model. Further, a heteroscedasticity robust F-test is conducted to confirm whether the predictability enhancement is statistically significant or not. The result leads rejecting the restricted model, thus the macro fundamentals help to predict the nominal exchange rate changes better when jointly included in the regression model. The result shows a highly statistically significant result at a 1% significance level. In addition, the Wald test is used to test different macro fundamentals' impact on the predictability individually. Moreover, each macro variable is added to the baseline regression model individually alongside a five-year change in RER. Table 6 reports the results for the Wald test. Consequently, expected inflation differentials, RDIFFs, and NFAs have a statistically significant impact, meaning that above mentioned variables increase the nominal exchange rate predictability when added to the baseline regression model individually. In contrast, HBS and OG do not yield a statistically significant increase in predictability.

Table 6. Wald test.

The Wald test is used to assess the statistical significance of individual macro fundamentals' impact on the predictability of exchange rate changes. Variable refers to the macro fundamentals examined. P-value shows the Wald test's p-value of the null hypothesis that the macro fundamental slope coefficient equals zero. The sample period is from 1976Q1 to 2023Q1.

Wald test	
Variable	P-value
$\beta E\pi$	0
β_{RDIFF}	0
β_{HBS}	0.19
β_{OG}	0.49
β_{NFA}	0

5.1.1 Long-horizon regressions

The predictability relationship is next examined similarly to Menkhoff et al. (2017) through long-horizon regressions presented in equation 10. The key idea of the long-horizon regressions is to examine the value signal's predictable horizon and convergence speed to zero. Inference is based on clustered standard errors, precisely clustered by time.

Figure depicts the dynamic responses of currency returns to five-year changes in RER. In addition, the regression equation includes expected inflation differentials and lagged dependent variables as control variables. Interestingly, the predictable coefficient stays rather stable until a notch in the ninth quarter. Eventually, the value signal dies between the 12th and 13th quarter. Indeed, the predictable relationship is statistically significant at the 5% level during the first eight quarters. Notwithstanding, the ninth quarter is still statistically significant at a 10% significance level. Overall, the interpretation of the results from the two graphs 2 is that the five-year change in RER positively predicts the subsequent currency returns until the relationship turns negative in the 13th quarter.

Next, the focus is shifted to include the other macro fundamentals in the regression as control variables. The motivation to do the following is the assumption that underlying macro fundamentals play a role in the RER movements. Therefore, similar fashion as previously, the dynamic responses of currency returns to five-year change in RER are plotted in Figure 2 lower graph. Consequently, by comparing the upper and lower panel in Figure 2, the goal is to observe the changed relationship in predictability after controlling for the RDIFF, HBS, OG, and NFA. In general, the two plotted responses look similar when compared, with the distinction that when macro fundamentals are included, the plot is not as stable. Moreover, the coefficient level starts higher and progressively decreases until breaching the zero line in the 12th quarter. Now, the coefficients for the first, third, and fourth quarters are statistically significant at a 1% significance level. Nevertheless, the statistical significance of the five-year change in the RER coefficient drops below the 10% significance level in the ninth quarter, indicating a one-quarter-ahead loss of predictability compared to the regression model excluding the RDIFF, HBS, OG, and NFA fundamentals. To summarize the findings of long-horizon regressions, the predictability of a five-year change in RER over subsequent nominal exchange rate changes does not extend further when additional macro fundamentals are included. However, the predictive coefficient is higher especially at the shorter horizons when additional macro fundamentals are included.

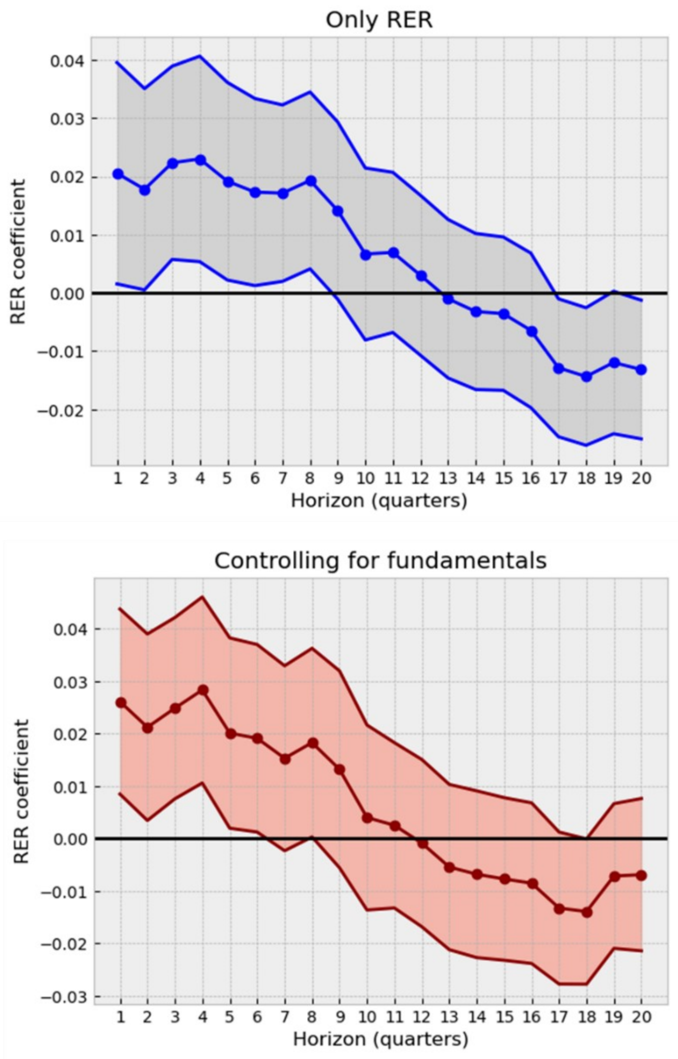

Figure 2. Dynamic responses.

The figures above plot the RER slope coefficient in 1,2…20 quarter predictable horizon. The first graph Only RER corresponds to estimating a regression equation including five-year change in RER, past one-quarter nominal exchange rate change, and expected inflation differentials. The second graph Controlling for fundamentals extends the above-mentioned regression equation with RDIFF, HBS, OG, and NFA fundamentals. The corresponding 95% confidence interval for the slope coefficient is also plotted. The sample period is from 1976Q1 to 2023Q1.

5.1.2 Different currency groups

The third research question of the thesis addresses the predictable power and convergence speed of the value indicator between different currency groups. Therefore, the focus is next shifted to observe the dynamic responses of each currency group relative to the base currency group. In the following section, the currencies are categorized into four distinctive groups, Other type currency, Emerging market currency, Commodity currency, and Safe haven currency. The base currency group is the Other type currency group that includes DE, ES, FR, GB, IT, NO, SE, SG, and TW. Then the emerging market currency group holds HU, IN, ID, KR, MX, ZA, TH, and TR. The classification of the emerging market is based on Morgan Stanley Capital International (MSCI) market classification. Next, previous literature have been identifying different commodity currencies as stated earlier, hence the distinction is not that straightforward. As a result, in this thesis AU, CA, and NZ are considered commodity currencies. Lastly, the safe haven currency group consists of CH and JP. Table 7 summarizes the categorizing.

Table 7. Currency groups.

The table below presents the different currency groups as well as the corresponding currencies within these groups.

Group	Economy
Safe haven currencies	JP, CH, US
Commodity currencies	AU, CA, NZ
Emerging market currencies	HU, IN, ID, KR, MX, ZA, TH, TR
Other type currencies	DE, ES, FR, GB, IT, NO, SE, SG, TW

The regression model in equation 20 is next employed to resolve the different currency groups' predictable features. In Figure 3, the dynamic responses are presented similarly to the previous section with the distinction that now there are four different five-year changes in RER slope coefficients, each representing one of the currency groups. In addition, the higher graph in Figure 3 corresponds to a regression equation in which expected inflation differentials and lagged dependent variables are included whereas the lower graph corresponds to a regression equation in which additional macro fundamentals are also included as control variables. All the RER slope coefficients follow a rather similar path, indicating similar responses between the groups. Nonetheless, the exception is the safe haven currency group which is experiencing a fast decreasing of the slope coefficient starting from the 12th quarter. Comparing the graphs to see whether the additional macro fundamentals are included or not, leads to observing that any significant changes are not visible. Nonetheless, the exception is the safe haven currency group which gains short-term predictable power when the additional macro fundamentals are included. The finding suggests that for CH and JP the macro fundamentals work well by bringing out the clearer measure of currency value indicated by the five-year change in RER.

By observing the statistical significance of the interaction terms and dummies, the thesis accepts or rejects the third hypotheses and related group hypotheses. Table 8 presents the P-values for the relevant coefficients for the long-horizon regressions with dummy and interaction terms. The interaction term for safe haven currencies is statistically significant starting from the 14th quarter. Based on Figure 3, the result of safe haven currencies' different pattern was already concerned and now confirmed. The statistically insignificant slope coefficient for interaction terms of commodity and emerging market currencies leads to the conclusion that there is no difference between the five-year change in RER predictive characteristics in commodity or emerging market currency groups relative to the base group based on period-by-period analysis. As mentioned above, the interaction term for the safe haven currency group is statistically significant for some periods. Hence, the hypothesis of different predictive content of five-year change in RER between the base currency group and safe haven currency group cannot be confirmed for the whole five-year period based on period-by-period estimation.

Interestingly, the dummy variable for emerging market currency is statistically significant for the whole horizon period at a 1% significance level. The average slope coefficient during the 20-quarter horizon for emerging market groups is -0.0103, indicating that there is persistent negative expected nominal exchange rate change for emerging market currencies when other variables are set to zero. Safe haven and commodity dummy variables are statistically insignificant, suggesting that a currency belonging to the commodity and safe haven group does not itself affect the expected subsequent nominal exchange rate changes.

Table 8. P-values of slope coefficients excluding additional macro fundamentals.

The table below presents the p-values for slope coefficients obtained from the regression equation 20 including only expected inflation differentials and lagged dependent variables as control variables. The first column corresponds to the five-year change in the RER predictive slope coefficient for the base currency group. The second column denotes the commodity currency dummy variable. The third column denotes the safe haven dummy variable. The fourth column denotes the emerging market dummy variable. The fifth column denotes the interaction term for commodity currency and the five-year change in RER. The sixth column denotes the interaction term for safe haven currency and the five-year change in RER. The last column denotes the interaction term for emerging market currency and the five-year change in RER. The bolded color indicates statistical significance. The sample period is from 1976Q1 to 2023Q1.

Quarter	$\Delta^{(5y)}q_{j,t}$	D_{Com}	D_{safe}	D_{EM}	$\Delta^{(5y)}q_{j,t} * D_{Com}$	$\Delta^{(5y)}q_{j,t} * D_{safe}$	$\Delta^{(5y)}q_{j,t} * D_{EM}$
1	**0.03**	0.86	0.16	**0.00**	0.92	0.74	0.61
2	**0.05**	0.83	0.19	**0.00**	0.99	0.90	0.62
3	**0.02**	0.82	0.22	**0.00**	0.83	0.55	0.59
4	**0.02**	0.94	0.15	**0.00**	0.90	0.80	0.43
5	**0.04**	0.94	0.15	**0.00**	0.88	0.74	0.39
6	0.10	0.90	0.23	**0.00**	0.82	0.93	0.65
7	**0.08**	0.86	0.30	**0.00**	0.82	0.69	0.49
8	**0.05**	0.89	0.31	**0.00**	0.88	0.72	0.46
9	**0.05**	0.88	0.31	**0.00**	0.99	0.71	0.30
10	0.12	0.85	0.45	**0.00**	0.96	0.46	0.27
11	0.13	0.96	0.65	**0.00**	0.88	0.45	0.25
12	0.18	0.98	0.56	**0.00**	0.62	0.41	0.24
13	0.37	0.96	0.51	**0.00**	0.66	0.12	0.41
14	0.57	0.98	0.52	**0.00**	0.81	**0.04**	0.53
15	0.61	0.99	0.54	**0.00**	0.56	**0.01**	0.66
16	0.71	0.98	0.49	**0.00**	0.30	**0.00**	0.63
17	0.91	0.97	0.54	**0.00**	0.20	**0.00**	0.58
18	0.88	0.98	0.66	**0.00**	0.13	**0.00**	0.50
19	0.89	0.93	0.61	**0.00**	**0.09**	**0.00**	0.42
20	0.91	0.85	0.61	**0.00**	0.11	**0.01**	0.55

Including the macro fundamentals RDIFF, HBS, OG, and NFA in the regression model does not yield any significant changes compared to the earlier findings. Table 9 shows the relevant coefficients' P-value. Similar observations are continuing in Table 9 as in Table 8 before. Likewise, the interaction term for the safe haven currency group is statistically significant starting from 14th quarter, suggesting that the five-year change in RER predicts predictive content is statistically significant for safe haven currencies relative to the base group. However, the short-horizon predictable power of five-year change in RER is similar to all currencies, since the interaction terms for all the currency groups are statistically insignificant.

The dummy variable for the emerging market dummy is again statistically significant. Surprisingly, not as statistically significant in every period as in Table 8 case. Besides, the average slope coefficient decreases to -0.007, suggesting that there is a smaller negative effect related to the emerging market currencies after including the additional macro fundamentals as control variables. Dummy variables for commodity and safe haven currencies are statistically insignificant, except for safe haven currency first quarter. Results state that currencies belonging to these groups experience similar return characteristics no matter are the additional macro fundamentals included or not. Overall, when comparing the P-values of dummy variables from Tables 8 and 9, the emerging market dummy becomes statistically less significant, and commodity and safe haven groups become statistically more significant, yet insignificant overall.

Table 9. P-values of slope coefficients including additional macro fundamentals.

The table below presents the p-values for slope coefficients obtained from the regression equation 20 including all the macro fundamentals as control variables. The first column corresponds to the five-year change in the RER predictive slope coefficient for the base currency group. The second column denotes the commodity currency dummy variable. The third column denotes the safe haven dummy variable. The fourth column denotes the emerging market dummy variable. The fifth column denotes the interaction term for commodity currency and the five-year change in RER. The sixth column denotes the interaction term for safe haven currency and the five-year change in RER. The last column denotes the interaction term for emerging market currency and the five-year change in RER. The bolded color indicates statistical significance. The sample period is from 1976Q1 to 2023Q1.

Quarter	$\Delta^{(5y)}q_{j,t}$	D_{Com}	D_{safe}	D_{EM}	$\Delta^{(5y)}q_{j,t} * D_{Com}$	$\Delta^{(5y)}q_{j,t} * D_{safe}$	$\Delta^{(5y)}q_{j,t} * D_{EM}$
1	**0.01**	0.37	**0.09**	**0.03**	0.58	0.15	0.38
2	**0.01**	0.45	0.12	**0.03**	0.65	0.24	0.27
3	**0.00**	0.53	0.12	**0.02**	0.87	0.83	0.28
4	**0.01**	0.62	0.12	**0.01**	0.80	0.34	0.26
5	**0.04**	0.73	0.17	**0.02**	0.78	0.07	0.29
6	**0.10**	0.90	0.29	**0.03**	0.90	0.23	0.85
7	**0.10**	0.96	0.34	**0.05**	0.90	0.57	0.41
8	**0.10**	0.92	0.34	**0.02**	0.87	0.72	0.63
9	**0.08**	0.89	0.23	**0.01**	0.99	0.88	0.21
10	0.17	0.93	0.28	**0.02**	0.97	0.54	**0.06**
11	0.26	0.84	0.46	**0.05**	0.98	0.21	0.11
12	0.49	0.78	0.65	**0.03**	0.79	0.39	0.22
13	0.78	0.76	0.63	**0.01**	0.84	0.15	0.31
14	0.93	0.72	0.62	**0.00**	0.90	**0.04**	0.60
15	0.83	0.64	0.56	**0.00**	0.90	**0.01**	0.85
16	0.82	0.65	0.51	**0.00**	0.56	**0.01**	0.80
17	0.58	0.57	0.65	**0.01**	0.41	**0.01**	0.53
18	0.55	0.60	0.60	**0.01**	0.30	**0.00**	0.85
19	0.92	0.74	0.45	**0.00**	0.16	**0.00**	0.96
20	0.76	0.77	0.40	**0.00**	0.11	**0.02**	0.50

Table 10 presents the results for a regression similar to equation 9 but adds the group dummy variables and group interaction terms to the equation as independent variables. Interestingly, the safe haven currency group's interaction term is statistically significant at a 1% significance level. The result indicates that the slope coefficient for the safe haven currency group is substantially smaller than for the base group, on average 1% increase in five-year change in RER results in an expected -0.21% smaller increase in the subsequent 20 quarter nominal exchange rate change compared to the base group. Further, the interaction term for the emerging market currency group is statistically significant at a 10% significance level. The interaction term slope coefficient is -0.15 indicating that a 1% increase in the five-year change in RER results in a -0.15% smaller expected five-year nominal exchange rate change for the emerging market currency group relative to the base group. Overall, the five-year change in the RER slope coefficient has a value of 0.39 and is statistically significant at a 1% significance level. The finding indicates that a 1% increase in the five-year change in RER leads to a 0.36% increase in the expected nominal exchange rate change for the base group. To conclude, higher five-year changes in RER indicate an appreciating nominal exchange rate in the following five-year horizon.

The dummy variable for the safe haven currency group is statistically significant at a 5% significance level. Further, the result indicates that relative to the base group, the safe haven group is expected to have a 13% higher five-year expected nominal exchange rate change compared to the base group when holding other variables at zero. In contrast, the emerging market currency group dummy is -0.14 and statistically significant at a 1% significance level. Also, the dummy indicates that relative to the base group, the emerging market group is expected to have -14% lower expected five-year nominal exchange rate change compared to the base group when holding the other variables at zero. The findings above are in line with the previous literature finding that safe haven currencies tend to appreciate continuously. For instance, Menkhoff et al. (2015) observe that rather than mean reverting nominal exchange rates, some currencies seem to depreciate and appreciate persistently. For the emerging market currency group, the result is the opposite, indicating a tendency to experience depreciating nominal exchange rates relative to the base currency group.

Also, notable is the difference in the expected inflation differentials slope coefficient compared to Table 5. Previously, the expected inflation differentials were reported to have a slope coefficient of -1.22 which is now decreased to -0.83 when group dummies and interaction terms are included. Still, -0.83%/5=-0.17% means that a 1% five-year expected inflation differential increase leads to a 0.17% decrease in the expected five-year nominal exchange rate change. Another interesting variable is the HBS effect which implies that a 1% increase in the five-year real GDP growth results in a 0.25% expected increase in the five-year nominal exchange rate change.

To conclude, based on the period-by-period and cumulative changes regression models, the hypotheses related to 3A and 3B can be summarized as follows: The predictive content of five-year change in RER is statistically significant for safe haven and emerging market currencies, leading to accepting the alternative hypotheses. Hypotheses related to different currency groups' predictability, measured with group dummies, can be accepted for safe haven and emerging market currencies. For both 3A and 3B related hypotheses concerning commodity currencies, null hypotheses are accepted.

Table 10. Slope coefficients for cumulative returns including group effects.

The table below reports the slope coefficients from regression equation 9 and includes currency group dummies and group interaction terms. The rows represent each independent variable in the regression equation. The second column denotes the estimated slope coefficients for the independent variables. T-statistics are based on heteroscedasticity and autocorrelation robust standard errors. *, **, *** indicate statistical significance of the slope coefficient at 10%, 5%, and 1% significance level, respectively. The sample period is from 1976Q1 to 2023Q1.

Medium-term predictability: Subsequent 20-quarter return	
Variable	**1**
α	-0.01
$\beta\Delta^{(5y)}q_{j,t}$	**0.36*** **
$\beta E\pi_{j,t}$	**-0.83*** **
β_{RDIFF}	-0.40
β_{HBS}	**0.25*** **
β_{OG}	-0.03
β_{NFA}	-0.02
βD_{Com}	0.01
βD_{safe}	**0.13*** **
βD_{EM}	**-0.14*** **
$\beta\Delta^{(5y)}q_{j,t} * D_{Com}$	-0.13
$\beta\Delta^{(5y)}q_{j,t} * D_{safe}$	**-0.21** **
$\beta\Delta^{(5y)}q_{j,t} * D_{EM}$	**-0.15* **
R-squared	0.45
Number of observations	2733

To examine more about the safe haven and emerging market dummies statistical significance, the thesis conducts a restricted and unrestricted regression and then F-test to observe the effect of including safe haven and emerging market dummies. The restricted version includes only all macro fundamentals, and the unrestricted version includes adding first safe haven currency and emerging market currency individually, and then jointly. Hence, the thesis tests whether $\beta_{safe} = 0$, and $\beta_{EM} = 0$, and jointly $\beta_{safe} = \beta_{EM} = 0$.

First, the null hypothesis $\beta_{safe} = 0$ is rejected, the result is statistically significant at a 1% significance level, hence meaning that including the safe haven currency dummy helps to predict the subsequent nominal exchange rate changes better. Secondly, the null hypothesis of $\beta_{EM} = 0$ can be also rejected at a 1% significance level, indicating that including the emerging market dummy helps predict subsequent nominal exchange rate changes better. Lastly, the joint null hypothesis $\beta_{safe} = \beta_{EM} = 0$, the estimation leads to reject the joint null, indicating that the dummy variables together increase the predictability, too.

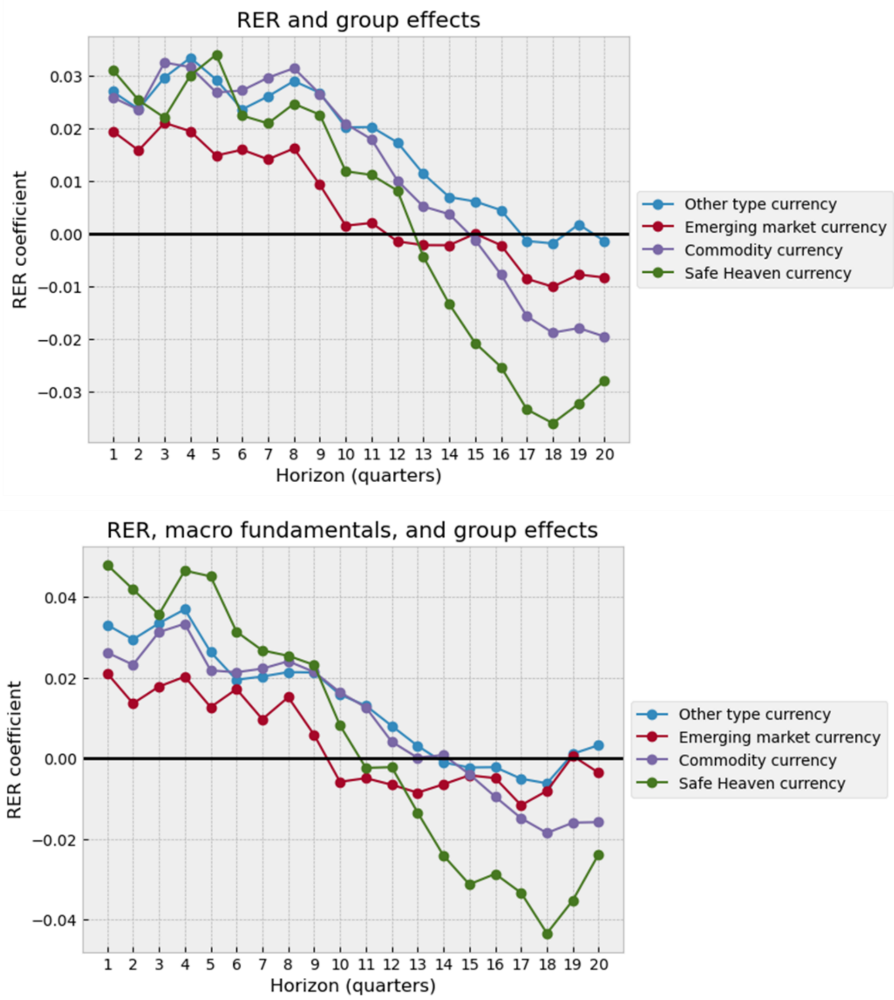

Figure 3. Dynamic responses of different currency groups.

The figure above plots the RER slope coefficients for different currency groups in 1,2…20 quarter predictable horizon. The first graph RER and group effects corresponds to estimating an regression equation including five-year change in RER, group dummies, interaction terms, past one quarter nominal exchange rate change, and expected inflation differentials. The second graph RER, macro fundamentals, and group effects extends the above-mentioned regression equation with RDIFF, HBS, OG, and NFA fundamentals. The sample period is from 1976Q1 to 2023Q1.

5.2 Currency value portfolios

First applied to foreign currency investments by Lustig and Verdelhan (2007), the currency portfolios provide insights into how the investigated signal or strategy performs as a pure investment strategy. The motivation of this chapter is to examine the nominal exchange rate predictability using the currency value signal and portfolio construction methods.

5.2.1 Benchmark results

The examination starts with the benchmark portfolios which are constructed using the plain value signal. Table 11 presents the results from four different investment cases for portfolios that are rebalanced on a quarterly basis. In other words, the short-term predictability of the value signal is covered. Beginning, panel A, excess currency returns, of Table 11 refers to a scenario in which portfolio returns are obtained by including both the interest rate differential and nominal exchange rate movement. In effect, the plain value signal can harvest great yields with a Sharpe ratio ranging from 0.33 to 0.40 for the three portfolio construction methods. The positive and statistically significant results are well in line with previous studies, for instance, Menkhoff et al. (2017) conclude that the five-year change in RER contains statistically and economically significant weight in currency value portfolio construction. In addition, Asness et al. (2013) find similar results for currency value, with the Sharpe ratio ranging from 0.34 to 0.44 for HML and Rank portfolio, correspondingly. Another interesting detail is the Linear portfolio's highly positively skewed return distribution, implying that the strategy is obtaining frequent small losses and occasional large gains.

Panel B, nominal exchange rate returns, of Table 11 presents the results for the value portfolios when only nominal exchange rate returns are used. Now, the short-term predictability drops which can be seen from the performance of the value portfolios. Thus, value portfolios can deliver a risk-adjusted return from 0.14 to 0.21. Further, the volatility increases by 12% for the Rank value portfolio comparing the excess return and nominal exchange rate return. The drawdowns also increase substantially, hence for excess return Rank portfolio a drawdown of -19.02% turns into a hefty -58.12% when looking at only nominal exchange rate return, a threefold increase.

Next two panels C and D divide the sample of currencies into G10 and other currencies groups. The motivation to do that lies in the assumptions of the value signal mean reversion and through what channel the mean reversion takes place. Arguably, for the G10 group, for instance, the inflation expectations can be viewed as more homogeneous within the group compared to the other sample currencies. The RER mean reversion can happen either by a combination of adjustments in the price level differentials and the nominal exchange rate or through one of the two. Ca' Zorzi and Rubaszek (2020) find that for a selected currency group consisting of Australia, Canada, Japan, New Zealand, Switzerland, Great Britain, Euro area, Korea, Norway, and Sweden the nominal exchange rate works as an adjustable force behind the mean reversion, accounting basically all the adjustment paces. Likewise, the five-year change in RER seems to work well for G10 countries. However, when excluding the G10 countries, the results are poor, namely risk-adjusted returns drop from 0.34 for G10 countries to 0.10 for the HML portfolio. In addition, for the HML portfolio, the drawdown increases when G10 currencies are excluded from -32% to -66%.

Table 11. Benchmark currency value portfolios.

The table below presents the benchmark portfolios obtained by using the five-year change in RER as a currency value indicator. Panel A provides results for portfolios using excess currency returns. Panel B provides results for portfolios using the nominal exchange rate change. Panel C provides results for portfolios using the nominal exchange rate change and including only G10 currencies. Panel D provides results for portfolios using the nominal exchange rate change and excluding the G10 currencies from the sample. Mean return and volatility are annualized. The sample period is from 1976Q1 to 2023Q1.

Short-term predictability: rebalancing portfolios quarterly

Panel A: Excess currency returns						
Statistics	**P1**	**P2**	**P3**	**HML**	**PF Rank**	**PF Linear**
Mean %	0.53	1.56	3.65	3.12	2.94	1.81
Volatility %	8.73	8.56	9.27	8.04	7.30	5.52
Skewness	-0.11	0.14	0.57	0.83	0.50	1.13
Kurtosis	3.51	3.25	4.26	4.94	3.91	10.97
t-value	0.41	1.23	2.70	2.66	2.76	2.24
Sharpe Ratio	0.06	0.18	0.39	0.39	0.40	0.33
Max Drawdown %	-0.49	-0.45	-0.40	-0.15	-0.19	-0.11
Panel B: Nominal exchange rate return						
Statistics	**P1**	**P2**	**P3**	**HML**	**PF Rank**	**PF Linear**
Mean %	-4.90	-1.74	-2.94	1.96	1.73	0.78
Volatility %	8.94	7.29	8.47	9.92	8.15	5.74
Skewness	-0.52	0.31	0.46	-0.17	0.09	0.20
Kurtosis	4.54	3.65	3.99	5.88	5.25	7.10
t-value	-3.76	-1.64	-2.38	1.36	1.46	0.93
Risk-adjusted return	-0.55	-0.24	-0.35	0.20	0.21	0.14
Max Drawdown %	-0.93	-0.66	-0.81	-0.64	-0.58	-0.39
Panel C: Nominal exchange rate return: G10						
Statistics	**P1**	**P2**	**P3**	**HML**	**PF Rank**	**PF Linear**
Mean %	-1.36	0.53	1.40	2.75	2.64	1.56
Volatility %	9.66	9.10	8.54	8.17	7.65	4.49
Skewness	0.20	0.03	0.33	-0.26	-0.17	0.07
Kurtosis	4.29	3.48	3.17	4.41	4.07	4.21
t-value	-0.96	0.40	1.12	2.31	2.37	2.39
Risk-adjusted return	-0.14	0.06	0.16	0.34	0.35	0.35
Max Drawdown %	-0.70	-0.44	-0.39	-0.32	-0.29	-0.17
Panel D: Nominal exchange rate return: G10 excluded						
Statistics	**P1**	**P2**	**P3**	**HML**	**PF Rank**	**PF Linear**
Mean %	-7.76	-3.77	-6.54	1.22	1.00	0.22
Volatility %	9.67	7.03	10.13	11.72	10.68	7.32
Skewness	-1.59	-0.03	0.41	0.67	0.82	0.66
Kurtosis	7.26	4.93	4.52	5.11	5.44	8.14
t-value	-5.50	-3.68	-4.43	0.71	0.64	0.21
Risk-adjusted return	-0.80	-0.54	-0.65	0.10	0.09	0.03
Max Drawdown %	-0.98	-0.86	-0.97	-0.66	-0.63	-0.50

Figure 4 depicts the cumulative returns for the HML portfolios presented in Table 11 in panels A, B, C, and D, correspondingly. The cumulative returns continue the same story as Table 11**.** The highest cumulative return is achieved by the HML portfolio that is formed with excess currency returns. Right after cumulative currency excess returns comes the HML portfolio formed by including only nominal exchange rate return and the

G10 currencies. Consequently, the HML portfolios formed using nominal exchange rate returns for the whole sample and excluding G10 have positive but lower cumulative returns. The common characteristic for all the portfolios is poor performance in recent decades. For excess currency return HML portfolio the profits are achieved almost solely in the 1990s. Nevertheless, since the beginning of the current century, the strategy has been flat, indicating that the returns have been virtually zero. The same pattern is true for the G10 HML portfolio, however, the flatness starts around 2009. The HML portfolios formed using the whole sample and excluding G10 start strongly at the beginning of the sample period but then experience sharp losses, overall, since 2013 the portfolios of the two portfolios have been experiencing negative returns.

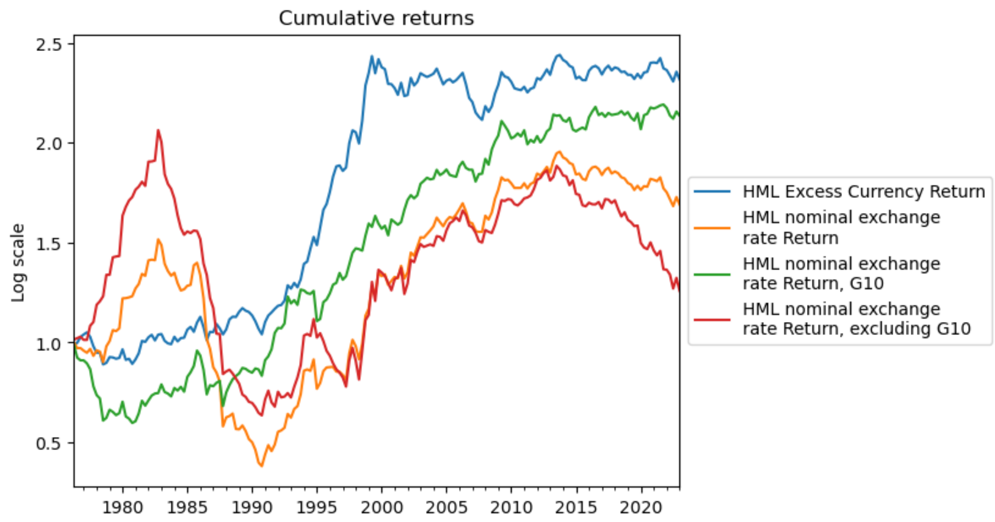

Figure 4. Cumulative returns for benchmark portfolios.

The figure above plots the cumulative returns for different HML portfolios formed using the plain value signal. The blue line represents the excess return HML portfolio. Then, the orange line represents the nominal exchange rate change HML portfolio. Next, the green line represents the nominal exchange rate change HML portfolio formed using only G10 currencies. Lastly, the red line represents the nominal exchange rate change portfolio formed from a sample excluding the G10 currencies. The sample period is from 1976Q1 to 2023Q1.

5.2.2 Adjusted value signal

This section seeks to answer whether the poor performance of nominal exchange rate predictability with plain RER signal in the benchmark portfolio cases is due to the expected inflation differentials between economies and bad fundamentals of an economy. Intuitively, adjusting the plain RER signal with expected inflation differentials is justified based on the theory of PPP. Hence, if one economy is expected to experience higher inflation in the future than another, then the higher-inflation economy should see its nominal exchange rate depreciating. In addition, as argued before, transitory disparities can be explained by the macro fundamentals such as HBS, OG, and NFA. Thus, purging the macro fundamentals effect out of the RER signal can potentially result in a clearer measure of currency value. Another way to think about the adjustment is that the rational risk, related to macro fundamentals, is sought out. Besides, equation 11 shows that controlling for the forces affecting the long-run RER potentially results in a clearer measure of future excess currency risk premiums. Nevertheless, the relationship here is tested for nominal exchange rate change-related premiums. Table 12 presents the results for adjusted value signal portfolios. Lastly, the macro fundamentals HBS, OG, and NFA are not available for all the economies at every point in time during the sample period, thus the results in panels B and C are not directly comparable to the benchmark currency value portfolios.

Table 12. Adjusted currency value portfolios.

The table below presents the portfolios formed according to the adjusted currency value signals. Panel A corresponds to the value signal that is obtained by subtracting the expected inflation differentials from the plain signal. In panels B and C, the plain signal is adjusted by cross-sectional regression, where fitted and residual signal time series are obtained. The difference between panels B and C is as follows: In panel B regressions, macro fundamentals HBS, OG, and NFA are included whereas panel C adds also the expected inflation differentials to the regressions. Panel D includes portfolios formed using the excess currency returns for comparison. The sample period is from 1976Q1 to 2023Q1.

Short-term predictability: rebalancing portfolios quarterly:						
Panel A: RER signal adjusted by subtracting expected inflation differential						
Statistics	**P1**	**P2**	**P3**	**HML**	**PF Rank**	**PF Linear**
Mean %	-6.82	-1.96	-0.48	6.34	5.77	4.31
Volatility %	8.73	7.38	8.45	9.79	7.99	5.86
Skewness	-0.30	0.19	0.50	0.67	0.64	1.06

Statistics	PF Linear	PF linear fitted	PF linear residual	PF Rank	PF rank fitted	PF rank residual
Kurtosis	4.43	3.61	4.13	4.35	4.02	5.82
t-value	-5.35	-1.82	-0.39	4.44	4.95	5.05
Risk-adjusted return	-0.78	-0.27	-0.06	0.65	0.72	0.74
Max Drawdown %	-96.91	-70.37	-44.84	-6.09	-4.13	-1.00
Panel B: Adjusting with HBS, OG, and NFA						
Statistics	**PF Linear**	**PF linear fitted**	**PF linear residual**	**PF Rank**	**PF rank fitted**	**PF rank residual**
Mean %	0.67	-0.22	0.89	1.60	-0.09	1.79
Volatility %	6.26	2.61	4.32	8.93	7.05	8.20
Skewness	0.12	0.12	0.28	0.21	0.63	0.09
Kurtosis	7.01	12.06	4.86	5.61	4.49	5.46
t-value	0.74	-0.57	1.41	1.23	-0.08	1.49
Risk-adjusted return	0.11	-0.08	0.21	0.18	-0.01	0.22
Max Drawdown	-42.03	-24.59	-29.33	-59.98	-43.96	-52.12
Panel C: Adjusting with HBS, OG, NFA, and expected inflation differential						
Statistics	**PF Linear**	**PF linear fitted**	**PF linear residual**	**PF Rank**	**PF rank fitted**	**PF rank residual**
Mean %	0.67	-0.73	1.40	1.60	-0.32	2.23
Volatility %	6.26	3.88	3.33	8.93	8.16%	6.64
Skewness	0.12	-0.04	0.38	0.21	0.68	0.15
Kurtosis	7.01	7.82	5.07	5.61	4.83	3.90
t-value	0.74	-1.30	2.89	1.23	-0.27	2.30
Risk-adjusted return	0.11	-0.19	0.42	0.18	-0.04	0.34
Max Drawdown %	-42.03	-42.23	-8.30	-59.98	-57.08	-21.32
Panel D: Excess returns, adjusting with HBS, OG, and NFA						
Statistics	**PF Linear**	**PF linear fitted**	**PF linear residual**	**PF Rank**	**PF rank fitted**	**PF rank residual**
Mean %	1.73	0.24	1.49	3.03	0.67	2.65
Volatility %	5.76	2.79	3.95	7.49	7.32	6.78
Skewness	0.97	2.62	0.17	0.52	0.88	0.06
Kurtosis	11.54	23.46	4.11	4.31	5.95	3.22
t-value	2.06	0.60	2.59	2.78	0.63	2.68
Sharpe Ratio	0.30	0.09	0.38	0.40	0.09	0.39
Max Drawdown %	-11.06	-8.80	-8.99	-19.02	-27.95	-15.99

Starting from Panel A in Table 12, the plain RER signal is adjusted by subtracting the expected inflation differentials from the signal. In this way, the adjusted signal more accurately takes into account the future nominal exchange rate fluctuations hypothesized by the PPP, since the higher inflation economies should see depreciating nominal exchange rates. The adjusted signal predictability is higher than for the plain RER signal. The risk-adjusted return is 0.65 for the HML portfolio which is substantially larger than the previously observed 0.20 in Table 11 panel B. The adjustment made here is intuitive and easy to understand since the nominal exchange rate depreciation in high-inflation economies seems to have taken place. Concern related to the results in panel A is the dominating currencies, for instance, in this case Turkish Lira and Mexican Peso that have seen a continuous depreciation throughout the years. Plotting the adjusted and plain signals together, I observed that for TR and MX the signals have large differences. Thus, in Appendix A the results of panel A in Table 12 are presented without including the TR or MX in the sample.

Panels B and C represent the portfolios for plain, fitted, and residual signals using either linear portfolios or rank portfolios. The linear portfolio's advantage is the allowing of precise decomposition of the signal, in this case, the plain RER, into two compelling parts. Hence, rank portfolios are presented for robustness check. Continuing, panel B adjusts the plain RER signal with HBS, OG, and NFA macro fundamentals. As a result, the fitted signal depicts the portfolio obtained using the change in RER attributable to macro fundamentals, meaning that the risk related to these fundamentals is observable. In contrast, the residual signal depicts the part of RER change that is not attributable to macro fundamentals and hence is related to unobservable risk premium.

Panel B in Table 12 shows a clear pattern of residual signal outperformance compared to the overall signal and fitted value signal. For linear portfolios, the contrast between the portfolios is larger. Risk-adjusted return for the residual signal portfolio yields a 0.21 whereas the overall signal harvests a 0.11 ratio. In addition, the mean return increases alongside decreasing volatility when using the residual signal to construct the portfolio. Similar results hold for rank portfolios, although the contrast between overall and residual signals is not large. Nonetheless, the fitted signal is yielding negative returns in both linear and rank portfolio cases. Overall, panel B's results suggest that purging the impact of macro fundamentals of the RER results in a clearer measure of expected risk premiums associated with the nominal exchange rates. Menhoff et al. (2017) find similar results, although the authors use excess currency returns. Excess currency returns are included in panel D for comparison. For excess currency returns the residual signal performs better than the overall signal in the linear portfolio case. For the rank portfolio, the overall signal and residual signal yield similar results.

Panel C includes the expected inflation differentials to the cross-sectional regression which is used to purge the impact of macro fundamentals on the five-year change in RER. The procedure is an exact copy of panel B's method, and hence there are expected inflation differentials available for the whole set of economies, panel B and C can be directly compared. Consequently, the impact of adding the expected inflation differential as an adjustive variable affects the results. Now, for the linear portfolio, the risk-adjusted return ratio increases to 0.42 from 0.09. The performance is similar for the rank portfolio. Remarkably, the expected inflation differentials can indeed boost the performance of currency value as a forecasting tool for future nominal exchange rate fluctuations.

5.3 Overlapping holding period portfolios

The aim of the thesis is to evaluate the medium-term horizon predictability of nominal exchange rate changes using the PPP indicator as a currency value. Therefore, the overlapping portfolios are deployed next to cover the medium-term predictability. Starting from Table 13, the summary statistics are presented for different horizons overlapping holding period portfolios formed using different signals. Panel A begins by using the unadjusted five-year change in RER as a currency value signal. 4, 8, 12, and barely 16 quarter overlapping holding period portfolios returns are positive. However, observing from the table, the return drops sharply after 12 quarters. Further, the mean return for overlapping holding periods of 20 quarters is negative, indicating that the unadjusted five-year change in RER is unable to harvest medium-term horizon returns. In addition, the finding is in line with the regression analysis conducted earlier in the thesis, emphasizing the rightful acceptance of the null hypothesis related to research question one. Moreover, the result pronounces the need for adjustment of the signal, likewise earlier macro fundamentals added to the regression as control variables. Figure 5 shows the risk-adjusted return for all overlapping holding period portfolios and for two subsamples.

Continuing to panel B, the plain five-year change in RER is adjusted by subtracting the expected inflation differentials from the signal. As a result, the performance is increased in terms of mean return and risk-adjusted return. Hence, the mean returns do not experience a significant sharp drop at any point on the horizon. Moreover, the result suggests that expected inflation differentials bear valuable information about the future direction of the nominal exchange rates. Above all, the adjustment made here is very simple and intuitive to understand: if one economy is expected to experience higher inflation in the future than the other, then the nominal exchange rate should move to balance the purchasing power between the countries. The simple adjustment works well in the cross-sectional dimension, where all the currencies are evaluated based on the overall cross-sectional distribution of signals. The simple adjustment's risk-adjusted returns are plotted for all overlapping holding period portfolios in Figure 6.

Panel C presents the results for a plain five-year change in RER adjusted with the HBS, OG, and NFA macro fundamentals. Precisely, the adjustment is made according to equation 18 and the residual term is used as an approximation of currency value. Now, the mean and risk-adjusted returns are better than for the plain signal at the 4, 8, and 12 quarters. However, the difference is marginal and for the longer periods, the relationship is inversed. One interpretation of the result can be derived from Menkhoff et al. (2015) paper. Thus, the authors find that the currency value adjusted with HBS and differences in export quality result in a predictive content that is mainly driven by undervalued currencies appreciating exchange rates. The effect goes on for 6 months and eventually, the predictable power dies after 12^{th} quarter. The authors conclude that the adjusted currency value is more related to the macro fundamentals, and the predictability of RER overall relates to the nominal exchange rates configuration of the right level suggested by the macro fundamentals. A similar pattern is observable in the thesis results, and the adjustment phase is denoted in Figure 7.

Next, the key question is, can the macro fundamentals predictability be enhanced by including the expected inflation differentials to the cross-sectional regression as a control variable. Panel D presents the results for the aforementioned adjusted signal. Indeed, the results are better, hence the mean and risk-adjusted returns improve at every overlapping holding period portfolio horizon. Above all, the five-year holding period shows a positive return. Nevertheless, the results are poorer compared to the simple adjustment method. Figure 8 plots the risk-adjusted return for all overlapping holding period portfolios. The subsamples, namely G10 and excluding G10, look quite different for the whole five-year period.

Table 13. Overlapping holding period portfolios.

The table below shows different horizons overlapping holding period portfolios' summary statistics formed by using different currency value signals. 4, 8, 12, 16, and 20 indicate the overlapping holding period portfolios rebalancing interval. All the interval statistics are based on portfolios formed in an HML manner. Panel A denotes the plain five-year change in the RER signal. Panel B denotes the plain five-year change in the RER signal adjusted by subtracting the expected inflation differentials from the plain signal. Panel C denotes the plain five-year change in RER adjusted with HBS, OG, and NFA. Panel D denotes the plain five-year change in RER adjusted with HBS, OG, NFA, and expected inflation differentials. Mean, volatility, and risk-adjusted return are annualized. Sample period from 1981Q2 to 2023Q1.

Different horizon predictability: Nominal exchange rate changes					
Panel A: Unadjusted five-year change in RER					
Statistics/ overlapping holding period	**4**	**8**	**12**	**16**	**20**
Mean %	2.10	1.45	0.73	0.09	-0.50
Volatility %	8.86	7.62	6.87	6.31	5.81
Skewness	-0.34	-0.49	0.10	0.22	0.14
Kurtosis	6.92	7.65	4.85	4.07	4.44
t-value	1.53	1.24	0.69	0.10	-0.56
Risk-adjusted return	0.24	0.19	0.11	0.01	-0.09
Panel B: RER signal adjusted by subtracting expected inflation differential					
Statistics/ overlapping holding period	**4**	**8**	**12**	**16**	**20**
Mean %	6.85	6.50	5.88	5.28	4.71
Volatility %	8.78	7.83	7.32	6.90	6.43
Skewness	0.73	0.52	0.54	0.48	0.40
Kurtosis	3.99	3.85	4.17	4.14	4.07
t-value	5.08	5.39	5.22	4.98	4.77
Risk-adjusted return	0.78	0.83	0.80	0.77	0.73

Panel C: Adjusting with HBS, OG, and NFA					
Statistics/ overlapping holding period	**4**	**8**	**12**	**16**	**20**
Mean %	2.37	1.55	0.75	-0.11	-0.76
Volatility %	7.35	6.34	5.91	5.45	4.93
Skewness	-0.55	-0.02	0.52	0.29	0.14
Kurtosis	6.95	5.58	4.33	3.64	3.80
t-value	2.12	1.61	0.83	-0.16	-1.02
Risk-adjusted return	0.32	0.24	0.13	-0.02	-0.16
Panel D: Adjusting with HBS, OG, NFA, and expected inflation differential					
Statistics/ overlapping holding period	**4**	**8**	**12**	**16**	**20**
Mean %	3.38	3.06	2.10	1.20	0.52
Volatility %	6.02	5.37	5.08	4.75	4.43
Skewness	0.13	0.44	0.58	0.44	0.41
Kurtosis	2.89	3.02	3.96	3.68	3.72
t-value	3.66	3.71	2.71	1.65	0.77
Risk-adjusted return	0.56	0.57	0.41	0.25	0.12

Then the thesis measures the significance of the predictability between benchmark and signal using time-series regressions. Specifically, the thesis is interested if the selected currency value strategy can yield statistically significant and positive alpha. Eiter the P1 or P3 bin is the dependent variable in the regression and the independent variable is the market factor, or benchmark. In this way, the intercept of the regression shows how much under or outperformance the examined currency value signal has yielded over the market or benchmark return. Then the P3 and P1 alphas are compared using the alpha spread test.

Table 14 presents the findings of the time-series regressions and alpha spread tests. Beginning from panel A, the different signals are regressed on the market portfolio. The plain five-year change in the RER signal cannot beat the market portfolio with statistical significance on any horizon. Hence, the alpha spread is not statistically significant, indicating that going long in weak currencies and going short in expensive ones does not provide an advantage over a simple market portfolio. The finding is not surprising, keeping in mind the earlier results showing that the unadjusted currency value signal is not, to begin with, a statistically significant predictor of subsequent nominal exchange rate fluctuations. Next, the plain five-year change in the RER signal is adjusted by subtracting the expected inflation differentials from the signal. Now, the results show statistically significant alpha at a 1% significance level. Hence, the simple adjustment works well and provides a more robust and clearer measure of currency value relative to holding a market portfolio of sample currencies. Then, the plain five-year change in RER is adjusted with the macro fundamentals HBS, OG, and NFA through cross-section regression. The results indicate that accordingly adjusted currency value signal is unable to provide any statistically significant performance improvement relative to the market portfolio. Thus, the finding suggests that the expected inflation differentials need to be accounted for in the adjustment process. Lastly, the plain five-year change in RER is adjusted with HBS, OG, NFA, and expected inflation differentials. The adjusted signal yields statistically significant outperformance relative to the market portfolio in a 4 to the 12-quarter holding period. However, the 16 and 20-quarter holding periods are not statistically significant, yet positive.

Panel B of table 14 shows similar alpha spread computations as in panel A but now the market portfolio is replaced with the benchmark portfolio using the plain five-year change in RER signal. Starting from the simply expected inflation differentials subtracted signal, the outperformance is statistically significant at a 1% significance level relative to the unadjusted five-year change in the RER signal. Moreover, the alpha stays relatively stable for all overlapping holding period portfolios presented here, around 1.24% to 1.30%. Next, the candidate is the macro fundamental, HBS, OG, and NFA, adjusted signal. The results show that there is positive outperformance for 4, 6, and 12 overlapping holding period portfolios but the outperformance is not statistically significant. For 16 and 20 overlapping holding period portfolios the outperformance turns into a underperformance. The results are consistent with the findings from Table 13, and also with Menkhoff et al. (2015) finding that after 12 quarters the macro-adjusted signal dies. Rather, the plain five-year change in RER can capture the medium-term predictability better than the HBS, OG, and NFA adjusted signal. Besides, the finding is in line with the intuition that undervalued currencies', measured as the HBS, OG, and NFA adjusted signal, nominal exchange rate reverts toward the level suggested by the macro fundamentals. Then, the last row of panel B corresponds to the plain five-year change in the RER signal adjusted with HBS, OG, NFA, and expected inflation differentials. Now, the outperformance is statistically significant at a 1% level for 4 and 8 quarters overlapping holding period portfolios. For a 12-quarters overlapping holding period portfolio, the outperformance is statistically significant at a 5% significance level, and for a 16-quarters overlapping holding period portfolio outperformance is statistically significant at a 10% significance level. However, for 20 quarters overlapping the holding period portfolio, the outperformance is not statistically significant, yet it is positive, 0.20%.

Table 14. Statistical significance of currency value.

The table below presents the alphas obtained from time-series regression and alpha spreads. Panel A denotes the alpha spreads obtained from a time-series regression using the market portfolio as a benchmark. Panel B denotes the alpha spreads obtained from a time series using plain five-year change in the RER return series as a benchmark. $\Delta^{(5y)}q$, $\varepsilon q_{E\pi}$, εq_{MA}, and $\varepsilon q_{E\pi+MA}$ correspond to the plain five-year change in RER, signal adjusted by subtracting the expected inflation differentials from the plain signal, only HBS, OG, and NFA adjusted signal, and HBS, OG, NFA, and expected inflation differentials adjusted signal. Time-series regression t-statistics are based on Newey-West (1987) autocorrelation and heteroskedasticity robust standard errors. *, **, *** indicate statistical significance of the alpha at 10%, 5%, and 1% significance level, respectively. Results per quarter and in percentage form. The sample period is from 1976Q1 to 2023Q1.

Statistical significance of currency value

	Panel A: Benchmark market portfolio, alpha spreads P3 – P1				
	Overlapping holding period				
Signal	**4**	**8**	**12**	**16**	**20**
$\Delta^{(5y)}q$ P3 – P1	0.45	0.26	0.08	-0.08	-0.24
$\varepsilon q_{E\pi}$ P3 – P1	**1.67*** **	**1.53*** **	**1.37*** **	**1.23*** **	**1.09*** **
εq_{MA} P3 – P1	0.57	0.32	0.12	-0.09	-0.26
$\varepsilon q_{E\pi+MA}$ P3 – P1	**0.90*** **	**0.76*** **	**0.49* **	0.27	0.10
	Panel B: Benchmark $\Delta^{(5y)}q$, alpha spreads P3 – P1				
	Overlapping holding period				
Signal	**4**	**8**	**12**	**16**	**20**
$\varepsilon q_{E\pi}$ P3 – P1	**1.24*** **	**1.29*** **	**1.30*** **	**1.30*** **	**1.29*** **
εq_{MA} P3 – P1	0.21	0.12	0.05	-0.05	-0.10
$\varepsilon q_{E\pi+MA}$ P3 – P1	**0.58*** **	**0.58*** **	**0.43** **	**0.29* **	0.20

Then, the thesis evaluates the risk-adjusted performance of the plain five-year change in the RER and adjusted value signals performance. The key idea is to find evidence that the adjustment of the signal with various macro fundamentals is efficient. The hypothesis is that the risk-adjusted returns are the same and the alternative hypothesis then states that there is a statistically significant difference between the risk-adjusted returns. Table 15 shows the result of the risk-adjusted performance comparison between the signals, and every signal's subsample is evaluated against the overall signal as well. Therefore, panel A denotes the plain five-year change in the RER signal's risk-adjusted performance against the alternative adjusted signals. Starting from the first row, the difference between the plain signal and simple adjustment, expected inflation differentials subtracted, is negative and statistically significant at a 1% significance level. Finding means that the adjusted signal can perform better on a risk-adjusted basis and the difference is even increasing as the horizon extends. Then the HBS, OG, and NFA adjusted signal, there is no statistically significant difference between the risk-adjusted performance compared to the plain signal. Notably, the macro-adjusted signal performs worse when the horizon extends. Next, the macro and expected inflation-adjusted signal performs statistically better in risk-adjusted terms. The statistical significance is at a 1% level during the 4 and 8 quarter horizons, however dropping to a 5% significance level during the 12 and 16 quarter horizon and evenly dropping to a statistically insignificant level at the 20 quarter horizon. The subsample analysis shows that the G10 group can beat the overall sample and excluding the G10 sample statistically significant terms, the significance level varying from 5% to 10%. An exception is that the G10 group cannot beat the whole sample at the 4-quarter horizon. Similarly, the whole sample delivers statistically significant risk-adjusted returns compared to the excluding G10 sample. One exception is the 20-quarter horizon when there is not statistically significant overperformance.

Panel B shows the results for the signal adjusted by subtracting the expected inflation differences from the plain signal. The simple adjustment delivers statistically significant overperformance compared to the signal adjusted by HBS, OG, and NFA while the significance level is 4 out of 5 times at a 1% level. Then, the signal adjusted with HBS, OG, NFA, and expected inflation differentials, the results show that simple adjustment is better when the horizon extends. Hence, in shorter horizons, there is no statistically significant difference between these two adjustments' risk-adjusted performance. Subsample analysis shows that there are statistically significant differences when the horizon extends to 16 and 20 quarters. Thus, the whole sample can beat the G10 group at 20 quarters horizon. In contrary, to the plain signal, the group excluding G10 can outperform the G10 group at 16 and 20 quarter horizons. The finding suggests that expected inflation differentials are especially important to account for the non-G10 currencies.

Panel C reports the results for the macro, HBS, OG, and NFA, adjusted signal. First, the signal is compared to the signal adjusted with HBS, OG, NFA, and expected inflation differentials. At 4 quarter horizons, there is not statistically significant difference. Nevertheless, as the horizon extends the HBS, OG, NFA, and expected inflation differentials adjusted signal starts to outperform in a statistically significant manner, and the outperformance stays quite stable until the 20-quarters horizon. Then the subsamples, notably the non-G10 group are experiencing worse performance constantly at every horizon compared to the G10 and whole sample. The finding suggests that adjusting only with HBS, OG, and NFA is not enough for the non-G10 currencies, rather the expected inflation differentials are needed.

Panel D presents the results for the subsample of plain signal adjusted with HBS, OG, NFA, and expected inflation differentials. Now, there are only statistically significant differences between the whole sample and both the subsamples at 4 quarters horizon. Thus, the whole sample can outperform both the subsamples at a 4-quarters horizon. The result suggests that the cross-sectional regression can deliver better-adjusted signals when the whole sample is included in the cross-sections. Another interesting finding is that G10 currencies underperform against the whole and non-G10 sample at shorter horizons but deliver better risk-adjusted returns when the horizon extends, although not statistically significant.

Table 15. Statistical significance of risk-adjusted performance.

The table below presents the risk-adjusted return performance differences. Panel A denotes the plain five-year change in RER versus the adjusted signals, and in every panel's bottom, there is a subsample analysis of the risk-adjusted performance between the overall sample, G10, and excluding G10. Panel B denotes the signal adjusted by subtracting the expected inflation differentials from the plain signal. Panel C denotes the macro, HBS, OG, and NFA, adjusted signal. Panel D denotes the macro, HBS, OG, NFA, and expected inflation differentials adjusted signal. $\Delta^{(5y)}q$, $\varepsilon q_{E\pi}$, εq_{MA}, and $\varepsilon q_{E\pi+MA}$ correspond to the plain five-year change in RER, signal adjusted by subtracting the expected inflation differentials from the plain signal, only HBS, OG, and NFA adjusted signal, and HBS, OG, NFA, and expected inflation differentials adjusted signal. *, **, *** indicate statistical significance of the risk-adjusted return performance difference at 10%, 5%, and 1% significance level, respectively. Results per quarter. The sample period is from 1976Q1 to 2023Q1. Note that signal comparison is done only once, hence the number of signals decreases in every panel.

Statistical significance of performance

Panel A: $\Delta^{(5y)}q$					
Overlapping holding period					
Signal	**4**	**8**	**12**	**16**	**20**
$\varepsilon q_{E\pi}$,	**-0.27*****	**-0.32*****	**-0.35*****	**-0.38*****	**-0.41*****
εq_{MA},	-0.04	-0.03	-0.01	0.02	0.03
$\varepsilon q_{E\pi+MA}$	**-0.16*****	**-0.19*****	**-0.15****	**-0.12****	-0.10
Whole - G10	-0.14	**-0.14***	**-0.18****	**-0.17****	**- 0.15****
Whole - Excl. G10	**0.11****	**0.09***	**0.11***	**0.10***	0.09
G10 - Excl. G10	**0.25****	**0.24****	**0.28****	**0.27****	**0.23****
Panel B: $\varepsilon q_{E\pi}$,					
Overlapping holding period					
Signal	**4**	**8**	**12**	**16**	**20**
εq_{MA},	**0.23****	**0.29*****	**0.34*****	**0.39*****	**0.44*****
$\varepsilon q_{E\pi+MA}$	0.11	0.13	**0.20***	**0.26****	**0.31*****
Whole - G10	0.11	0.14	0.14	0.17	**0.23***
Whole - Excl. G10	0.04	0.03	0.01	-0.01	-0.01
G10 - Excl. G10	-0.07	-0.11	-0.13	**-0.18***	**-0.24****
Panel C: εq_{MA},					
Overlapping holding period					
Signal	**4**	**8**	**12**	**16**	**20**
$\varepsilon q_{E\pi+MA}$	-0.12	**-0.16****	**-0.14***	**-0.14****	**-0.14*****
Whole - G10	-0.02	-0.8	**-0.15***	**-0.19****	**-0.20*****
Whole - Excl. G10	**0.14****	**0.10***	**0.12***	**0.13***	**0.12***
G10 - Excl. G10	0.16	0.18	**0.27****	**0.32*****	**0.34*****
Panel D: $\varepsilon q_{E\pi+MA}$					
Overlapping holding period					
Signal	**4**	**8**	**12**	**16**	**20**
Whole - G10	**0.16***	0.14	0.03	-0.05	-0.08
Whole - Excl. G10	**0.13***	0.10	0.10	0.08	0.05
G10 - Excl. G10	-0.03	-0.05	0.06	0.11	0.11

The graphs below show the risk-adjusted returns for every period up to the 20 quarters. From the graphs can be obtained that the medium-term horizon predictability looks better for adjusted signals in general, as the previous statistical tests already suggest.

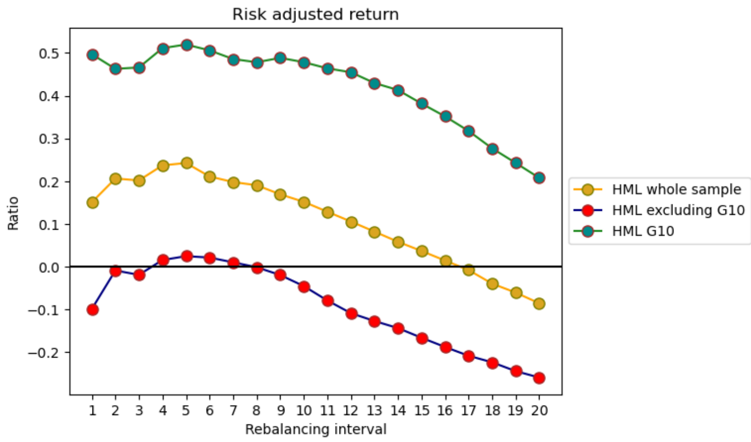

Figure 5. Risk-adjusted return plain five-year change in RER signal.

The graph above shows the risk-adjusted return ratios for currency value portfolios using nominal exchange rate change with different holding periods. The currency value used is the five-year change in RER. The golden dot stands for the HML portfolio for the whole sample of currencies. The red dot stands for the HML portfolio when G10 currencies are excluded from the sample. The Cyan dot stands for the HML portfolio including only G10 currencies. The data in the figure are annualized. The sample period is from 1986Q2 to 2023Q1.

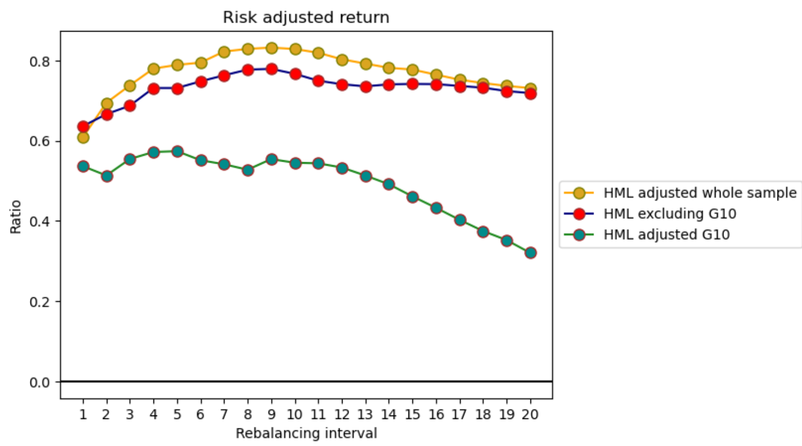

Figure 6. Risk-adjusted return for expected inflation differentials adjusted value signal.

The graph above shows the risk-adjusted return ratios for currency value portfolios using nominal exchange rate change with different holding periods. The currency value used is the five-year change in RER. The golden dot stands for the HML portfolio for the whole sample of currencies. The red dot stands for the HML portfolio when G10 currencies are excluded from the sample. The Cyan dot stands for the HML portfolio including only G10 currencies. The data in the figure are annualized. The sample period is from 1986Q2 to 2023Q1.

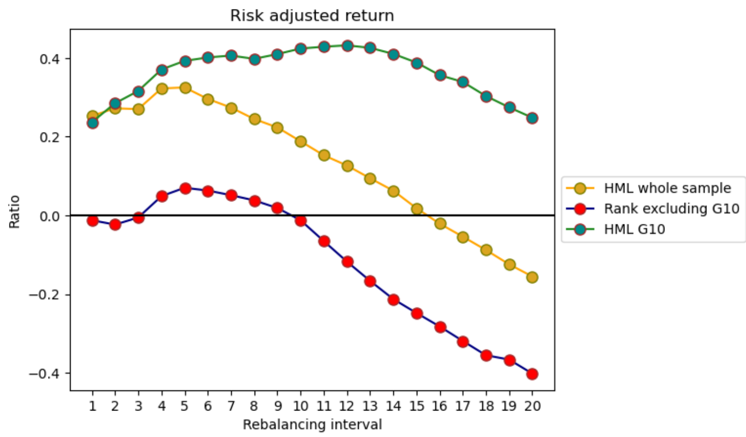

Figure 7. Risk-adjusted return for currency value signal adjusted with HBS, OG, and NFA.

The graph above shows the risk-adjusted return ratios for currency value portfolios using nominal exchange rate change with different holding periods. The currency value used is the five-year change in RER. The golden dot stands for the HML portfolio for the whole sample of currencies. The red dot stands for the HML portfolio when G10 currencies are excluded from the sample. The Cyan dot stands for the HML portfolio including only G10 currencies. The data in the figure are annualized. The sample period is from 1986Q2 to 2023Q1.

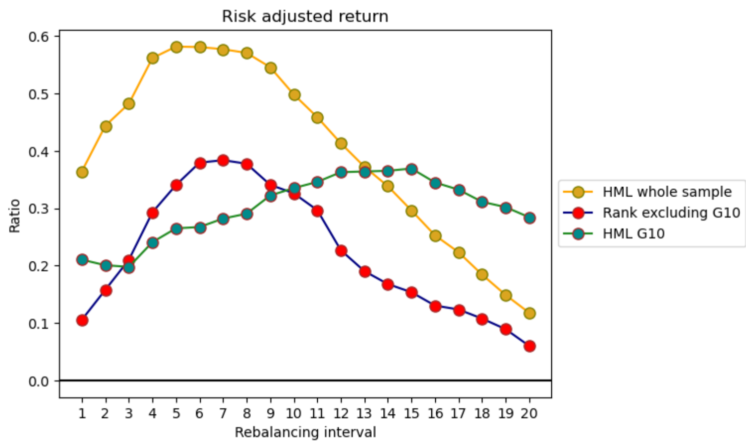

Figure 8. Risk-adjusted return for currency value signal adjusted with HBS, OG, NFA, and expected inflation differentials.

The graph above shows the risk-adjusted return ratios for currency value portfolios using nominal exchange rate change with different holding periods. The currency value used is the five-year change in RER. The golden dot stands for the HML portfolio for the whole sample of currencies. The red dot stands for the HML portfolio when G10 currencies are excluded from the sample. The Cyan dot stands for the HML portfolio including only G10 currencies. The data in the figure are annualized. The sample period is from 1986Q2 to 2023Q1.

Overall, the results in this section suggest that the signal adjusted by subtracting the expected inflation differentials from the plain signal deliverers the best risk-adjusted performance. In addition, the performance tests suggest, and back up, the earlier findings from the regression analysis that it is suggestable to adjust the plain five-year change in RER with macro fundamentals. The most important fundamental is the expected inflation differentials, hence including them in the adjustment process yields better performance of currency value strategy. However, the plain five-year change in RER is a strong predictor of future currency returns for the G10 group, and by adjusting the signal for G10 currencies, the predictability decreases, especially in the shorter-term horizon.

6 Additional results

Additional results are provided for a robustness check and for challenging the broadly used five-year change in RER as a dominating currency value indicator. First, the chapter presents the RER level and changes in more detail and compares them since both are used in the previous literature, see Table 1. Then, the RER is constructed using PPI and CPI indices with different samples of currencies and timeframes. Robustness is assessed by addressing whether CPI is the accurate option to use in RER construction. Next, the chapter moves on to tackle the weakening currency value signals retrieved from the RER. Lastly, the volatility effect is examined in the different currency groups to see if discrepancies appear and if the volatility has implications for the nominal exchange rate predictability.

6.1 Levels and changes in RER

Comparing the level and change in RER gives better insights into the predictable power behind the RER. Table 16 Panel A starts by decomposing the RER level information into two parts, namely lagged level, and change in RER, using excess currency returns. Menkhoff et al. (2015) use a similar method to decompose the RER level into subcomponents. The authors find that 75% of the level of predictability stems from the RER change. Nonetheless, currently, the situation has been balanced more between the lagged level and change as is visible from Table 16 since the overall signal yields 1.90% and the subcomponents 1.01% and 0.89%, respectively. Recently, Hutchinson et al. (2022) argued that currencies do not respond to the value factor anymore. The findings of the authors might explain why the change in RER has lost its touch. Furthermore, the change in RER can be decomposed into two factors, a change in inflation differentials, and a change in the spot exchange rate. For panel B, the same decomposition pattern applies, however, the difference is the usage of nominal exchange rate change.

Table 16. Decomposing RER.

This table presents the results of the decomposition of the RER level using linear portfolios. Thus, the composite signal in this table is the RER level. First, panel A represents the results of using the excess currency return. Secondly, panel B represents the results of using the nominal exchange rate changes. T-statistics are based on Newey-West (1987) autocorrelation and heteroskedasticity robust standard errors. The figures are annualized. The sample period is from 1976Q1 to 2023Q1.

	Decomposing the RER level				
	q_t	q_{t-5y}	$\Delta^{(5y)}q_{j,t}$	$-\Delta^{(5y)}s_{j,t}$	$-\Delta^{(5y)}\pi_{j,t}$
Panel A: Excess returns					
Mean %	1.90	1.01	0.89	4.78	-3.89
T-value	2.93	2.02	2.39	3.23	-2.95
Sharpe ratio	0.40	0.27	0.35	0.68	-0.63
Panel B: Exchange rate changes					
Mean %	-3.45	-3.81	0.36	-11.36	11.72
T-value	-4.40	-5.89	0.52	-5.13	5.77
Sharpe ratio	-0.74	-0.97	0.12	1.45	-1.33

The predictive content for the exchange rate changes is quite different. Consequently, the RER level now predicts -3.45% depreciating nominal exchange rate changes. The predictability stems from lagged levels which predict -3.81% depreciation, hence accounting for over 100% of the predictability. As a result, the five-year change in RER predicts a 0.36% appreciation on average, going against the overall pattern. Menkhoff et al. (2015) observe the finding also and argue that RER levels and RER changes predictability stem from different sources. Therefore, the authors continue, the RER level seems to be associated with the nominal interest rate differentials since weak RERs compensate for the future nominal exchange rate depreciation. However, intuitively the RER changes are more associated with both excess returns and nominal exchange rate changes. Thus, currency value works this way, currencies with long-term appreciation in the RER see depreciation going forward and vice versa, exactly how the mean reversal effect should work. Notably, the mean reversal effect manifestation is still uncovered, hence the nominal exchange rate change accounts for only around 40% (for the authors, 45%) of the excess return. Further, the above means that most of the excess currency predictability offered by the five-year change comes from the interest rate differentials.

The two last columns of Table 16 decompose the five-year change in RER into two subcomponents, negative nominal spot exchange rate change and negative inflation differential change. First, panel A suggests that when using the excess currency returns, the predictability comes from the nominal spot exchange rate. Therefore, going long on currencies that have depreciated for the past five years commands high returns, suggesting that there is a risk premium associated. In contrast, the changes in inflation differentials predict the opposite, meaning that higher inflation countries enjoy some kind of risk premium. In panel B, when using the nominal exchange rates, the signs change for the opposite. As a result, a negative five-year nominal exchange rate change predicts that previously appreciated currencies will appreciate even more. In contrast, for negative change in inflation differentials, the result suggests that high-inflation currencies will have depreciating nominal exchange rates going forward.

Menkhoff et al. (2015) find similar results when decomposing the five-year change in RER into a change in nominal exchange rate and change in inflation differentials. The authors pose a problem of how to interpret the result of a change in nominal exchange rate to predict excess currency returns positively. The standard way in literature has been to assume the mean reversion effect, as De Bondt and Thaler (1985) found while studying the equity market's mean reversion effect. All in all, the mean reverting nominal exchange rates seem to be an illusion considering also that RER levels negatively predict the nominal exchange rate changes. The authors state that a more reasonable explanation, when excluding the mean reverting exchange rates, is that specific currencies depreciate or appreciate relative to each other on an abiding basis. Economies commanding strong RERs have low-risk premiums whereas weak RER economies tend to have high-risk premiums. Low-risk premium currencies such as Japan and Switzerland have seen their nominal exchange rates appreciating on average.

Table 17 is akin to Table 12 construction where portfolios are formed based on the overall, fitted signals, and residual signals. Again, the cross-sectional regressions, equation 18, are run and fitted and residual signal time series are obtained. The portfolio construction procedure is the same as in Table 12. Panel A of Table 17 presents the adjustment of the RER level and corresponding results. The left-hand side of the table uses excess currency returns and the right-hand-side nominal exchange rate changes. Linear portfolios are used to decompose the overall signal exactly to the subcomponents. Starting from the excess currency return portfolios, the RER level achieves a 1.91% mean return, whereas the fitted signal, constructed using HBS, OG, and NFA macro fundamentals, yields a 1.16% average return, and the residual signal 0.75% mean return. Then, on the nominal exchange rate change side, the RER level predicts -4.05% mean return, the fitted signal predicts -2.97% mean return, and the residual signal predicts -1.08% mean return. Residual signal accounts for a large part of the negative predictability but not all. Results are similar manner as Menkhoff et al. (2015) findings. However, the authors have a quality of exports metric included as a macro fundamental variable which accounts largely for the negative predictability of the RER level in the nominal exchange rate case. Residual signal predicted that way slightly positively the nominal exchange rate change in the author's study.

Table 17. Currency signal adjustment.

This table presents the results for adjusting the currency value signal with macro-fundamentals HBS, OG, and NFA. Adjusting is made with cross-sectional regressions where fitted and residual signal time series are obtained. Then, linear portfolios are constructed using the composite signal, fitted signal, and residual signal. In panel A, the currency value indicator is the RER level. In panel B, the currency value indicator is a five-year change in RER. T-statistics are based on Newey-West (1987) autocorrelation and heteroskedasticity robust standard errors. The figures are annualized. The sample period is from 1976Q1 to 2023Q1.

	Excess returns				Exchange rate changes		
			Panel A: RER level				
	q_t	$\widehat{q_t}$	εq		q_t	$\widehat{q_t}$	εq
Mean %	1.91	1.16	0.75		-4.05	-2.97	-1.08
T-value	2.94	2.73	2.18		-4.72	-5.10	-2.99
Sharpe ratio	0.40	0.34	0.35		-0.85	-0.86	-0.52
			Panel B: Five-year change in RER				
	$\Delta^{(5y)}q_{j,t}$	$\widehat{\Delta^{(5y)}q_{J,t}}$	εq		$\Delta^{(5y)}q_{j,t}$	$\widehat{\Delta^{(5y)}q_{J,t}}$	εq
Mean %	1.73	0.21	1.52		0.67	-0.24	0.91
T-value	1.95	0.41	2.39		0.61	-0.50	1.09
Risk-adjusted return	0.30	0.08	0.39		0.11	-0.09	0.21

Panel B represents the five-year change in RER and its decomposition into fitted and residual value signals. Likewise for panel A results, the predictability of excess return goes majorly to the residual signal part. Hence, the exact figures are for the overall signal a 1.73% mean return, a 0.21% mean return for the fitted signal, and lastly, a 1.52% mean return for the residual signal. Then, the nominal exchange rate predictability is divided into the overall signal, accounting for 0.67% mean return, the fitted value signal -0.24% mean return, and finally the residual signal 0.91% mean return. Consequently, the residual signal accounts more than fully for the exchange rate predictability. Nonetheless, the 0.91% mean return does not fully account for the excess return of 1.52% as the currency value strategy would suggest. Indeed, figure 9 plots the five-year change in RER excess currency return residual signal performance and corresponding residual signal performance using the nominal exchange rate change from panel B. Specifically, the rolling 10-year one-quarter mean return is plotted for both signals. The excess return residual signal performance has been positive until a sharp decline during the recent few years. The nominal exchange rate change residual signal performance has been quite different. Starting positively in 1986, the performance dropped to the negative side in 1988, until it reached a positive level again in 1997. The most interesting timeframe is from 2005 to 2015 since during this period, the nominal exchange rate changes residual signal outperformed the excess return corresponding to one. Further, the value signal worked as it was supposed to work during the 2005 and 2015 timeframe. Currently, both residual signals are showing negative performance on a rolling 10-year basis.

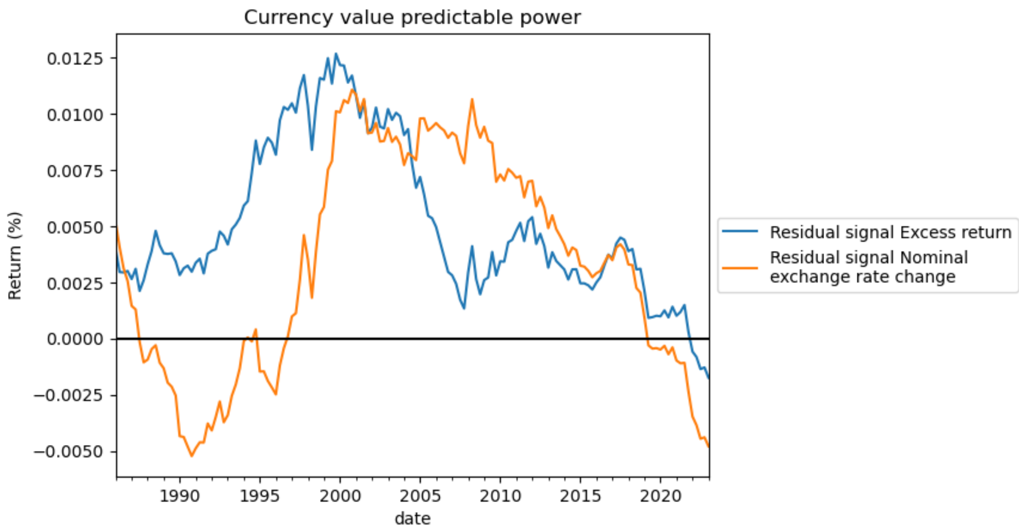

Figure 9. Rolling 10-year one-quarter mean return.

In the figure above, the five-year change in RER residual value signals are plotted for excess currency returns and nominal exchange rate changes on a 10-year rolling basis. The blue line represents the excess currency return residual signal portfolio performance. The orange line represents the nominal exchange rate change residual signal portfolio performance. The sample period is from 1976Q1 to 2023Q1.

Appendix B holds a robustness check by using the OECD PPP rates. PPP rates do not require any base year, but the downside is that they are released only once per year. Overall, the RER derived from the OECD PPP rates yields highly similar results.

6.2 PPI versus CPI-based RERs

PPI-based RER is used to better account for the index tradability between economies and in that way purge a clearer measure of the PPP indicator, ultimately rendering a better indication of currency value to predict future exchange rate changes. Therefore, the assumption is that PPI gives a better picture of the prices of truly tradable goods. The problem presented in equation 1 bears a link to the PPI usage as PPI is assumed to represent a fraction of traded goods more comprehensively than CPI. In Table 18, the PPI, and CPI-based five-year changes in RERs descriptive statistics and corresponding inflation differentials computed from PPI and CPI are compared. The sample of currencies is narrowed to 19 currencies quoted against USD. The excluded currencies from the examination are

France, India, and Taiwan because of the lack of historical PPI data. In addition, the RERs are set to unity as of 1986Q1. Table 18 does not show significant deviations between RERs.

Table 18. Descriptive statistics.

This table presents descriptive statistics for PPI and CPI-based five-year changes in RER and corresponding inflation differentials. Sample period from 1986Q1 to 2022Q4. RER figures are based on quarter frequency. Inflation differentials are annualized.

	$\Delta^{(5y)} q_{PPI}$				$\Delta^{(5y)} q_{CPI}$			
Currency	Mean	STD	Median	Inflation differential	Mean	STD	Median	Inflation differential
AU	-0.02	0.25	-0.01	-0.16	0.05	0.34	0.01	0.29
CA	0.06	0.17	0.01	-0.86	-0.02	0.17	-0.01	-0.42
CH	-0.03	0.21	-0.05	-2.23	-0.01	0.25	-0.01	-1.58
DE	0.01	0.25	0.00	-0.60	0.00	0.24	0.04	-0.83
ES	0.09	0.36	0.08	0.44	0.03	0.31	0.04	0.32
GB	0.00	0.22	-0.02	0.59	0.02	0.20	-0.03	0.04
HU	0.05	0.17	0.07	5.73	0.01	0.21	0.05	6.84
ID	0.12	0.23	0.10	6.56	0.08	0.26	0.04	5.20
IT	0.00	0.20	0.05	-0.57	-0.01	0.23	0.04	0.04
JP	0.07	0.15	0.07	-2.60	0.02	0.19	0.02	-2.20
KR	0.00	0.18	0.00	-0.17	-0.07	0.26	-0.01	0.78
MX	0.05	0.15	0.05	9.64	0.06	0.16	0.08	10.15
NO	0.03	0.17	0.02	3.04	0.03	0.19	0.02	-0.10
NZ	0.08	0.20	0.11	0.37	0.07	0.20	0.08	0.09
SE	0.03	0.17	0.01	0.18	0.00	0.18	-0.01	-0.37
SG	-0.06	0.32	-0.04	-1.88	0.05	0.19	0.05	-0.98
TH	0.06	0.18	0.06	0.47	0.08	0.21	0.09	0.20
TR	0.04	0.13	0.04	24.42	0.03	0.18	0.06	27.14
ZA	0.02	0.14	0.02	3.40	0.04	0.14	0.06	4.24

Table 19 presents the results for portfolio sorts based on CPI and PPI five-year change in RER signal. First, both signals seem to capture future returns. Furthermore, comparing PPI and CPI-based RER changes reveals that the CPI-based indicator beats the PPI-based indicator marginally. Even though the portfolios have yielded high average returns and great risk-adjusted returns, it's in the past. Clearly, when plotting the cumulative returns in Figure 10, for around the past decade, the strategies have offered only zero-sum profits. To conclude, the PPI index usage does not reveal a significant re-evaluation of the RER's predictable power over future returns.

Table 19. PPI versus CPI.

This table reports HML portfolio statistics for five-year changes in RER value indicators using excess returns and nominal exchange rate changes. Both the PPI and CPI-based RERs are indexed to unity at 1986Q1. The figures are annualized. The sample period is from 1991Q2 to 2022Q4.

	Excess returns	Exchange rate changes
Five-year change in RER		
RER based on PPI		
	HML	HML
Mean %	4.26	4.08
T-value	2.97	2.82
Sharpe ratio	0.53	0.50
RER based on CPI		
	HML	HML
Mean %	4.71	5.03
T-value	3.07	3.34
Risk-adjusted return	0.54	0.59

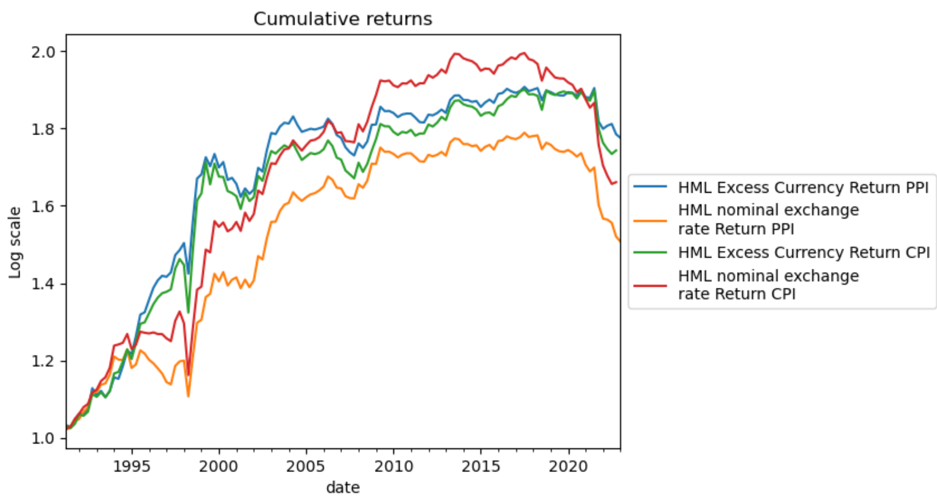

Figure 10. Cumulative returns.

This figure presents the cumulative returns for HML portfolios using the excess returns and exchange rate changes. The blue line represents the excess currency return HML portfolio obtained using PPI-based RER. The orange line represents the nominal exchange rate change HML portfolio obtained using PPI-based RER. The Green line represents the excess currency return HML portfolio obtained using CPI-based RER. The red line represents the nominal exchange rate change HML portfolio obtained using CPI-based RER. The currency value indicators are indexed to unity as of 1986Q1. Sample period from 1986Q1Q1 to 2022Q4.

6.3 Weakening signal

The weakening currency value signal has been observed throughout the thesis. Now, the key question is, can the signal be used anymore to predict future currency returns. Recent findings of Hutchinson et al. (2022) about traditional risk factors in the currency market give a clear explanation that the lack of momentum, value, and carry returns is true. In essence, the authors study if the returns obtained using the three above-mentioned factors stem from mispricing or rational expectations of risk. Mispricing would vanish after academia has examined and recognized the factor, handing the factor to the public. On the contrary, the returns obtained by the rational expectations of risk would not vanish after releasing the academic studies about the factor, since the return is a compensation of taking higher risk. The examination reveals that after the factor has been discovered by academia, rational investors exploit it to death. Therefore, the factor premiums have been associated with the mispricing behavior in the markets.

Figure 11 presents a 10-year rolling one-quarter mean returns for overlapping portfolios of rebalancing intervals 1, 12, and 20. The rolling returns are obtained from the plain five-year change in the RER signal by subtracting the expected inflation differentials from the signal. Moreover, the aforementioned signal is the best performer, so it is reasonable to delve into it. The rolling returns started positively at the beginning of the 90s, even increasing to the highest level in 2000. Nevertheless, after 2000, the rolling returns have seen a sharp decline throughout the years. Most recent years, the rolling returns have been negative, suggesting a misfunctioning of the adjusted currency value signal. Notably, no matter the portfolio rebalancing interval, the returns are negative.

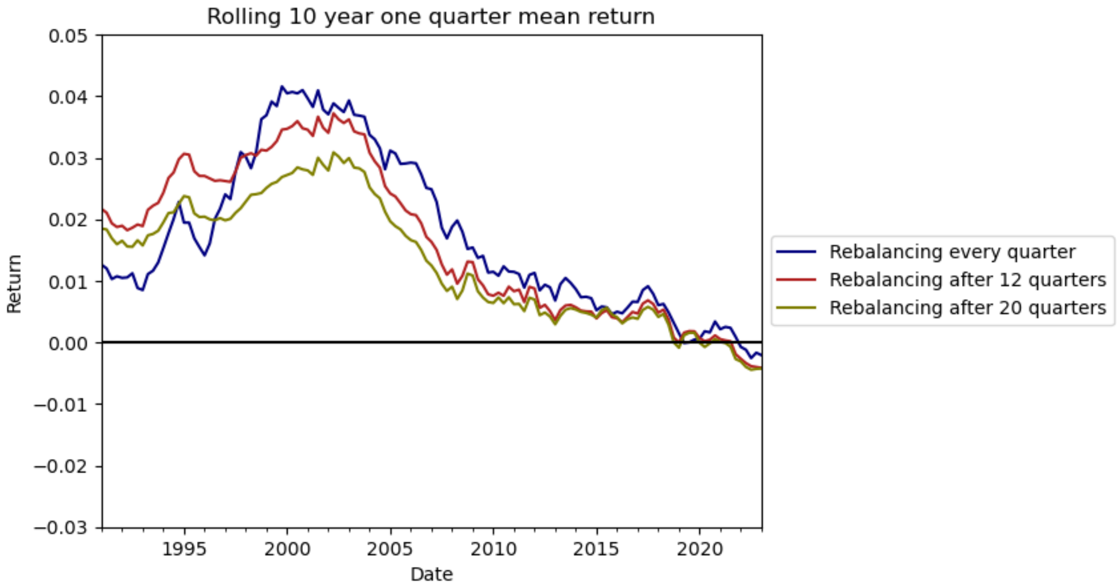

Figure 11. Rolling 10-year one quarter mean returns.

The figure above shows the rolling 10-year one quarter mean returns for the nominal exchange rate HML portfolios formed using the adjusted five-year change in RER signal, presented in table XX and figure XX. Blue line represents the HML portfolio rebalanced every quarter. Red line represents the HML portfolio rebalanced after 12 quarters. Olive line represents the HML portfolio rebalanced after 20 quarters. The sample period is from 1981Q2 to 2023Q1.

Next, the signals' decreased predictive power is examined with rolling window regressions. Consequently, the regressions are in a similar manner as in equation 9. The rolling window isolates the time-varying nature of the predictive coefficient better than normal static regression. Further, the rolling window of 10 years is motivated by a long enough window to capture the long-term relationship evolvements in the signal's predictive power. Figure 12 plots the short-term and medium-term predictive slope coefficients and corresponding 95% confidence intervals, based on heteroscedasticity and autocorrelation robust standard errors. The upper graph of Figure 12 plots the short-term predictive slope coefficient of a five-year change in RER when expected inflation differentials are included as a control variable. Hence, the predictive power of a five-year change in RER over the subsequent one-quarter nominal exchange rate changes is weak. Even if all the additional macro fundamentals, RDIFF, HBS, OG, and NFA, are included as control variables, the slope coefficient remains statistically insignificant at a 5% significance level starting from 2001. Turning the focus on the lower graph in Figure 12, which denotes the medium-term horizon predictive slope coefficient, leads to observing a similar pattern as in the short-term graph. The sharp drop started in 2012, indicating an underlying change in the predictive nature. Consequently, the predictive coefficient has been statistically insignificant since 2016, no matter are the macro fundamentals controlled or not. To conclude, the results are similar manner as in the paper by Hutchinson et al. (2022), and the results here suggest that the five-year change in RER based currency value indicator does not offer additional predictive content to the currency investor anymore.

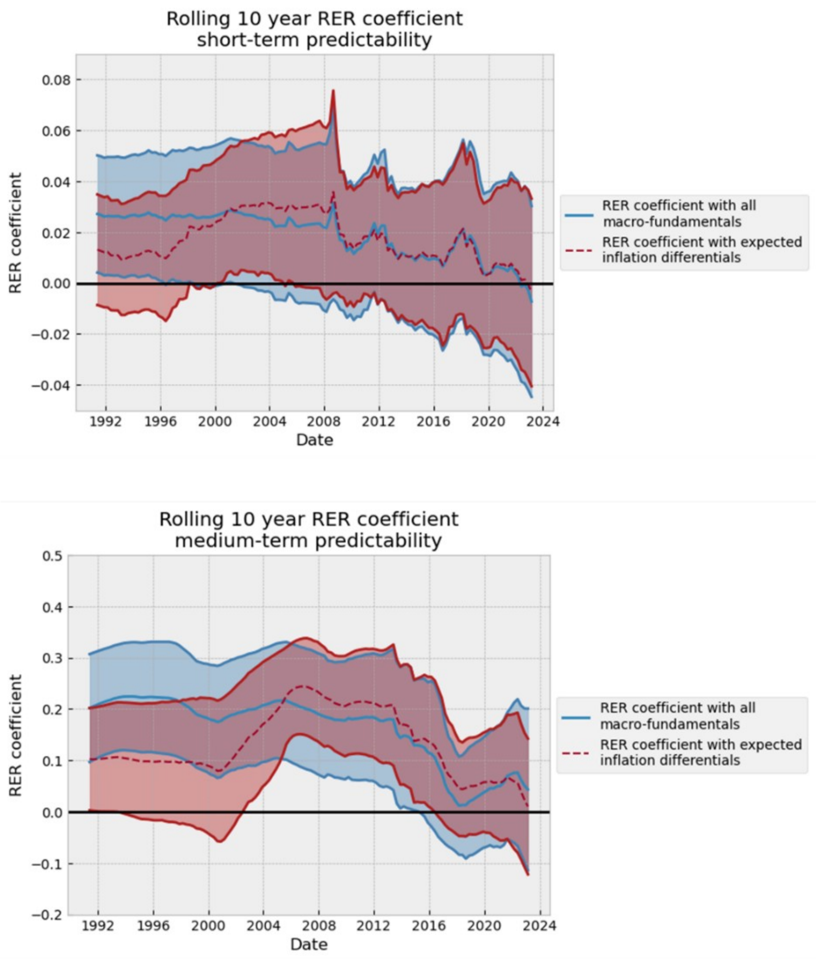

Figure 12. Rolling window regressions.

The figure above denotes the five-year change in the RER predictive coefficient in a rolling 10-year manner. The coefficient is obtained from a rolling window regression, the regression equation is as in equation 9. The upper graph depicts the short-term predictability, subsequent one-quarter nominal exchange rates are regressed on five-year change in the RER and control variables. The lower graph depicts the medium-term predictability, subsequent five-year nominal exchange rate change is regressed on five-year change in RER and control variables. In both graphs, the blue color signals the five-year change in the RER slope coefficient and corresponding 95% confidence intervals when only expected inflation differentials are included as control variables. Similarly, the red color signals the five-year change in the RER slope coefficient and corresponding 95% confidence intervals when HBS, OG, NFA, and expected inflation differentials are included as control variables. Inference is based on heteroscedasticity and autocorrelation robust standard errors. The sample period is from 1981Q2 to 2023Q1.

7 Conclusions

The main emphasis of this study has been to evaluate the currency value indicators' predictive power over the subsequent 20 quarters of nominal exchange rate changes. The currency value denoted as a five-year change in RER can be improved by accounting for the differences in macro fundamentals between the economies in the cross-sections. The result implies that the currency value risk premium is associated with the underlying fundamentals of an economy.

Regression analysis shows that there is a positive but statistically insignificant relationship between a five-year change in RER and subsequent 20-quarter nominal exchange rate changes. However, when controlling for the key macro fundamentals, namely expected inflation differentials, RDIFF, HBS, OG, and NFA, the study is able to enhance the predictability and amplify the five-year change in RER predictive power. Notwithstanding, all the macro fundamentals do not individually increase the predictive power, herein according to the Wald test, HBS and OG do not increase the predictive power when put alongside with five-year change in RER to the regression equation. The predictive slope coefficient of a five-year change in RER dies approximately after 12 quarters and turns negative, no matter are the macro fundamentals controlled. Examination of different currency groups shows that the five-year change in RER predictive content is statistically different for safe haven and emerging market currency groups relative to the base group. In addition, the study finds that safe haven and emerging market currency groups have abnormal expected return characteristics overall compared to the base group. Thus, the dummy variables are highly statistically significant for both aforementioned groups, and a F-test confirms that the group dummies are significant individually, and also jointly.

Portfolio sorts are further used to examine the currency value’s predictive power. As a result, the study finds similar results for short-term excess return predictability as Asness et al. (2013) and Menkhoff et al. (2017) in the portfolio setting, as a corollary, the Sharpe ratio ranges from 0.33 to 0.39 for different portfolio construction types. Nonetheless, the short-term nominal exchange rate change predictability with plain currency value signal does not yield as robust results as the excess return case. Therefore, the plain currency value signal is adjusted with macro fundamentals. After adjusting the plain currency value signal, the short-term predictability is improved.

Overlapping holding period portfolios are utilized to examine the medium-term horizon predictability of nominal exchange rate changes. Consequently, from a horizon of 4 quarters to 20 quarters, the plain currency value signal does not yield statistically significantly improved predictability compared to an equal-weight benchmark portfolio. However, the adjusted currency value signals yield statistically better predictability compared to the equal-weight benchmark portfolio, although not all adjusted signals do well. Rather the best way to adjust the plain signal is to simply subtract the expected inflation differentials from the signal. In addition, the plain currency value signal is used as a benchmark against the adjusted value signals, yet the simple adjustment strategy beats the plain benchmark with statistical significance.

The risk-adjusted returns of overlapping holding period portfolios formed using different currency value indicators are compared to each other. The task shows that the simple adjustment strategy is superior compared to the plain and HBS, OG, and NFA adjusted currency value signals. However, a comprehensive competitor for the simple adjustment is the HBS, OG, NFA, and expected inflation differentials adjusted currency value signal which is able to deliver statistically similar results on a 4-quarter horizon. Nevertheless, the simple adjustment outperforms even the second-best competitor in the medium term with a 1% significance level. The subsamples are also examined for different signals to find out what adjustment method works best for the whole sample, G10, and non-G10 currencies. Thus, the simple adjustment strategy works particularly well for non-G10 currencies. The plain signal is a robust predictor of G10 currencies' subsequent nominal exchange rate changes, whereas the plain signal does not work for non-G10 currencies at all. By adjusting with all the macro fundamentals, HBS, OG, NFA, and expected inflation differentials, the currency value signal works well for all the samples until a decrease in the risk-adjusted return starting in the horizon of 9 quarters.

Additional results show that the predictable power of a five-year change in RER as a currency return predictor has been decreasing throughout the last decade for both the short-term and medium-term. The short-term predictive slope coefficient is currently negative while the medium-term predictive slope coefficient is almost zero on a 10-year rolling basis. The findings are in line with Hutchinson et al. (2022) who state that currencies no longer respond to the traditional risk factor including momentum, carry, and value.

The study contributes to the existing literature by showing that the five-year change in RER adjusted with key macro fundamentals can yield better medium-term horizon predictability than the market or plain signal benchmarks in the cross-section of currencies. Nonetheless, an equally important contribution is the finding that the five-year change in RER, even when adjusted with macro fundamentals, does not currently work as a predictable element of subsequent nominal exchange rate changes. The implication is that the mean reversion effect of exchange rates, where the five-year change in RER heavily relies, does not work currently as hypothesized. As Hutchinson et al. (2022) state, the mispricing associated with the traditional risk factors related to currencies has been exploited. Suggestions for future research direction are as follows. First, the macro fundamentals effect on the subsequent nominal exchange rate changes between different currency groups can be examined. In addition, the sample of currencies can be extended to cover yet unexplored currencies as well and the selection of macro fundamentals can be wider.

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Appendix A

The table below shows the result for a plain five-year change in the RER signal adjusted by subtracting the expected inflation differentials from the signal. The difference between Table 12 and Panel A is that Turkey and Mexico are excluded from the sample. The results here indicate that after excluding Turkey and Mexico the performance drops. The finding is anticipated since both aforementioned economies have suffered high inflation and have seen continuously depreciating nominal exchange rates relative to the US.

Table 20. Adjusted value signal, excluding Turkey and Mexico.

Mean, volatility, and risk-adjusted return are annualized. The sample period is from 1976Q1 to 2023Q1.

Short-term predictability: rebalancing portfolios quarterly: Nominal exchange rate return						
Panel A: RER signal adjusted by subtracting expected inflation differential						
Statistics	**Strong**	**neutral**	**Weak**	**HML**	**PF Rank**	**PF Linear**
Mean %	-2.86	-0.81	0.75	3.61	3.37	2.11
Volatility %	7.98	7.35	8.45	7.89	6.90	4.48
Skewness	-0.19	0.23	0.49	0.41	0.40	0.60
Kurtosis	4.10	3.56	4.33	4.47	4.02	8.85
t-value	-2.46	-0.75	0.61	3.14	3.35	3.23
Risk-adjusted return	-0.36	-0.11	0.09	0.46	0.49	0.47
Max Drawdown %	-81.39	-56.45	-28.61	-27.89	-25.78	-15.16

Appendix B

Appendix B presents results for portfolios that are built up using the RER based on OECD's PPP rates. The upside with these PPP rates is that there is no need to index the RER to some base year, but the downside is that OECD publishes the rates only once a year. Still, the RER formed by using the PPP rates works well for robustness purposes and to verify the earlier results obtained in the thesis.

Table 21. Portfolios formed using RER based on OECD absolute PPP rates.

The table below presents the summary statistics for portfolios formed by using RER which is based on OECD's PPP rates. Mean, volatility, Sharpe ratio, and risk-adjusted return are annualized. The sample period from 1976Q1 to 2022Q4.

Short-term predictability: rebalancing portfolios quarterly						
Panel A: RER based on absolute PPP rates, level						
Excess return						
Statistics	**P1**	**P2**	**P3**	**HML**	**PF Rank**	**PF Linear**
Mean %	-0.15	2.77	4.53	4.68	4.79	2.34
Volatility %	9.47	8.82	9.08	7.68	7.61	4.01
Skewness	0.25	0.18	0.29	0.27	0.24	0.41
Kurtosis	3.34	3.96	3.38	3.81	3.88	4.30
t-value	-0.09	2.00	3.42	4.19	4.34	4.04
Sharpe Ratio	-0.02	0.31	0.50	0.61	0.63	0.58
Max Draw-down %	-48.06	-18.99	-37.43	-4.70	-2.48	-2.17
Panel B: RER based on absolute PPP rates, level						
Nominal exchange rate change						
Statistics	**P1**	**P2**	**P3**	**HML**	**PF Rank**	**PF Linear**
Mean %	-0.74	-0.66	-8.82	-8.07	-7.17	-3.77
Volatility %	9.35	7.61	8.26	8.64	8.01	4.11
Skewness	0.17	-0.06	-0.18	-0.61	-0.31	-0.45
Kurtosis	3.57	3.53	3.95	5.07	4.12	4.13
t-value	-0.55	-0.58	-7.33	-6.42	-6.17	-6.31
Risk-adjus-ted return	-0.08	-0.09	-1.07	-0.93	-0.90	-0.92
Max Draw-down %	-49.57	-56.57	-98.71	-98.16	-97.09	-83.63
Panel C: RER based on absolute PPP rates, five-year change						
Excess return						
Statistics	**P1**	**P2**	**P3**	**HML**	**PF Rank**	**PF Linear**
Mean %	1.50	3.19	2.75	1.26	1.19	0.65
Volatility %	10.21	9.52	8.06	8.30	8.51	5.66
Skewness	-0.11	0.48	-0.01	0.49	0.17	0.14

Kurtosis	3.66	3.15	3.61	4.40	3.34	6.02
t-value	1.00	2.13	2.35	1.04	0.94	0.81
Sharpe Ratio	0.15	0.34	0.34	0.15	0.14	0.11
Max Draw-down %	-46.20	-18.36	-41.52	-20.90	-24.80	-19.19

Panel D: RER based on absolute PPP rates, five-year change						
Nominal exchange rate change						
Statistics	**P1**	**P2**	**P3**	**HML**	**PF Rank**	**PF Linear**
Mean %	-5.35	-1.55	-3.13	2.21	2.38	1.48
Volatility %	9.70	8.76	7.46	9.45	9.52	5.83
Skewness	-0.36	-0.11	0.11	0.34	0.40	0.75
Kurtosis	4.24	3.69	3.63	3.90	4.42	5.65
t-value	-3.80	-1.22	-2.88	1.61	1.71	1.75
Risk-adjus-ted return	-0.55	-0.18	-0.42	0.23	0.25	0.25
Max Draw-down %	-94.26	-64.90	-81.41	-38.46	-40.80	-23.53