Zurich University of Applied Sciences
School of Management and Law
Master of Science - Banking and Finance - PiE

Purchasing Power Parity and FX Rates since the financial crises

Master's Thesis

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Master in Science - Banking and Finance
Submission date: 15.06.2023

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Keywords: nominal exchange rate, real exchange rate, purchasing power parity, exchange rate, mean reversion, deviations, Law of One Price, relative PPP, absolute PPP, PPP Puzzle, forecasting, Augmented Dickey-Fuller test.

Citation proposal: APA – American Psychological Association.

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ABSTRACT

This master's thesis examines the behavior of purchasing power parity (PPP) and exchange rates in the period following the financial crisis. The study focuses on three currency pairs: CHF/EUR, CHF/BRL, and CHF/ZMW. The analysis begins by comparing the nominal exchange rates with the corresponding PPP rates for each currency pair. The movements of the real exchange rates are then observed.
To further investigate the behavior of the real exchange rates, a mean reversion test is conducted. The logarithmic returns of the real exchange rates are utilized in this test, and the Dickey-Fuller test is applied using the Python program. The results of the Augmented Dickey-Fuller test provide evidence for rejecting the null hypothesis, suggesting that the real exchange rates of each currency pair are mean reverting. The findings of this thesis contribute to the understanding of how real exchange rates behaved toward PPP in the post-financial crisis period.

Keywords: Purchasing Power Parity, Exchange Rates, Financial Crisis, Nominal Exchange Rates, Real Exchange Rates, Mean Reversion, Dickey-Fuller Test, Switzerland, Germany, Brazil, Zambia, HBS Effect.

Table of Contents

List of Figures

List of Tables

List of Equations

1. Introduction

The Financial Crisis of 2007 left a lasting impact on the global economy, shaking the foundations of established economic theories and models. Kohler (2010) noted the unusual movements of exchange rates during the Financial Crisis, as currency depreciation was seen across a big number of economies that were not at the center of turmoil. The substantial volatility of the exchange rate has posed significant challenges for policymakers, compelling a more profound understanding of the fundamental drivers that influence real exchange rates.

The Purchasing Power Parity (PPP) plays a crucial role in macroeconomic models, serving as an important pillar that captures the concept of a stable long-term equilibrium real exchange rate. Assessing whether fluctuations in exchange rates correspond to a sustainable equilibrium level is of paramount importance for those responsible for decision-making in this domain. In this regard, empirical testing of PPP, a theory that suggests exchange rates should adjust to equalize the prices of goods and services across different nations, has long been a subject of interest and debate among economists. (Zhou & Kutan, 2011).

Vo and Vo (2022), when analyzing citations of 6 important papers published on PPP, show a strong increasing awareness in this research area, with annual average growth rates going from 4% to 12% in the last 20 years, approximately. Understanding the dynamics of exchange rates and the role of PPP in the post-financial crisis era is of utmost importance. Policymakers need accurate information to design effective monetary and fiscal policies, investors require insights to make informed decisions, and researchers strive to enhance the existing body of knowledge. This master's thesis aims to contribute to this understanding by conducting a comprehensive analysis of exchange rate movements and PPP since the financial crisis for three currency pairs.

The primary objective of this study is to examine the behavior of both nominal and real exchange rates in relation to PPP and assess the extent to which the theory was held in the post-financial crisis period. By adopting Switzerland and, consequently, the CHF as the standard country and currency, a comparison against Germany (Euro - EUR), Brazil (Brazilian Real – BRL), and Zambia (Zambian Kwacha – ZMW) is conducted. The goal is to understand the dynamics of each of the three currency pairs' (CHF/EUR; CHF/BRL; CHF/ZMW) exchange rate and their convergence to PPP.

Additionally, by embracing the three countries, a brief assessment can be made to comprehend whether the Harrod-Balassa-Samuelson effect could have exerted some influence on the exchange rates deviations from PPP, since different productivity and income levels are faced among Switzerland, Germany, Brazil, and Zambia.

To achieve this goal, the first session of this thesis brings an extensive literature review to explore the theoretical underpinnings of PPP and examine relevant empirical studies conducted. The literature review aims to identify key concepts, methodologies, and gaps in the existing research, which will serve as the foundation for the analysis.

The second session focuses on the relationship between exchange rates and PPP post-financial crisis, analyzing data from the period of January 2007 until December 2021. The nominal exchange rates of the selected currency pairs against their corresponding PPP rates are compared, targeting to identify deviations and grasp the factors driving these disparities. Furthermore, the relationship between real exchange rates and PPP is explored. Real exchange rates reflect changes in price levels between countries and offer insights into the relative purchasing power of currencies. By scrutinizing the movements of real exchange rates and their convergence towards PPP values, we can gain a deeper understanding of their long-term behavior.

Next, in the third session, a mean reversion analysis is conducted to assess the dynamics of the real exchange rates for the countries here considered and their tendency to revert to long-run equilibrium levels. The evaluation will be performed using the Augmented Dickey-Fuller (ADF) test, a widely used econometric tool for testing stationarity and mean reversion. By applying the ADF test to the real exchange rates of the selected currency pairs, the presence of mean reversion is detected in all three cases. Furthermore, a concise overview of forecasting exchange rates is presented, enabling an understanding of the role that Purchasing Power Parity plays in this context.

The final section of this thesis will summarize the main findings, draw conclusions based on the analysis, and discuss their implications for society. Additionally, the limitations of the study are highlighted, and recommendations for future research are suggested to further enhance the comprehension of PPP and exchange rates.

2. Literature Review

2.1 The Law of One Price

Purchasing Power Parity (PPP) is a theory that initiated and is grounded on the Law of One Price concept. The Law of One Price (LOP) states that identical goods must sell for the same price in different competitive markets when transportation costs and barriers between the markets are not considered. The fundamental argument to explain why LOP should hold is centered on the idea of frictionless goods arbitrage (Sarno & Taylor, 2002).

The concept of the LOP is readily grasped within a domestic market context. For instance, it would be illogical for an individual to purchase a bottle of water for CHF 3 in one location when an identical bottle is available just 100 meters away for CHF 1.50. It is important to note that the LOP may not hold under conditions involving transportation costs, trade barriers, or regulatory constraints. However, in the absence of such factors, the law suggests that the price of the same bottle of water should be identical in Switzerland, Germany, or Brazil.

This Law is, however, frequently violated. Lamont and Thaler (2003) illustrate how such violations can easily occur during day-to-day life by using aspirin as an example. The case is built on the premise that we have two brands producing aspirin, Bayer, and a store brand, not commonly known. Bayer costs twice as much as the store brand because consumers believe it to have better quality. The Law of One Price suggests that any price difference between two identical goods should be eliminated through arbitrage, but arbitrage in this case is not really possible. As Lamont and Thaler (2003) correctly observed, one way of taking advantage of arbitrage in the aspirin situation is replacing the store brand aspirin (cheaper) package with a Bayer aspirin (more expensive). Obviously, this practice is not legally achievable.

Another way would be to wait until Bayer consumers realize that there are, in fact, no discrepancies in the quality between both products and start buying the store brand, so Bayer's aspirin price would have to decrease. Again, it is neither practical nor is it predictable to know when will consumers change their views on the products. Thus,

arbitrage is not always easy or conceivable between identical products for a series of factors.

To conclude, by considering the impact of transportation costs, trade barriers, and regulations, deviations from the Law of One Price may occur. Nevertheless, within a theoretical framework assuming the absence of these factors, it posits that identical goods should have the same price across different geographic locations.

2.2 Exchange Rates

The exchange rate between two currencies characterizes the rate at which one currency can be traded for another. It is widely recognized that exchange rate volatility plays a crucial role in various aspects. For instance, a depreciation in the exchange rate can actually improve the competitiveness of a country's exports relative to its imports. This can lead to an increase in export revenues and potentially enhance the country's terms of trade. It can also result in higher prices for imported goods, leading to imported inflation and potentially reducing the purchasing power of domestic consumers. Furthermore, currency depreciation can escalate the costs associated with foreign investment, introducing additional risks. Thus, the exchange rate is a vital economic variable, particularly in the context of international trade cooperation (Liao et al., 2019).

The exchange rate is also considered as the price of one nation’s currency relative to another. Changes in the demand and supply of a currency directly influence the exchange rate. Therefore, in economic literature, exchange rates are generally considered to be determined by factors such as money supply, price levels, national income, interest rates, output, and other pertinent economic variables. Various quantitative models incorporating these economic variables have been proposed to analyze exchange rate dynamics (Liao et al., 2019).

As in any financial and economic subject, the distinction between nominal and real rates is very important to fully grasp the concept of theories and how they behave in the real world, thus, a review of the nominal exchange rate and real exchange rate appears to be relevant.

A nominal exchange rate is the one at which one currency can be exchanged to another, it represents the value of one currency against the other. This is the published exchange rate by the banks and institutions.

The real exchange rate (RER), for instance, considers changes in relative prices between nations. Mussa (1986) states that the real exchange rate can be understood as the price relationship between the goods and services that make up the consumption basket of one economy and those of another economy. Hence, it represents the relative cost of consuming a given basket of goods in one country compared to the cost of consuming the same basket in another country. It can be expressed mathematically as:

(1)

$$R = s \frac{P}{P*}$$

where:

R = Real exchange rate
s = Nominal exchange rate expressed in indirect quotation
P = Price in the domestic country
*P** = Price in foreign country

To illustrate the interpretation of the real exchange rate, let's consider the following example: The exchange rate between the Euro (€) and the Swiss Franc (CHF) is € 0.80/CHF. In Switzerland, an iPhone costs 2000 CHF, while in Germany, it is priced at 1600 €. Using the given numbers, we can substitute them into the formula:

(2)

$$R = 0.8 \frac{2000}{1600} = 1$$

When the real exchange rate is equal to 1, it indicates that both Germany and Switzerland possess equal levels of competitiveness, implying that they have the same purchasing power. In simpler terms, disregarding factors like transportation costs, trade barriers, tariffs, and other related considerations, it would be inconsequential whether one buys an iPhone in Switzerland or Germany. The equivalence in the real exchange

rate suggests that the cost of purchasing the iPhone in either country would be identical.

2.3 The Purchasing Power Parity

The Purchasing Power Parity (PPP) theory was originally formulated by the Swedish economist Gustav Cassel (1918, p. 413) who defined that a country's exchange rate tends to depreciate in the same proportion as the price level increases.

Sarno and Taylor (2002) describe the PPP as an exchange rate between two currencies that would balance the price levels of the respective countries when expressed in a common currency. In other words, it aims to ensure that the purchasing power of one unit of currency is equal in both economies. This theoretical exchange rate would bring about equivalence in the relative prices of goods and services, allowing for a comparable standard of living between the two nations.

Likewise, the International Monetary Fund (IMF, 2023) describes the PPP as the exchange rate which represents the conversion rate between two currencies that enables the purchase of an equivalent quantity of goods and services in both countries. Therefore, in essence, the PPP is the rate that adjusts the purchasing power of distinct economies by abolishing the disparities in price levels of different nations.

This cross-country analogy is the groundwork for the famous “Big Mac Index”, published by the *Economist*. The Big Mac Index considers the McDonald’s Big Mac hamburger prices all over the world and compares them to the US Dollar, a common currency, at the market exchange rate (nominal exchange rate) to analyze whether a currency is overvalued or undervalued regarding the dollar at the current exchange rate. Since the hamburger is sold practically identically worldwide, it is possible to understand and compare the purchasing power of people in different economies. For instance, if the Big Mac in Brazil is sold for USD 2,00 and the average American price is USD 3,00, then the Brazilian Real would be considered undervalued against the US dollar.

While the Big Mac Index is an easy and entertaining way of observing the PPP of different nations, it is intuitively easy to understand why they are sold at different prices across different economies. Factors that include differences in production costs, labor wages, rent, taxes, import tariffs, and market competition play a crucial role in

determining the price of a Big Mac. Additionally, local economic conditions, such as inflation rates and exchange rates, also interfere with the price.

2.3.1 The absolute PPP

Cassel's concept of absolute price parity emphasizes the importance of internal purchasing power within a country, which refers to the number of goods and services that can be purchased with a single unit of currency. When applying this concept to two different countries, the exchange rate represents the value of one currency of a country relative to the other country's currency. The ratio of the internal purchasing powers or price levels between the two economies defines the notion of absolute PPP (Officer, 1976, p. 6).

For the comparison of PPP, a basket of similar goods is used, and it can be expressed as in the equation below (Officer, 1996):

(3)

$$PPP_t^{abs} = \frac{PL_t^B}{PL_t^A}$$

where:

PPP_j^{abs} = absolute PPP in period *j* (number of units of country B's currency per unit of country A's currency)
PL_j^i = price level in country *i* in period *j*
t = the current time period

Vo and Vo (2022) emphasize that the core principle of PPP is the notion that an exchange rate equalizes the prices of goods across different nations. This fundamental concept forms the basis of the theory. It reflects the equilibrium exchange rate that would harmonize the prices of goods in various countries when expressed in a common currency.

To compute PPP, Cassel (1925) states that a general price level is the most suited parameter. He does not, however, determine which kind of general price level would be optimal to do so. Nowadays, the natural and most logical interpretation of a general

price level is the Gross Domestic Product (GDP)[1], a concept not yet developed at Cassel's time as pointed out by Officer (1976). One important remark provided by Officer (1976) is that the purchasing power of a currency should reflect the production of goods and services within the country, which means that import prices should not be considered in the measure while export prices should be included.

Furthermore, Cassel (1928) makes a connection on the impact of the exchange value of currency under or above PPP and the balance of payments of a country. He states that a country would see an increase (decrease) in its commodity exports when the exchange value of its currency is below (above) PPP, due to an upsurge (reduction) in the demand for the currency. Cassel, then, notes that only under free international trade conditions is the exchange rate expected to have minimum deviations from the PPP.

The dilemma is, however, that transportation costs, tariffs, quotas, and other trade barriers do play an important role and, thus, distance and location of delivery must be considered, bringing the theory to an unrealistic scenario. This explains why PPP exchange rates differ from market exchange rates (short-run equilibrium exchange rates).

2.3.2 The relative PPP

The relative PPP, consequently, restates the theory and holds when the change in the exchange rate of two economies matches the changes in aggregated price inflation between them (Sarno & Taylor, 2002). This version of PPP can be understood by the equation below (Officer, 1976):

(4)

$$PPP_t^{rel} = \frac{P_t^B}{P_t^A} * R_o$$

where:

PPP_j^{rel} = relative PPP in period *j* (number of units of country B's currency per unit of country A's currency)

P_j^i = price index in country *i* in period *j*

[1] Gross Domestic Product is the final value of all goods produced and services provided in an economy over the period of one year (Gross Domestic Product (GDP) - OECD Data, 2023).

R_j= actual exchange rate in period *j* (number of units of country B's currency per unit of country A's currency).
t = the current time period
o = a base period

In Cassel's research, he presents the relative PPP as the current exchange in a base period multiplied by the ratio of proportionate changes in price levels of the economies involved. The base period defined by Cassel should be a "normal" period, and by that, he meant when the exchange rate and the absolute PPP rate are the same (Officer, 1976).

Discussions over proportionate changes in exchange rates and price levels resulting in no real changes are provided by Samuelson (1964, p. 146) and others. For instance, Samuelson (1964) proposed that in the short run, the relative PPP would not hold due to real changes in economies and that it might hold in the long run, albeit in a close manner, if the monetary changes dominate the real changes.

2.3.3 PPP Propositions

Dornbusch's (1985) conclusion that PPP is "a theory of exchange rate determination" can be easily understood when analyzing the main propositions of thecconcept : (a) the short-run equilibrium exchange rate[2] – the exchange rate applied when its essential principles are at their present settings, disregarding the impact of random factors (market bubbles i.e.) – is a function of the long-run equilibrium exchange rate. In other words, the short-run tend equilibrium exchange rate tends to approach the long-run equilibrium exchange rate[3], and (b) that the PPP itself is the long-run equilibrium exchange rate or the main element of it.

Following this thinking, we can express (a) as (Officer, 1976):

(5) $$R^t_{short-run} = f\ (PPP_t, \dots)$$

[2] This idea of short-run equilibrium exchange rate is similar what Officer (1976) defines as "the rate that would exist under a freely floating exchange rate system". This is perhaps the hardest equilibrium concept to define in economic terms.
[3] Officer (1976) defines the long-run equilibrium exchange rate as "the fixed exchange rate that would yield the balance of payments equilibrium over a time period incorporating any cyclical fluctuations in the balance of payments (including those related to business cycles at home and abroad)". The definition presumes the nonexistence of special policy maneuvers such as monetary or fiscal restraint to avoid disequilibrium in the balance of payments.

where:

$R^{t}_{short-run}$ = short-run equilibrium exchange rate in period *t*

$f\ (PPP_t, \dots)$ = an arbitrary increasing function regarding the independent variable with the ellipsis indicating additional explanatory variables.

In the most extreme scenario of Purchasing Power Parity, exchange rates would not deviate from the current value of the PPP rate at all, even temporarily. However, this notion was refuted by Cassel himself and does not have any proponents. In fact, Cassel (1918, 1925) acknowledged that while the PPP is a primary or essential determinant of the exchange rate, it is not the sole variable that influences it.

Cassel's concept of the "f function" implies that other explanatory factors and random influences also contribute to the determination of the exchange rate, although to a lesser extent. These additional variables are recognized as playing a role in shaping the exchange rate, nonetheless, their impact is considered less critical compared to the PPP.

Vo and Vo (2022) found, when modeling data from the International Financial Statistics (IFS) containing statistics from 159 countries over the period of 1974 – 2018, information suggesting that PPP does not hold in the short-run. In this study, the authors presented how deviations from PPP can emerge in the short run and how it seems to reinforce PPP as the time horizon increases. Similarly, Lothian and Devereux (2019) confirm, in their study, the same tendency of short-run deviation and long-run adjustment of the real exchange rate to PPP.

These findings can be supported by similar discussions made by Sarno and Taylor (2002) on an empirical evidence study and Frankel (1978) implying that PPP serves as an essential benchmark in long-run exchange rate determination. Dornbusch (1985, p.30) also encourages this view in his study, when he says that PPP serves as a target against which the level of an exchange rate can be evaluated. Taylor and Taylor (2004) and Lothian and Devereux (2011) recognize, likewise, the mean-reverting pattern of the exchange rate suggestive of long-run PPP.

Dornbusch (1985) guarantees that the Purchasing Power Parity has many applications and retains its significance as a fundamental aspect of open macroeconomics. He reiterates the argument of Cassel that discussions on the over or undervaluation of currencies would be significantly limited without the concept provided by PPP.

Officer (1976) outlined two empirical utilizations of PPP: first by the United Kingdom and former Czechoslovakia in determining the degree of currency overvaluation that would persist at a predetermined new exchange rate. This involved quantifying the necessary adjustments in domestic and foreign price levels to sustain the revised exchange rate. The objective was to measure the extent of price-level adjustments required both domestically and abroad to uphold the stability of the new exchange rate. Belgium, in a second example, computed a new exchange rate using PPP.

2.3.4 Limitations of the PPP

There are several reasons to investigate when trying to understand why the exchange rate in a floating regime deviates so frequently from the PPP. Many of these deviations can be linked to Cassel's acknowledged limitations of the theory. Officer (1976) provided a summary of said limitations.

One factor is the presence of trade barriers, which can be more stringent in one direction than the other. When trade barriers are stricter for imports in one country, the exchange value of the currency may move above PPP.

Speculation in the foreign exchange market is another factor that can affect exchange rates. Speculative activities, particularly when they are against a country's currency, can lead to a decrease in its exchange value below the level predicted by PPP. Speculators may take positions based on their expectations of future exchange rate movements, causing deviations from PPP.

Additionally, inflation expectations within a country can also impact exchange rates. If a country experiences higher inflation relative to its trading partners, it may result in a depreciation of its currency. Inflation erodes the purchasing power of a currency and can lead to deviations from PPP.

Changes in an economy's relative prices is also a factor of influence. If there are significant shifts in the prices of goods and services within a country compared to its trading partners, it can affect the competitiveness of its exports and imports, thereby provoking exchange rate movements away from PPP.

Furthermore, capital flows play a crucial role in determining exchange rates. The movement of capital into or out of a country can impact the demand and supply

dynamics of its currency, leading to deviations from PPP. Features such as interest rate differentials, investor sentiment, and economic conditions can drive capital flows and shock exchange rates.

Finally, government interventions in currency markets can also cause deviations from PPP. Central banks and governments may engage in foreign exchange market interventions to influence the value of their currencies. These interventions can disrupt the equilibrium implied by PPP and result in exchange rate movements that deviate from long-term expectations.

Other than the limitations here described and acknowledged by Cassel, a particular criticism of PPP is statistically related, referring to the parity's computing method. The setback lies in (1) the calculation of price indices, as they are based on a small sample of individual prices rather than encompassing all goods in the economy, leading to an imprecise reflection of overall price trends and (2) even if all goods in the economy were to be computed, the value of the parity is generally influenced by the specific choice of price level. Henceforth, the parity will fluctuate based on the weighting pattern used in the calculations.

2.3.5 The PPP Puzzle

The deviations from PPP are, generally, expressions of the PPP Puzzle reported by Rogoff (1996) in his study "The Purchasing Power Parity Puzzle". This Puzzle has two main concerns revolving around the PPP: the first one is regarding the validity of PPP in the long run and the second refers to the long half-life of PPP deviations.

According to Rogoff (1996), under a floating exchange rate regime, economists and researchers faced difficulties in dismissing the notion that exchange rates adhere to a random walk for a long time. Frankel (1986, 1990) debates that the reason for such failure in rejecting the random walk in exchange rates was due to lack of data, as a substantial amount of data is necessary to reject the presence of a unit root (a random walk component) in real exchange rates due to the gradual reduction of deviations from PPP. He, then, analyzed annual statistics for the dollar/pound exchange rate for the period of 1869-1984 and after being able to refute the random walk hypothesis, he arrived at the conclusion that there is an estimated rate of decline for the deviation of the real exchange rate of 14% per year, indicating a half-life for PPP deviation of 4.6 years. During the 90s several researchers conducted long-horizon PPP studies using

different approaches that tended to find evidence of mean reversion in real exchange rates[4].

The second PPP Puzzle appears when considering the apparent long half-life of deviations from PPP. Rogoff (1996) cited various studies where a consensus appeared as to the 3 to 5 years half-life of deviations from PPP. While it is not difficult to explain and understand why short-term exchange rate deviations occur (changes in portfolio preferences, price bubbles, monetary shocks), the 3-5 years half-life seems “far too long to be explained by nominal rigidities” (Rogoff, 1996, p. 648).

The PPP Puzzle remains, then, with the same question from its origin: “How can one reconcile the enormous short-term volatility of real exchange rates with the extremely slow rate at which shocks appear to dump out?” (Rogoff, 1996, p. 647).

Attempts to justify this slow-paced adjustment of the deviations from PPP can be seen across literature and research. One of them would be the failure to include real variables affecting the exchange rate, such as the HBS effect proposed by Harrod, Balassa (1964), and Samuelson (1964) exposing the effects of productivity differentials across nations. Lothian and Taylor (2004) argue that failure to include such influences could be a critical origin of omitted-variable bias.

2.4 The Harrod-Balassa-Samuelson Hypothesis

The Harrod-Balassa-Samuelson (HBS) effect is an economic theory that explains the relationship between productivity growth, income levels, and exchange rates. In this model, Harrod, Balassa (1964), and Samuelson (1964) argued that countries with higher productivity growth in their tradable sectors will experience higher income levels and appreciate exchange rates in the long run.

The HBS effect is based on the observation that productivity growth tends to be higher in the tradable sector compared to the non-tradable sector. The tradable sector includes industries that can compete in the global market, such as manufacturing and agriculture, while the non-tradable sector encompasses industries that are mainly domestically oriented, such as services and construction.

[4] See Vo and Vo (2022, p. 6) and Rogoff (1996, p. 656-657).

The theory states that countries with higher productivity growth in their tradable sectors will generate higher income levels. This is because increased productivity leads to higher output, which in turn leads to higher wages and profits. As a result, these countries will experience higher per capita income compared to countries with slower productivity growth in their tradable sectors. In other words, richer nations allegedly grow rich by accelerating and advancing productivity in the traded goods sector, whilst the nontraded goods sector productivity tends to remain the same, with no extraordinary advances in technology.

To demonstrate the intended impact, let's assume that the Law of One Price applies solely to traded goods. Higher productivity means companies will see an expansion and, consequently, pay higher wages. The higher wages are, however, matched by the increased productivity, so nothing really changes in terms of the domestic price of traded goods. In another hand, the non-traded goods sector will require higher income as well, and, since the rise in salaries of the non-traded goods sector is not matched by a boost in productivity, costs are reflected as higher prices to be passed onto consumers.

Likewise, higher income levels indicate a higher demand for non-tradable goods and services, which are predominantly domestically produced. As the demand for non-tradable goods increases, the prices of these goods rise relative to tradable goods. This price differential leads to an appreciation of the exchange rate, so the HBS effect also predicts that countries with higher income levels will see an appreciation of their exchange rates.

Correspondingly, Officer (1976, p. 19) states that a price parity determined by the overall price levels generates an exchange value of the more productive economy’s currency that is inferior to its real long-run equilibrium value, and the increasing productivity differences will tend to escalate this systematic bias between the concerned countries.

3. Exchange Rates vs. PPP rates in different economies

In this session, we will examine the floating currencies of Germany, Brazil, and Zambia in relation to the base country of Switzerland. The focus will be on calculating and comparing the PPP rates with the nominal and real exchange rates observed during the period from January 2007 to December 2021. This comparison allows us to assess whether these currencies are overvalued or undervalued relative to Switzerland, their behavior toward PPP values post-financial crisis, and the contrast between the nominal and real exchange rates movements from PPP.

3.1 Nominal Exchange Rate vs. the PPP Rate

Parting from equation (4) suggested by Officer (1976) which extracts the PPP value in relation to the Consumer Price Index -CPI of the nations involved, the monthly PPP rate from the period of January 2007- December 2021 was derived (expressed in units of CHF per unit of EUR/BRL/ZMW) having a base period the year of 2010[5].

Monthly data on CPI and nominal exchange rates for the CHF/EUR pair were gathered from the Central Bank of Ireland (2023), while for the CHF/BRL, the investing.com website database was used, as it provided the monthly rates of the CHF/BRL directly (no cross-rate in USD needed). As for the CHF/ZMW, the International Financial Statistics - IFS provided the necessary data for the cross-rate of ZMW/USD and CHF/USD, since there were no data found on the direct relationship of the CHF/ZMW.

Switzerland serves as the standard country for comparison. The analysis will then extend to three other nations: Germany, characterized by a comparable level of

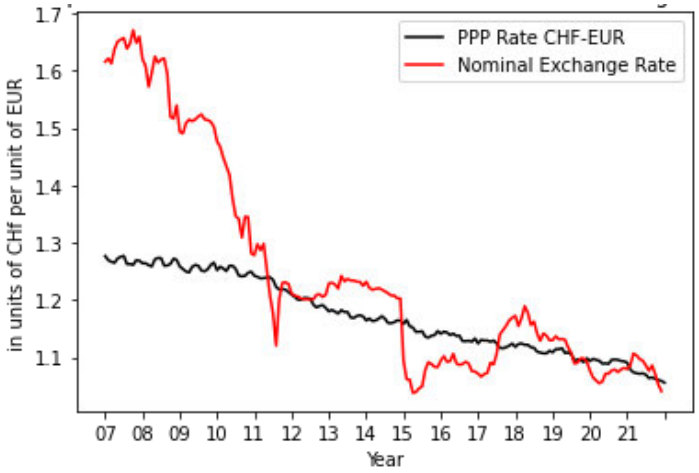
[5] Officer (1976, p. 20) points out that the relative PPP requires a base period for its calculation. There is, however, a challenging aspect on finding the right base period and this challenge is one of the criticisms offered by evaluators of the relative PPP. The data on CPI gathered from the IFS (2023) has 2010 as its base period (CPI=100) for all countries, hence, for simplicity purpose, the year of 2010 will be the base period of the exchange rate as well.

productivity[6] and being classified as a high-income country[7]; Brazil, categorized as an upper-middle income nation with a distinct productivity level compared to Switzerland; and finally, Zambia, identified as a low-income country.

3.1.1 Switzerland vs. Germany (CHF/EUR)

Figure 1 represents the relation between Germany and Switzerland, represented in CHF/EUR (number of units of Swiss Francs per unit of Euro). In this image, it is possible to evaluate that, although there are some deviations of the exchange rate from the PPP rate, both rates tend to be closely related for the most part of this time series. The largest deviations come, understandably, within the Financial Crisis period. However, the exchange rate seems to persistently revert to numbers close to the PPP once again. It appears to reach the PPP levels after nearly 4 years, which goes in line with Rogoff (1996) and others also observed in their research, that the deviations from PPP have a half-life of circa 2,5 to 5 years[8].

Figure 1: Nominal Exchange Rate deviations from PPP (CHF/EUR)



Source: Central Bank of Ireland, own calculations.

[6] Here productivity is measured by Gross Domestic Product (GDP) per capita. Switzerland is ranked 7th, with a GDP per capita of 77,324 INT$ (2019), while Germany has a GDP per capita of 57,927 INT$ (2019), Brazil has 16,056 INT$(2019) and lastly Zambia has 3,623 INT$ (2019). (INT$ - International Dollar, is a fantasy currency developed to make comparisons between countries easier). (World Bank, 2023).

[7] World Bank Country Lending Group guidelines (all values USD): Low-income economies — GNI per capita of up to $1,085 / Lower-middle-income economies — GNI per capita of $1,086 to $4,255 / Upper-middle-income economies — GNI per capita of $4,256 to $13,205 / High-income economies — GNI per capita of $13,206 or more. (GNI = Gross National Income). (World Bank, 2023).

[8] See Rogoff (1996, p.656).

The nominal exchange rate for each period being over the PPP rate line means that the Euro was overvalued against the Swiss Franc. The appreciation of the Swiss Franc was significant over the course of the Financial Crisis. This happened because many investors perceived the Swiss franc as a safe haven and secured large quantities to safeguard themselves from market instability both in the European Union and in the United States. This high demand for Swiss francs resulted in its value appreciating significantly, bringing the CHF/EUR exchange rate from CHF 1.67 in 2007 to CHF 1.02 in 2011. Consequently, Swiss goods and services became more costly internationally, hence, less competitive compared to other economies.

To address this issue, the Swiss National Bank (SNB), responsible for setting the monetary policies in Switzerland, intervened and established a ceiling of CHF1.20 per euro in 2011. This action aimed to instill confidence in investors and protect Swiss exporters from further loss of competitiveness due to currency appreciation. However, implementing the currency cap came with consequences. To maintain the cap, the SNB had to print more francs and purchase euros in the market, which significantly enlarged its balance sheet. As a result, currency reserves rose to around 80% of the country's GDP by 2014.[9]

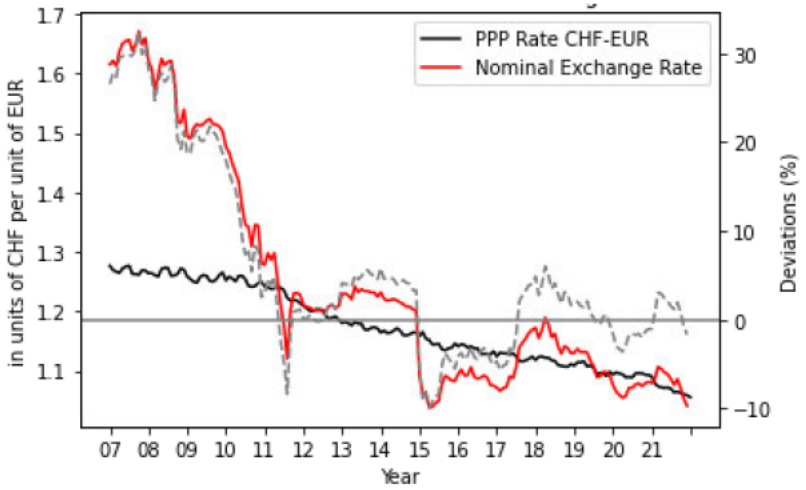
In 2015, nevertheless, the SNB made the decision to discontinue the aforementioned currency cap. Consequently, the Swiss Franc experienced a substantial appreciation against the Euro, leading to pronounced market volatility and substantial losses for investors. Auer et al. (2021) demonstrate that the real appreciation of the Swiss Franc against the Euro exhibited persistence, with the exchange rate only reverting to its December 2014 level by the end of 2017. This observation further reinforces the notion of a prolonged half-life for the deviation consensus proposed by numerous researchers (Rogoff, 1996, p. 656). Both this sudden appreciation of the CHF can be seen in Figure 1 when the nominal exchange rate line goes to levels below the PPP line, meaning an overvaluation of the Swiss Franc (hence, undervaluation of the Euro).

Figure 2 demonstrates the percentage deviation of the PPP rate and the nominal exchange rate. The chart shows that whilst the exchange rate presented significant deviations during the crises of 2007, lasting until 2011, and during the years 2015 until the end of 2017, a persistent trend of convergence between the PPP rate and the exchange rate can be observed. Moreover, the divergences generally remained within

[9] European Parliament notes (21st January 2015).

a relatively narrow range of one to three percentage points of each other, except for the periods mentioned before.

Figure 2: Magnitude of deviations of Nominal Exchange Rate and PPP (CHF/EUR)

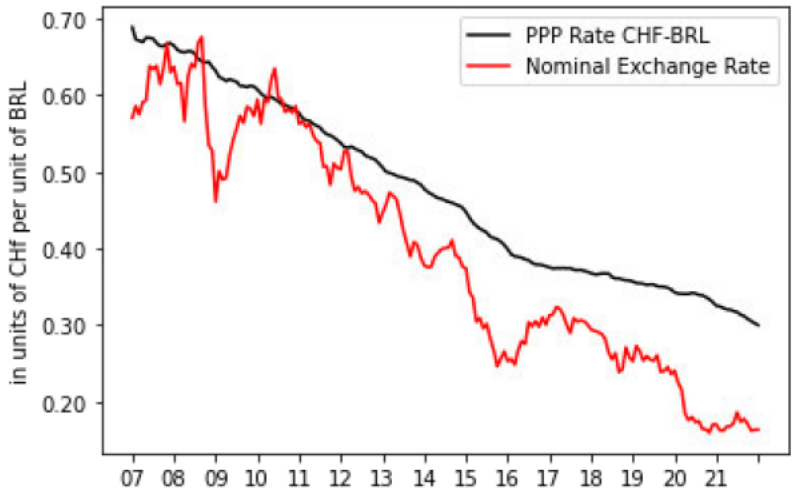


Source: Central Bank of Ireland, own calculations.

3.1.2 Switzerland vs. Brazil (CHF/BRL)

Continuing with the analysis, Figure 3 depicts the interrelationship between Brazil and Switzerland, as reflected by the CHF/BRL exchange rate (representing the number of Swiss Franc units per one unit of Brazilian Real).

Figure 3: Nominal Exchange Rate deviations from PPP (CHF/BRL)



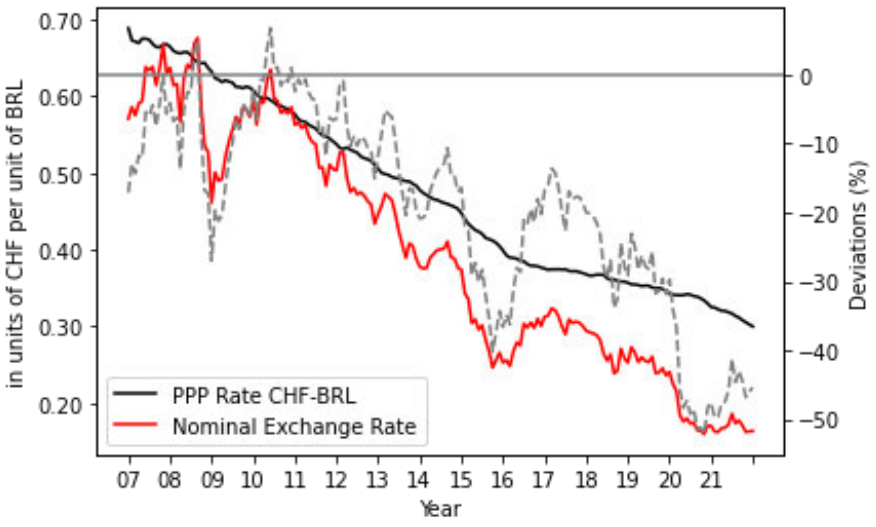
Source: Investing.com, own calculations.

Based on the chosen base period of 2010, the PPP rate line positioned above the nominal exchange rate signifies that the Brazilian Real is undervalued in relation to the

Swiss Franc. Notably, in 2015, during the SNB event, there was a more pronounced appreciation of the Swiss Franc against the Brazilian Real. Additionally, Brazil experienced an economic crisis from 2014 to 2017, accompanied by significant domestic events such as the impeachment of former president Dilma Rousseff. Nonetheless, it is noteworthy that there is a recurring inclination for the two exchange rates to converge, despite the apparent half-life of approximately two and a half to five years as previously mentioned. The outbreak of the Coronavirus pandemic in 2020 emerged as the next significant driver of exchange rate deviations from the PPP.

As formerly discussed, the Harrod-Balassa-Samuelson Hypothesis posits that countries with higher productivity levels will exhibit higher price levels, primarily influenced by the relative weight of the traded goods sector and the technological advantage typically found in high-income and productive economies (particularly within the traded goods sector). This hypothesis further suggests that the disparity in price levels will widen as the discrepancy in productivity levels between countries increases (Officer, 1976).

Figure 4: Magnitude of deviations of Nominal Exchange Rate and PPP (CHF/BRL)



Source: Investing.com, own calculations.

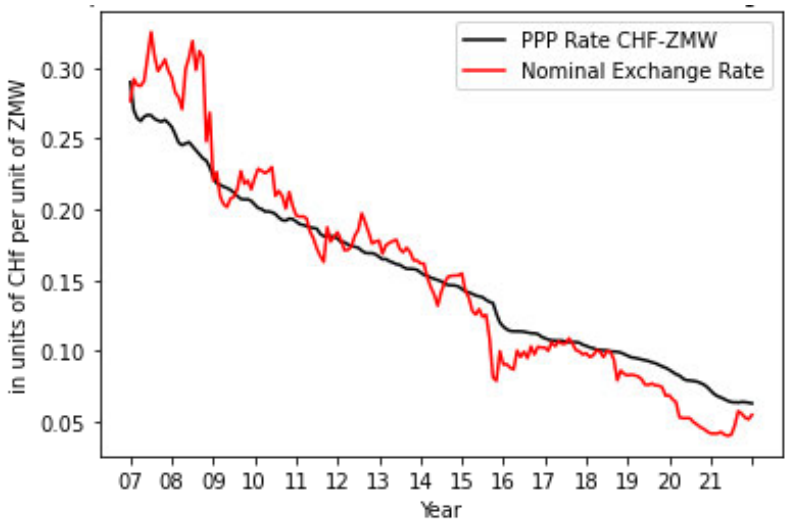
Figure 4 exhibits the percentage deviation between the exchange rate and the purchasing power parity rate for the currency pair of Brazil and Switzerland. The observed deviations indicate a certain degree of alignment with the Harrod-Balassa-Samuelson effect. The magnitude of the deviations, reaching nearly 50% in this comparison, is greater than those observed when comparing Germany and Switzerland, which may be partially explained by a stronger influence of productivity

and income differences on the exchange rate dynamics between Brazil and Switzerland.

3.1.3 Switzerland vs. Zambia (CHF/ZMW)

Figure 5 presents the analysis of the relationship between Zambia and Switzerland, represented by the cross-rate of the Zambian Kwacha and the Swiss Franc in USD. Due to the unavailability of direct exchange rate data between the two currencies for the period of 2007 to 2021, the cross-rate in USD was utilized as a substitute measure.

Figure 5: Nominal Exchange Rate deviations from PPP (CHF/ZMW)



Source: International Financial Statistics – IFS, own calculations.

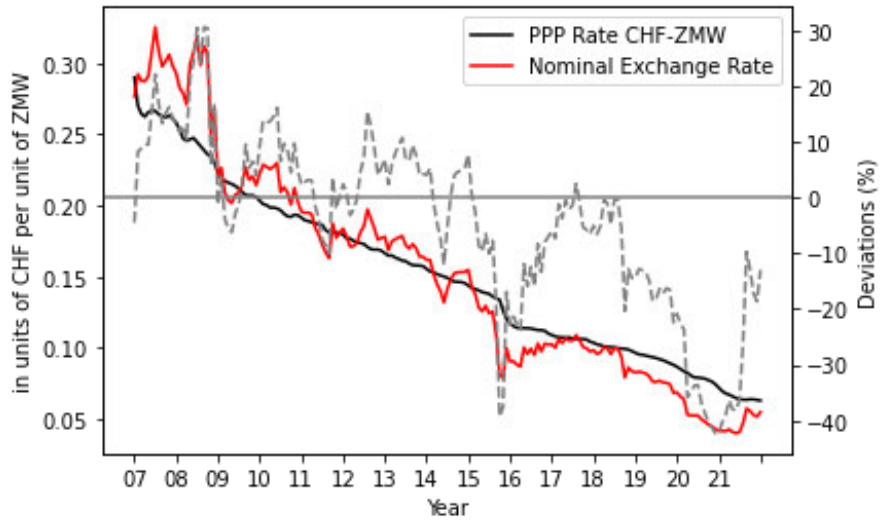
The analysis of Zambia and Switzerland provides intriguing insights that challenge the conventional assumptions of the Harrod-Balassa-Samuelson effect. According to this hypothesis, PPP is less likely to hold when comparing countries with significant disparities in productivity and income levels. However, the observed data presents a notable tendency of convergence between PPP and the exchange rates of the Zambian Kwacha and the Swiss Franc, with the rates remaining closely aligned for the most part of the period.

This might imply that the market perceives the current (nominal) exchange rate between these currencies as reasonably appropriate, considering the respective economic conditions and development of both nations.

Despite the natural appreciation of the Swiss Franc against the Zambian Kwacha, the degree of appreciation appears to be in line with expectations based on the relative economic fundamentals of the two countries. This finding highlights the complexities and nuances involved in understanding the relationship between exchange rates and PPP.

While the data generally support the validity of PPP for the CHF/ZMW exchange rate, Figure 6 emphasizes the substantial magnitude of distortions, comparable to the discrepancies observed between the Brazilian Real and Swiss Franc. This indicates that while PPP generally held, the deviations were substantial.

Figure 6: Magnitude of deviations of Nominal Exchange Rate and PPP (CHF/ZMW)



Source: International Financial Statistics – IFS, own calculations.

Remarkably, it is noteworthy that by the end of 2021, the two lines depicting PPP and the exchange rates are converging once again. This observation aligns with the perspective put forward by Cassel, as discussed by Officer (1976, p.9), which suggests that if monetary changes offset real changes, PPP tends to hold true, albeit not necessarily in an exact manner. This finding further emphasizes the dynamic nature of exchange rates and the potential for convergence over time, even in instances where deviations were previously substantial. Furthermore, it also enhances the relevance of considering both monetary and real factors in understanding the behavior of exchange rates.

Upon evaluating the three comparisons in this basic approach, it can be inferred that the Purchasing Power Parity theory remained valid during the period following the Financial Crises of 2008. Despite observing exchange rate deviations in all three cases, there was a discernible inclination towards convergence between the rates in the long-run. Nonetheless, the observed magnitude of deviations varied considerably between the different pairs of countries studied.

Switzerland and Germany exhibited minimal discrepancies, primarily ranging from 1 to 4%, exceptions aside. In contrast, Brazil and Zambia demonstrated more frequent and more significant divergences, within a range of nearly 50% (-50%). These substantial disparities can potentially be accredited to various economic factors and misalignments that contribute to deviations from PPP. Factors including but not limited to interest rate movements, inflation, government policies, market expectations, capital flows, and geopolitical events exert a substantial impact on exchange rates. Additionally, productivity levels, trade imbalances, and structural issues may have also played a role in the noteworthy incongruity in exchange rate movements and PPP.

Notably, despite both Brazil and Zambia displaying greater fluctuations from the nominal exchange rate to the PPP rate and significant inconsistencies, the correlation and relationship between PPP and the CHF/BRL appeared weaker and less consistent compared to that of the CHF/ZMW. Consequently, it is imperative to consider the relative size, economic structure, and foreign dependencies of each country when assessing the correlation between PPP and exchange rates. These aspects can contribute to disparities in the degree of alignment between exchange rates and PPP, as well as the level of correspondence observed among exchange rates across different countries.

As an upper-middle-income economy with a larger size and greater global connectivity, Brazil experiences a more complex and diverse set of economic factors influencing its exchange rate than Zambia. The Brazilian Real is subject to a wide range of influences, including domestic economic indicators, fiscal and monetary policies, commodity prices (given Brazil's role as a major exporter of commodities), political developments, and global market dynamics. The interplay of these factors can result in increased volatility and deviations from PPP in the Brazilian Real exchange rate. Hence, Brazil's macroeconomic conditions, such as higher inflation or fiscal imbalances, may have a more pronounced impact on the Brazilian Real exchange rate compared to Zambia's economic conditions.

On the other hand, Zambia, being a smaller and less globally integrated economy, may have exchange rates that are influenced by a narrower set of factors, primarily driven by its specific economic characteristics, such as copper prices (as Zambia is a major copper producer) and regional trade dynamics.

Furthermore, currency exchange rates are influenced by market forces, encompassing investor sentiment, capital flows, and market expectations. Market dynamics in Brazil and Zambia could have contributed to exchange rate deviations from PPP. Aspects such as political uncertainty, market volatility, or disparities in investor confidence may have intensified deviations in the CHF/BRL exchange rate relative to the CHF/ZMW exchange rate.

So, to conclude, whilst Zambia's exchange rate remains susceptible to fluctuations and deviations from PPP, the scope of factors that have an influence might be relatively more limited compared to those affecting Brazil.

3.2 Real Exchange Rate vs. the PPP Rate

It is crucial to highlight the limitations of using nominal exchange rates when evaluating the purchasing power of different currencies. Nominal exchange rates are simply the rates at which one currency can be exchanged for another, without accounting for price differences or inflation between countries. As a result, they may not accurately reflect the relative purchasing power of different currencies.

To address this issue, economists utilize real exchange rates, which adjust the nominal exchange rate for inflation differentials among the countries being compared. By considering the relative price levels of the nations involved, real exchange rates provide a more accurate reflection of the purchasing power of each currency. They provide a more comprehensive and nuanced perspective when analyzing exchange rate dynamics and their impact on trade flows, investment decisions, and overall economic performance.

The adjustment for inflation in the real exchange rate is achieved by dividing the nominal exchange rate by the ratio of price levels between the two countries. This ratio compares the average price level of goods and services in one country to that of

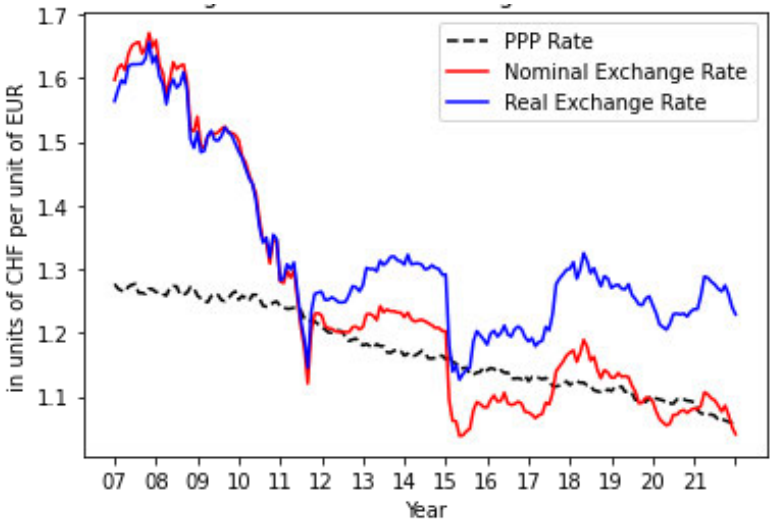
another. By incorporating this correction, the real exchange rate takes into account the impact of inflation on the purchasing power of currencies.

Using the same data for the previous analysis and equation (1) to compute the real exchange rate of the economies here concerned, a further study comparing the movements of the nominal and real exchange rates against the PPP is presented.

3.2.1 Switzerland vs. Germany (CHF/EUR)

In the first case, comparing the Swiss Franc and the Euro exchange rate, Figure 7 expresses this dissimilarity between the nominal and real exchange rates for this pair of countries. Even though it is important to note that a vast list of events can influence the movements of exchange rates and a single observation may not provide a complete picture, here we can draw a basic and first opinion on the relationship between the nominal exchange, the real exchange rate, and the PPP.

Figure 7: Nominal Exchange Rate vs. Real Exchange Rate deviations from PPP (CHF/EUR)



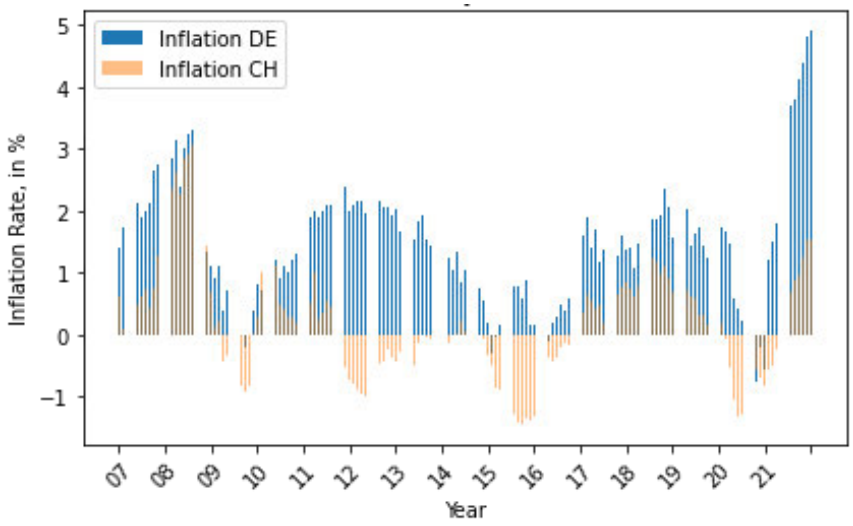
Source: Central Bank of Ireland, own calculations.

The nominal CHF/EUR exchange rate is generally in line with PPP (as seen before), proposing that the market value of the Euro is in accordance with what PPP predicts. However, as the real exchange rate considers inflation differentials between countries, when it is above the PPP line can be suggestive of inflationary pressures or higher price levels in Germany.

The alignment of the real exchange rate with the PPP rate during the period following the Swiss National Bank's monetary cap removal (2015), sheds light on the Euro's overvaluation. As soon as the Swiss Franc sharply appreciated, the real exchange rate converged to PPP levels, leading to a conclusion that the Euro was, indeed, overvalued against the CHF. Moreover, it suggests that the Euro's purchasing power was relatively higher compared to what it should have been based on the PPP principle. It also highlights the impact of significant events and economic policies on currency dynamics.

The PPP rate considers the relative purchasing power of currencies based on the price levels in each country. In this context, the real exchange rate reflects a closer approximation of the true value of the currencies by factoring in inflation differentials. The previous scenario may also insinuate that inflation in Germany (or the Euro area) has been higher than in Switzerland and it can be confirmed when examining the inflation data from both countries displayed in Figure 8.

Figure 8: Inflation rates in Germany and Switzerland



Source: OECD Data. Note: Inflation DE represents the inflation in Germany while Inflation CH represents inflation rates of Switzerland.

In the specific instance of Switzerland and Germany, or the Euro area, it can be inferred that the observed Euro overvaluation might be attributed, in part, to the monetary policies pursued by the Swiss National Bank. These policies aim to deliberately maintain a comparatively weaker currency against the Euro as a means of mitigating the potential adverse effects on Swiss exports. When such interventions

impact the nominal exchange rate, they can potentially influence the real exchange rate through their effects on inflation.

One of Cassel's recognized limitations of the PPP relates to this situation and was summarized by Officer (1976, p. 9), in which he states that the foreign exchange market can be impacted by government's interventions by bidding up the price of the foreign exchange rate over (under) the PPP line.

3.2.2 Switzerland vs. Brazil (CHF/BRL)

Continuing with the analysis, we observe a contrasting scenario when examining the relationship between Brazil and Switzerland. In the previous case of CHF/EUR, the nominal exchange rate was in line with PPP, while the real exchange rate was above PPP. However, when analyzing Brazil and Switzerland, we observe the opposite.

Figure 9 shows that, while the nominal exchange rate between CHF/BRL is mainly under the PPP line, suggesting an overvaluation of the CHF, the real exchange rate, on the other hand, approximately complies with PPP with the real exchange rate aligning with PPP several times over the period, and even after moments of strong deviation, it tends to reverse back to the PPP.

The nominal exchange rate being under PPP allows for the interpretation of an undervaluation of the Brazilian Real over the Swiss Franc, as previously discussed. The real exchange rate in line with PPP, however, might insinuate that the relative price of goods between both countries, adjusted for inflation, is aligned with the equilibrium exchange rate proposed by PPP.

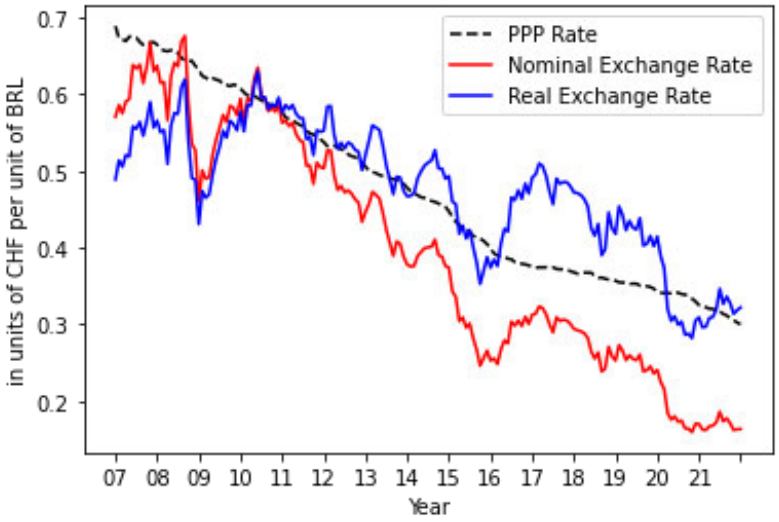
Here, it is interesting to see the relationship between the PPP and the real exchange rate for the pair of currencies analyzed. The real exchange rate seems to be much more in concordance with PPP than the nominal exchange rate, leading to an impression that the inflation differentials have been adequately reflected in the nominal exchange rate.

On the other hand, for the most part, the Brazilian Real seemed to be slightly overvalued against the Swiss Franc (real exchange rate above the PPP line) [10], and in

[10] Overvalued as in the sense that the BRL should have less value than it presented against the Swiss Franc, and not that the currency was stronger or valuing more than the Swiss Franc.

2015 when the SNB allowed the Swiss Franc to float freely, the real exchange rate bounced straight back to the PPP rate level and under, representing an overvaluation of the CHF. After this period, from the deviation observed in the graph (Fig. 9), it's possible to see the depreciation of the Swiss Franc, as the SNB implemented, once again, the cap for the CHF.

Figure 9: Nominal Exchange Rate vs. Real Exchange Rate deviation from PPP (CHF/BRL)



Source: investing.com, own calculations.

Together with the purposeful depreciation of the CHF, during the period from 2016 to 2019, the Brazilian Real experienced a significant appreciation attributed to several factors that influenced the Brazilian economy during that time.

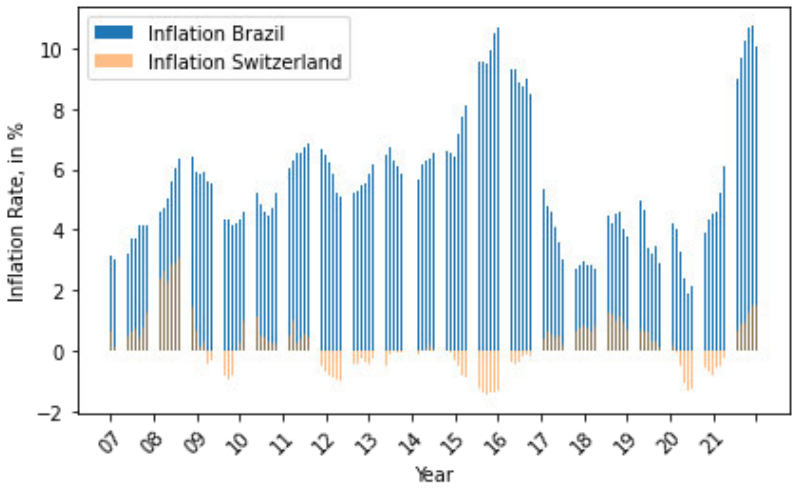
One major aspect was the improvement in Brazil's economic and political environment. Brazil went through a period of political stability after a stage of political turmoil and corruption scandals. This stability, along with market-friendly policies implemented by the government, improved investor confidence in the Brazilian economy. As a result, foreign investors were more willing to invest in Brazil, leading to increased demand for the Brazilian Real and consequently its appreciation.

Another factor that contributed to the BRL appreciation was the relatively high interest rates in Brazil during these years. The Central Bank of Brazil raised interest rates to combat inflation and stabilize the economy. Higher interest rates make investments in the country more attractive, attracting capital inflows and strengthening the currency. As noted by Officer (1976) capital inflows may appreciate a country's currency and, by

then, the interest rates in Brazil were (annually) 14,5% in 2015, 13,6% in 2016, 6,9% in 2017, 6,4% in 2018 and 4,4% in 2019 (Central Bank of Brazil, 2023).

Overall, the combination of improved political stability, market-friendly policies, higher interest rates, and favorable commodity prices worked together to drive the appreciation of the Brazilian Real in this timeframe.

Figure 10: Inflation rates in Brazil and Switzerland



Source: OECD (2023) and IBGE (2023)*
**Brazilian Institute of Geography and Statistics.*

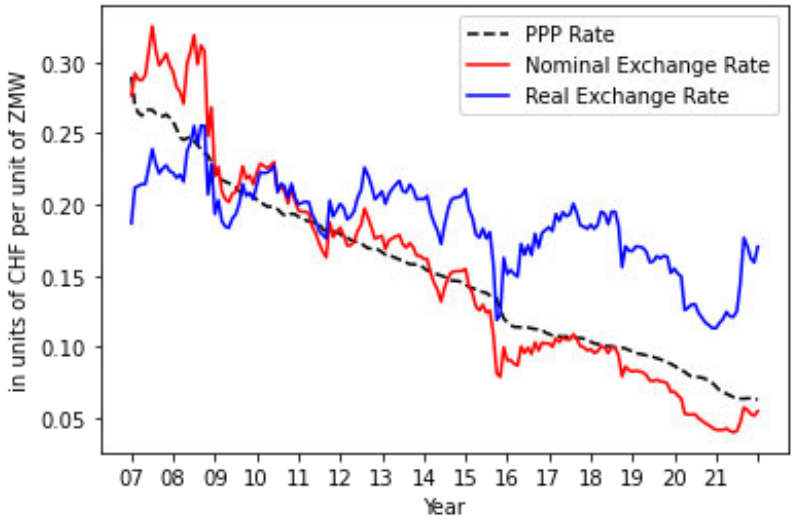
In 2020, when the Coronavirus pandemic hit, the Brazilian Real started to depreciate against the Swiss Franc again. Another point in Cassel's recognized limitations of PPP summarized by Officer (1976, p.9) may advocate this deviation. He says that market expectations of increasing inflation may depreciate the currency of a country. Figure 10 shows that, indeed, inflation increased substantially in Brazil after the COVID period.

3.2.3 Switzerland vs. Zambia (CHF/ZMW)

Lastly, Figure 11 brings the comparison between Zambia and Switzerland. The analysis of the CHF/ZMW exchange rate reveals that the nominal exchange rate, which represents the market value of one currency in terms of another, demonstrates a relatively close alignment with the PPP rate. This suggests that the nominal exchange rate between CHF and ZMW tends to reflect the relative prices of goods and services in both countries.

However, when considering the real exchange rate, which accounts for inflation differentials between the two countries, a notable deviation from PPP becomes apparent. The real exchange rate of CHF/ZMW is observed to be consistently higher than the PPP rate, implying that the Zambian Kwacha is relatively overvalued compared to the Swiss Franc when considering the inflation-adjusted purchasing power, similar to the Swiss Franc-Brazilian Real situation.

Figure 11: Nominal Exchange Rate vs. Real Exchange Rate deviations from PPP (CHF/ZMW)



Source: International Financial Statistics – IFS.

The observed deviations in the CHF/EUR, CHF/BRL, and CHR/ZMW, particularly in the real exchange rate, can be indicative of a link to the HBS effect, which suggests a positive relationship between a country's productivity and the real exchange rate.

As the magnitude of deviations of the real exchange rate from PPP is visible and progressively larger as we move from the CHF/EUR exchange rate to the CHF/BRL exchange rate, and it further increases as we analyze the CHF/ZMW exchange rate, Figure 12 illustrates the three pairs of countries and their deviations for comparison purposes, highlighting that the greater the difference in productivity between the pair of countries, the greater the deviation magnitude of the real exchange rate from its PPP.

This phenomenon might be an indication of the presence of differing productivity levels between Switzerland, Germany, Brazil, and Zambia. Switzerland, known for its high productivity and strong tradable sectors, may experience higher wage levels and increased demand for non-tradable goods. When compared to Germany, with similar

productivity and wage levels, the deviations of PPP are less significant than when compared to Brazil and Zambia.

Figure 12: Comparison of deviations from PPP

Source: own calculations. Data for CPI and nominal exchange rates used to derive the real exchange rate of: (1) Switzerland and Germany (IFS, 2023 and Central Bank of Ireland, 2023; (2) Brazil (investing.com, 2023 and IFS, 2023); (3) Zambia (IFS, 2023).

Across all three instances, a consistent pattern emerges wherein the real exchange rate converges towards the PPP and even below in the year 2015, coinciding with the abrupt appreciation of the Swiss Franc. This observed occurrence serves as a compelling indication of the tangible influence wielded by monetary policies on exchange rates.

Likewise, the same appreciation of the Swiss Franc is detected in 2011, the year that the Swiss National Bank decided to peg the Swiss Franc to the Euro, and similar to 2015, the three pairs of real exchange rates seemed to approach their respective PPP levels.

It is crucial to note that the comparisons were conducted using 2010 as the base year, however, it should be acknowledged that the accuracy of this chosen date remains uncertain. As highlighted by experts, this uncertainty regarding the base year selection constitutes one of the primary challenges in utilizing the concept of relative PPP[11].

[11] See Officer (1976, p. 20) on criticism of the relative parity and difficulties of selecting the base period.

4. Mean Reversion Pattern

Recalling Dornbusch (1985), “PPP is a theory of exchange rate determination”, or in other words, the Purchasing Power Parity is based on the idea that PPP provides a theoretical foundation for determining the equilibrium exchange rate between two countries. If the exchange rate deviates from its equilibrium level, it suggests that there might be imbalances in the relative prices between the two countries. When testing for mean reversion in an exchange rate, the aim is to observe whether the rate tends to revert back to its equilibrium value after experiencing deviations.

Mean reversion refers to the tendency of a variable to revert back to its long-term average or equilibrium level over time. This pattern suggests that extreme values or deviations from the average are likely to be followed by a correction, bringing the variable back toward its mean.

Jorion and Sweeney (1996) provided strong evidence of mean-reversion in real exchange rates during the 1973-1993 period. By testing for mean reversion and comparing the exchange rate to its PPP equilibrium, valuable insights can be drawn into the degree of exchange rate misalignment and the potential for the exchange rate to adjust and revert toward its equilibrium level. This analysis helps us understand the relationship between the exchange rate and the relative price levels between the two countries.

If an exchange rate consistently deviates from its PPP equilibrium, it indicates a potential misalignment between the exchange rate and the relative price levels. This misalignment can lead to market inefficiencies and opportunities for arbitrage, as goods and services may be relatively cheaper in one country compared to another.

Taylor and Lothian (2004) explain that the real exchange rate can be seen as an indicator of the deviation from PPP. To assess long-run PPP, researchers often test the null hypothesis that the process generating the real exchange rate series is linear and potentially non-stationary, characterized by a unit root, while the alternative hypothesis suggests that all roots of the process lie within the unit circle. This conventional approach assumes a linear autoregressive representation for the real exchange rate, implying continuous and constant-speed adjustment regardless of the extent of deviation from PPP. This framework is supported by the empirical observation that major real exchange rates, except during exceptional periods such as hyperinflation, do

not exhibit explosive behavior. Hence, real exchange rates can be interpreted as a measure of the deviation from PPP (Taylor & Lothian, 2004).

Sarno and Taylor (2002) further elaborate on why it is important to care for the stationarity (indication of mean reversion) and unit root (indication of a random walk, nonstationary) in the real exchange rate. According to the experts, these kinds of tests are important because: (1) valuable information about the impulses driving the real exchange rate movements can be acquired from the degree of persistence in the real exchange rate, (2) theoretically speaking, if exchange rates exhibit a nonstationary behavior then PPP is not a valid theory and (3) PPP exchange rates estimations are adopted for concrete purposes, such as appropriate policies responses to nominal exchange rate misalignments[12]. Additionally, in order for a variable to be forecasted effectively, it typically needs to exhibit some form of mean reversion pattern.

Rogoff (1996) conducted a study on the PPP Puzzle and documented tests based on long-horizon data sets by various experts. The findings revealed a consensus regarding the presence of a mean reversion pattern in the exchange rate. Frankel (1986, 1990), utilizing the standard Dickey-Fuller test, was able to reject the random walk hypothesis for the dollar/pound exchange rate spanning from 1869 to 1984.

Building on this principle, this section focuses on testing the Swiss Franc against the Euro, Brazilian Real, and Zambian Kwacha, respectively determined as the CHF/EUR, CHF/BRL, and CHF/ZMW exchange rates to identify a mean reversion pattern during the period from January 2007 to December 2021.

The monthly exchange rate between the Euro and the Swiss Franc (units of Swiss Franc per unit of Euro) dated from January 2007 until December 2021 was gathered from the Central Bank of Ireland. For the CHF/BRL, data from investing.com (2023) was assembled, and for the Zambian Kwacha the International Financial Statistics – IFS from the International Monetary Fund – IMF provided sufficient data for the exchange rate of ZMW/USD and CHF/USD, since there were no data available on the direct exchange rate between Switzerland and Zambia.

Next, the log of the real exchange rate according to the model (Ca' Zorzi et al., 2015).:

[12] See Sarno and Taylor (2002, p. 89) for a deeper review on the importance of unit root tests on exchange rates.

(6) $$yt = st + pt - p't$$

where:

st = log of the nominal exchange rate expressed as units of CHF per unit of EUR
pt = log of the home price level (Switzerland)
p't = log of the foreign price level (Germany)

Furthermore, the Dickey-Fuller test, a statistical test for stationarity and mean reversion was applied to test for mean reversion. The Augmented Dickey–Fuller test (ADF) tests the null of a unit root against the alternative of linear stationarity (Glaus & Thoma, 2018). Numerous studies have examined the validity of purchasing power parity by investigating the presence of mean reversion in the real exchange rate. The rationale behind this approach is that deviations from PPP are reflected in the volatility of the real exchange rate, or in other words, the volatility of the real exchange rate is equivalent to divergences from PPP (Glaus &Thoma, 2018; Taylor & Lothian, 2004).

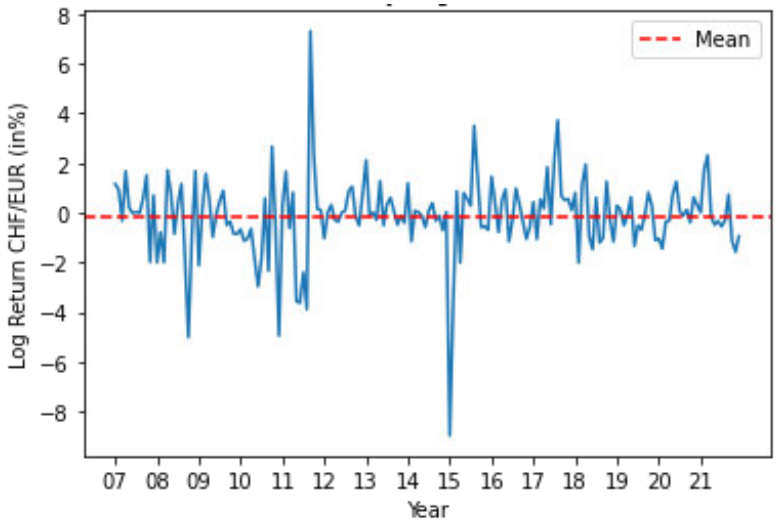
4.1 Switzerland vs. Germany (CHF/EUR)

The null hypothesis for the Augmented Dickey-Fuller test is that the CHF/EUR exchange rate possesses a unit root and is non-stationary (which suggests a random walk behavior). The alternative hypothesis posits that the CHF/EUR exchange rate is stationary (implying a mean reversion pattern). If the p-value is below the chosen significance level, there is enough evidence to reject the null hypothesis of a unit root and accept the alternative hypothesis of stationarity.

Figure 13 presents the monthly log returns of the EUR/CHF exchange rate. Evidently, a discernible mean reversion pattern can be observed within this exchange rate. Subsequently, conducting an Augmented Dickey-Fuller test further confirms that the time series is indeed stationary, supporting the presence of mean reversion.

The ADF statistic for the CHF/EUR exchange rate is -6.411975. This statistic measures the presence of a unit root in the time series data. In this case, it indicates whether the exchange rate exhibits a mean-reverting behavior or tends to follow a random walk.

Figure 13: Monthly log returns (CHF/EUR)



Source: Exchange Rates CHF/EUR: Central Bank of Ireland.
Note: Monthly log returns of the real exchange rate assuming the convention yt ≡ st + pt – p't, where st is the log of the nominal exchange rate expressed as units of CHF per unit of EUR, pt is the log of home price level (CPI CH) and p't is the log of foreign price level (CPI DE), respectively.

The p-value associated with the ADF statistic is 0.000000. This p-value represents the probability of observing a test statistic as extreme as or more extreme than the computed ADF statistic, assuming the null hypothesis of a unit root. Here, the low p-value suggests evidence against the null hypothesis, indicating that the CHF/EUR exchange rate series is likely stationary.

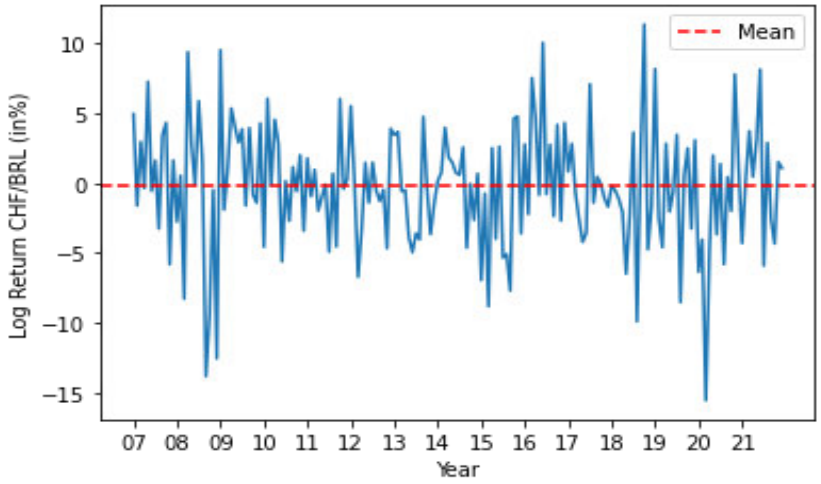
Furthermore, the critical value at the 1% confidence level is -3.468. The critical value represents the threshold beyond which we can reject the null hypothesis. If the ADF statistic is less than the critical value, we can reject the null hypothesis and conclude that the time series is stationary. In this scenario, the ADF statistic (-7.013215) is lower than the critical value, further supporting the rejection of the null hypothesis and indicating that the CHF/EUR exchange rate series exhibits a mean-reverting pattern.

Based on these results, we can conclude that the CHF/EUR exchange rate demonstrates mean reversion behavior over the analyzed period. This implies that deviations from the mean exchange rate are expected to be temporary, with the exchange rate eventually returning to its long-term average value.

4.2 Switzerland vs. Brazil (CHF/BRL)

Continuing with the analysis for the CHF/BRL exchange rate, we can apply the same framework used for the CHF/EUR exchange rate, and similar observations can be made. Figure 14 illustrates a clear mean reversion pattern evident in the log-returns of the exchange rate. Additionally, the results of the Dickey-Fuller test conducted for the CHF/BRL exchange rate provide further evidence supporting the rejection of the null hypothesis.

Figure 14: Monthly log returns (CHF/BRL)



Source: Exchange Rates CHF/BRL: investing.com (2023).
Note: Monthly log returns of the real exchange rate assuming the convention yt ≡ st + pt – p′*t, where st is the log of the nominal exchange rate expressed as units of CHF per unit of BRL, pt is the log of home price level (CPI CH) and p*′*t is the log of foreign price level (CPI BR), respectively.*

The ADF statistic obtained from the test is -9.829648, the calculated p-value associated with the ADF test is 0.000000, and the critical value at the 1% significance level is -3.467. Based on these results, the null hypothesis of a unit root and non-stationarity in the CHF/BRL exchange rate can be rejected at the 1% significance level. The statistically significant p-value of 0.000000 provides substantial evidence to support the alternative hypothesis of stationarity.

The rejection of the null hypothesis underscores the presence of mean reversion and suggests that the deviations from PPP are likely to damp out, which goes in line with previously mentioned research[13]. These results contribute to our understanding of the dynamics within the CHF/BRL exchange rate during the specified period.

[13] See Rogoff (1996) and Frankel (1986 and 1990).

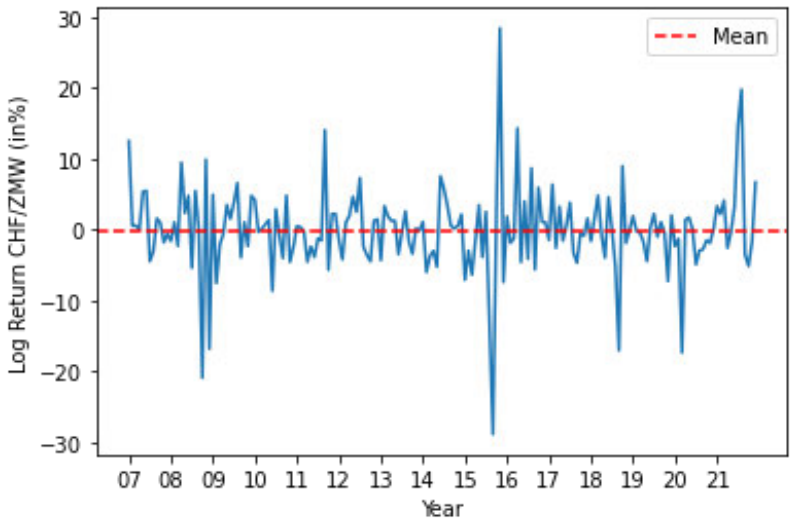
4.3 Switzerland vs. Zambia (CHF/ZMW)

Extending the analysis to the CHF/ZMW exchange rate, we can employ the same analytical approach utilized for the CHF/EUR and CHF/BRL exchange rates. Figure 15 illustrates the, again, visible mean reversion pattern of the currencies.

The ADF test conducted on the CHF/ZMW exchange rate reveals strong evidence of mean reversion in the time series. The ADF statistic of - -8.365681, significantly below the critical values of -3.468 (at the 1% confidence level), -2.878 (at the 5% confidence level), and -2.576 (at the 10% confidence level), indicates strong support for rejecting the null hypothesis. The p-value of 0.000000 further supports the rejection of the null hypothesis and confirms that the CHF/ZMW exchange rate exhibits a stationary behavior.

This implies the same deductions of mean reversion from the aforementioned currency pairs analyzed. In conclusion, the analysis affirms the presence of mean reversion in the CHF/ZMW exchange rate, indicating that any significant deviations from the average exchange rate between the Swiss Franc and the Zambian Kwacha are likely to be corrected in the future.

Figure 15: Monthly log returns (CHF/ZMW)



Source: Exchange Rates CHF/ZMW: International Financial Statistics – IFS (2023).
Note: Monthly log returns of the real exchange rate assuming the convention yt ≡ st + pt – p ‘t, where st is the log of the nominal exchange rate expressed as units of CHF per unit of ZMW, pt is the log of home price level (CPI CH) and p ‘t is the log of foreign price level (CPI ZMW), respectively.

Finally, the ADF tests conducted for the three currency pairs, namely CHF/EUR, CHF/BRL, and CHF/ZMW, indicate the presence of a mean reversion pattern in their respective exchange rates. The ADF test results consistently reject the null hypothesis of a unit root and provide evidence of stationarity in the time series, suggesting that, in all three cases, deviations from the long-term equilibrium are likely to be temporary, and the exchange rates have a tendency to revert back to their mean values over time.

It is, nevertheless, important to note that the mean reversion pattern observed in these cases is based on the specific time period analyzed and the assumptions made by the ADF test. It is necessary to exercise caution in generalizing these findings to other time periods or currency pairs, as market dynamics and factors influencing exchange rates can vary over time.

Further research and analysis are recommended to explore additional factors that may contribute to the observed mean reversion patterns and to assess the robustness of these findings across different time periods and economic conditions. Incorporating other variables such as economic indicators, interest rates, or geopolitical events can provide a more comprehensive understanding of the dynamics of exchange rate movements and enhance the accuracy of forecasting models.

It is also essential to acknowledge the limitations of the approach used to calculate the ADF test in each of the three scenarios: the results are based on the available data from January 2007 to December 2021. Therefore, the conclusions drawn from this analysis are specific to this time period and may not necessarily hold true for other time periods. Additionally, the ADF test assumes a linear relationship between variables, which may not accurately capture potential nonlinear dynamics, Taylor and Lothian (2004) noted that several authors have put forward the idea that the adjustment process of the real exchange rate toward equilibrium may exhibit nonlinearity.

Therefore, while the ADF test provides valuable insights into the potential mean reversion patterns, it is crucial to interpret the results in light of these limitations and exercise caution in drawing generalizable conclusions.

Table 1 - Augmented Dickey-Fuller (ADF) for three currency pairs (CHF/EUR; CHF/BRL; CHF/ZMW).

Currency Pairs	ADF Statistics	Critical Value at 1% Significance Level	Critical Value at 5% Significance Level	Critical Value at 10% Significance Level
CHF/EUR	-6.411975	-3.46806159	-2.87810619	-2.57560159
CHF/BRL	-9.829648	-3.46742014	-2.87782605	-2.57545208
CHF/ZMW	-8.365681	-3.46763152	-2.87791837	-2.57550135

4.4 Further observations

Noteworthy to point out is the magnitude of the variance from the mean observed in the three cases, which aligns with the earlier analysis of deviations from PPP. In the case of CHF/EUR, the magnitude of deviations from the long-term average was relatively smaller compared to the other two currency pairs, both when analyzing the log returns deviations from the mean and the magnitude of the real exchange rate divergences from PPP, indicating a potential alignment with the purchasing power parity. This means that the CHF/EUR exchange rate tends to exhibit more stable behavior, except for extraordinary situations (such as the sudden appreciation of the Swiss Franc in 2011 and 2015).

Sarno and Taylor (2002) and Rogoff (1996) explain that the level of persistence observed in the real exchange rate can provide insights into the main factors driving the fluctuations of the exchange rate. When the real exchange rate exhibits high persistence, resembling a random walk, it suggests that the driving forces behind the exchange rate movements are primarily related to real-side factors, particularly technology shocks.

On the other hand, if there is low persistence in the real exchange rate, it implies that the shocks affecting the exchange rate are predominantly associated with aggregate demand, such as changes in monetary policy. In this case, the findings insinuate that the exchange rate between the Swiss Franc and the Euro may be more closely influenced by factors such as inflation differentials, the strong economic ties between Switzerland and the Eurozone, well-established trade relationships, and the influence of monetary policies implemented by the European Central Bank (ECB) and Swiss National Bank (SNB).

In contrast to that, the CHF/BRL pair demonstrates much more significant and frequent deviations from the long-term average, corroborating the study in Session 2 of the real exchange rate deviations from PPP. Likewise, the CHF/ZMW exchange rate presents even larger deviations from the long-term average, in line with HBS effect.

Overall, considering the magnitude of deviations from the long-term average in conjunction with PPP provides valuable insights into the relative purchasing power of different currencies and their alignment with economic fundamentals. These observations can inform policymakers, investors, and market participants in understanding the dynamics of exchange rates, formulating trade strategies, and managing currency risks.

It is important to note that these observations are based on the analysis conducted in this study and may be subject to various other factors and limitations. Further research and analysis may be required to gain a comprehensive understanding of the underlying drivers of exchange rate behavior and their implications for market participants.

4.5 Forecasting Exchange Rates: the role and limitations of PPP and other methodologies

Forecasting exchange rates is a complex task that involves predicting future values based on historical data and statistical models. One approach to exchange rate forecasting is to consider the PPP theory, which serves as a benchmark for estimating long-term equilibrium exchange rates. By comparing the actual exchange rate with the PPP-based exchange rate, forecasters can identify deviations and make predictions about future exchange rate movements.

Nonetheless, it is essential to acknowledge the limitations and challenges associated with PPP-based forecasting. PPP relies on certain assumptions, such as the absence of transportation costs, trade barriers, and price distortions, which may not hold in the real world. Moreover, PPP is more applicable for long-term forecasting rather than short-term fluctuations in exchange rates. Other factors like economic conditions, market sentiment, geopolitical events, and monetary policies also impact exchange rates, often deviating from PPP-based predictions.

To improve the accuracy of exchange rate forecasting, it is crucial to consider additional factors and models alongside PPP. These factors may include interest rate

differentials, inflation differentials, balance of payments, investor sentiment, and technical analysis. Moreover, combining PPP with other forecasting methods, such as time series analysis, econometric models, or machine learning algorithms, can enhance the accuracy and robustness of exchange rate forecasts.

Analyzing the mean reversion pattern in currency pairs can also offer valuable insights for forecasting exchange rates. Mean reversion suggests that periods of overvaluation or undervaluation of exchange rates are likely to be followed by corrective movements toward the equilibrium level. Recognizing and exploiting these price deviations can present trading opportunities for market participants.

Mean reversion is an important concept in forecasting as it indicates that variables are not purely random or subject to unpredictable fluctuations. Instead, there is a systematic tendency for the variables to move back toward their average or equilibrium level. This characteristic makes the variables more predictable in the long run.

Conversely, variables that do not exhibit mean reversion or follow a random walk pose greater challenges for accurate forecasting, as future values are not influenced by past values. Hence, the presence of mean reversion in a variable provides valuable information for forecasting, indicating that deviations from the mean are likely to be temporary, and the variable will eventually revert back to its average or equilibrium level.

While PPP theory and mean reversion analysis provide a foundation for understanding exchange rate movements, it is crucial to recognize that forecasting exchange rates based solely on these methods can be challenging due to assumptions that may not hold in the real world.

Thus, to improve the accuracy of exchange rate forecasts, forecasters need to consider various factors and methodologies. For instance, one common tool employed in this process is the fundamental analysis. Fundamental analysis and models defend the influence of macroeconomic variables on the exchange rate (Maaerinskienn & Balciunas, 2014). So, a thorough examination of various economic factors, such as interest rates, inflation rates, GDP growth, trade balances, and fiscal policies are analyzed aiming to assess the intrinsic value of a currency and predict how changes in these factors will impact the supply and demand for the currency, ultimately influencing

its exchange rate. This approach requires a deep understanding of economic fundamentals and their interrelationships. This model is usually where PPP is applied. (

Technical analysis, on the other hand, focuses on studying historical price patterns, trends, and indicators to forecast future exchange rate movements (Maaerinskienn & Balciunas, 2014). Techniques such as moving averages, support and resistance levels, chart patterns, and oscillators are applied to seek better results. One setback of this approach is the wrong assumption that future values and performance will repeat themselves as they did in the past, and obviously, it is not always the case.

Another methodology is to use time series analysis, such as Moving Average (MA), Autoregressive Integrated Moving Average (ARIMA), and Exponential Smoothing (ES). It involves analyzing historical exchange rate data to make predictions based on past values and patterns (Lemonjava, 2019). Time series analysis can be useful for short-term or medium-term forecasting, capturing the inherent dynamics and autocorrelation present in exchange rate data.

Furthermore, other econometric models, such as Vector Autoregression (VAR), structural VAR, or cointegration models establish relationships between exchange rates and economic variables and offer a different approach to exchange rate forecasting by integrating economic theory and statistical techniques.

In reality, a combination of tactics is frequently used to enhance the accuracy of exchange rate forecasts as exchange rate forecasting is a challenging task due to the complexity and volatility of currency markets. While PPP theory provides a framework for understanding the relationship between exchange rates and relative purchasing power and serves as a reference point for long-term exchange rate projecting, forecasters should be mindful of the limitations and uncertainties inherent in the process. It is important to complement quantitative models with additional qualitative analysis and expert judgment to capture factors that may not be fully captured by data-driven models. Incorporating a holistic approach to forecasting can help improve the accuracy and reliability of exchange rate predictions.

5. Conclusion

In conclusion, this master's thesis aimed to explore the relationship between exchange rates and purchasing power parity (PPP) for the currency pairs CHF/EUR, CHF/BRL, and CHF/ZMW post-financial crisis. The findings shed light on several important aspects related to PPP, exchange rate movements, and the presence of the Harrod-Balassa-Samuelson (HBS) effect.

The analysis of the nominal exchange rate deviations and their relationship to Purchasing Power Parity (PPP) reveals that while PPP theory remains valid in the long run over the analyzed period, there are notable variations in the magnitude of deviations among different currency pairs studied. Switzerland and Germany show small discrepancies, except for extraordinary events of Swiss Franc appreciation, while Brazil and Zambia demonstrate more frequent and significant divergences.

Additionally, the correlation between PPP and the CHF/BRL nominal exchange rate appears weaker and less consistent compared to that of the CHF/ZMW. The complexity of Brazil's economy and its global connectivity might have contributed to increased volatility and deviations from PPP, while Zambia by being smaller and less globally integrated might experience exchange rate fluctuations more driven by specific economic characteristics and regional trade dynamics. These findings highlight the importance of considering the specific economic characteristics, foreign dependencies, and market dynamics of each country when assessing the relationship between exchange rates and PPP.

The analysis of real exchange rates and PPP revealed a connection to the Harrod-Balassa-Samuelson effect, as the magnitude of deviations increases as we move from the CHF/EUR exchange rate to the CHF/BRL and CHF/ZMW exchange rates, indicating a potential link between productivity differences and exchange rate disparities. Switzerland and Germany, both characterized by high productivity and strong tradable sectors, exhibit relatively smaller deviations from PPP. However, when comparing Switzerland to Brazil and Zambia, countries with lower productivity levels, the deviations become more significant, suggesting that the difference in productivity plays a role in the observed deviations from PPP.

Furthermore, in all three cases, the Swiss Franc appears undervalued, which is expected due to monetary decisions of the Swiss National Bank in maintaining the currency depreciated. Nonetheless, it is noteworthy the convergence of the real exchange rate towards PPP during periods of Swiss Franc appreciation (2011 and 2015). These instances further exemplify the influence of monetary policies on exchange rates.

The ADF tests conducted for the CHF/EUR, CHF/BRL, and CHF/ZMW currency pairs indicate the presence of a mean reversion pattern in their exchange rates. The rejection of the null hypothesis and evidence of stationarity suggest that deviations from the long-term equilibrium tend to be temporary, and the exchange rates tend to revert to their mean values over time.

The results regarding the magnitude of deviations from the long-term average align with the earlier analysis of deviations from PPP. The CHF/EUR pair exhibits relatively smaller deviations, indicating a potential alignment with purchasing power parity and more stable behavior, except for exceptional situations. In contrast, the CHF/BRL pair demonstrates larger and more frequent deviations from the long-term average, supporting the findings concerning real exchange rate deviations from PPP.

Nevertheless, further research is recommended to explore additional factors influencing mean reversion patterns and to assess the robustness of these findings. Incorporating variables such as economic indicators, interest rates, and geopolitical events can provide a more comprehensive understanding of exchange rate dynamics. It is crucial to acknowledge the limitations of the approach used, including the specific time period analyzed and the assumption of linear relationships. Considering these limitations and interpreting the results accordingly will enhance the accuracy and reliability of conclusions drawn from the analysis.

Lastly, a brief introduction to the forecasting of exchange rates was made. Forecasting exchange rates is a complex task that requires considering various factors and methodologies. While the purchasing power parity theory and mean reversion analysis provide valuable insights, they have limitations and may not fully capture the dynamics of exchange rate movements. To enhance accuracy, forecasters often combine different approaches, such as fundamental analysis, technical analysis, time series analysis, and econometric models.

Fundamental analysis examines macroeconomic variables and their interrelationships to assess the intrinsic value of a currency and predict its exchange rate. Technical analysis focuses on historical price patterns and indicators to forecast future exchange rate movements. Time series analysis utilizes past exchange rate data to identify patterns and make predictions. Econometric models, such as VAR and cointegration models, integrate economic theory and statistical techniques to establish relationships between exchange rates and economic variables.

By adopting a holistic approach that combines quantitative models with qualitative analysis and expert judgment, forecasters can improve the accuracy and reliability of exchange rate predictions. However, it is important to remain mindful of the uncertainties and limitations inherent in forecasting and continuously adapt the forecasting methodology to changing market conditions.

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Appendix 1

DECLARATION OF ORIGINALITY

Master's thesis for the School of Management and Law – Banking and Finance course.

By submitting this Master's thesis, the student attests to the fact that all the work included in the assignment is their own and was written without the help of a third party.

The student declares that all sources in the text (including Internet pages) and appendices have been correctly disclosed. This means that there has been no plagiarism, i.e. no sections have been partially or wholly taken from other texts and represented as the student's own work or included without being correctly referenced.

Any misconduct will be dealt with according to paragraphs 39 and 40 of the General Academic Regulations for Bachelor's and Master's Degree Courses at the Zurich University of Applied Sciences (dated 29 January 2008) and subject to the provisions for disciplinary action stipulated in the University regulations (Rahmenprüfungsordnung ZHAW (RPO)).

Town/City, Date: Signature:

Neunkirch, 15.06.2023 [redacted]