Currency Market Portfolio Constructions Based on Purchasing Power Parity Strategy and Refinement

Xinyi Ruan*
University of California Santa Barbara
Santa Barbara,
California 93106, United States
* Corresponding author. Email: xruan@ucsb.edu

Yuejia Zhang
San Jose State University
Washington Square, San José,
California 95192, United States

Zhiheng Zhang
University of California San Diego
9450 Gilman Drive, La Jolla
California 92092, United States

***Abstract*—Purchasing power parity is a powerful way to measure the currency value of different countries or regions. This strategy has been widely used in forecasting financial foreign exchange markets. Through purchasing power parity's evaluation of the value of currency, we have designed a foreign exchange investment strategy to predict whether to buy currency. We hope that PPP through simulated trading tests will become a good foreign exchange strategy and more people can make profits in foreign exchange market through purchasing power parity strategy. We tested the data of G20 countries from 1999 to 2019, and simulated trading whether these countries' currencies can be profitable under the purchasing power parity strategy. Through simulated trading tests, emerging markets have performed poorly, and developed markets have performed better than emerging markets. In the developed market, most of the simulated trading has made profits, while the emerging markets all show a loss. Through the stimulation, we believe that purchasing power parity is not a good foreign exchange trading strategy.**

Keywords-Purchasing Power Parity (PPP) ; Real Exchange Rate; Foreign exchange market; Emerging markets; Developed markets

I. INTRODUCTION

Purchasing Power Parity (PPP) is a value calculated based on each country's different price levels. [1] Its purpose is to compare the GDP, and we can analyze the country's living standards through data. Purchasing Power Parity is the currency exchange rate that equalizes the purchasing power of different currencies by eliminating the difference in price levels between countries. [2] We divide the PPP data by the exchange rate, and subtract one from the obtained value. When the real exchange rate is larger than 0, we determine the currency has been overvalued. When the real exchange rate is lower than 0, we determine the currency has been undervalued [3].

The frequency of our transactions is based on whether the daily ranking of our real exchange rate changes. [4] If the ranking of our real exchange rate changes, we will make a transaction and pay the transaction cost. We will separately calculate each currency's daily ranking in emerging markets and developed markets through the real exchange rate. And given the daily profit or loss situation, we will add each currency's interest rate every day to this value to get the final value. We look forward to using the real exchange rate to determine what currencies should be long and what should be short. The currencies of the three highest real exchange rates will be long, and the currencies of the three lowest real exchange rates will be short if the lowest ones are still undervalued. [5] We will go long and short the highest three and lowest three exchange rates. In this case, we will only choose the three highest exchange rates to go long. The highest real exchange rate will receive 25% of the total capital investment, while the remaining second and third highest real exchange rates will receive 12.5% of the investment. We will short the lowest three real exchange rates. The lowest real exchange rate will receive 25% of the total capital investment, and the second and third lowest real exchange rates will each receive 12.5% of the investment.

Based on the signal generation, our determination of which currency to trade is mainly influenced by the real exchange rate, so we compute the real exchange rate of each currency. However, the foreign exchange market can be divided into emerging markets [6] and developed markets, causing us to rank the RER of each currency separately and decide the allocation of investment according to the ranking in each part. The expected daily profit rate is 0.02%.

II. SPECIFICATION

Our Signal Generation is based on Real Exchange Rate (RER).

$$\text{RER} = \frac{\text{PPP}}{\text{Exchange Rate}} \tag{1}$$

The formula for Purchasing Power Parity [7] can be written as:

$$S = \frac{P1}{P2} \tag{2}$$

Where S represents the value of PPP, and P1, P2 represents the cost of goods in currency 1 and currency 2. [8] The result

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obtained represents the exchange rate of buying goods and services with the same amount of currency in another country. When we divide the cost of goods in currency 1 by the cost of goods in currency 2, the exchange rate can be obtained. In the purchasing power parity formula, we focus on calculating the exchange rate between different countries. PPP makes it easy for people to see the income level of each country. When PPP is used in foreign exchange transactions, it helps to predict the fluctuation of international currencies and indicate weakness [9].

Traders can use any difference between the Purchasing Power Parity exchange rate and the exchange rate to evaluate the long-term forecast and valuation of the currency. The theory of PPP indicates that the prices of similar traded goods and services in the two countries should be equal when discounted into local or foreign currencies. Long-term investors can benefit from seeking self-correction of deviations in purchasing power parity. Traders use exchange rates to predict the direction of currency pairs and use it to determine whether to buy or sell currencies. [10] If the PPP exchange rate shows that the relative value of the currency is undervalued, they can consider looking at the market from a long-term perspective. Traders can buy currencies that are considered undervalued or sell currencies that are overvalued according to where the Purchasing Power Parity balance point is. [11]

We choose the Chinese yuan (CNY) currency as the base currency in the foreign exchange market. The currency data set includes the selected G20 countries: China, India, Indonesia, Republic of Korea, South Africa, Brazil, Canada, Mexico, United States, Russia, United Kingdom, European Union, Singapore and Australia. The Saudi riyal is pegged to the U.S. dollar, the exchange rate is constant at 0.27, so we consider that SAR can represent value of USD and remove SAR from the portfolio to reduce USD's impact to the list. Although the SGD is partially pegged to U.S. dollar, it has a larger exchange rate range, and it is also affected by CNY exchange rate. As a result, we keep the Singapore dollar in the portfolio. The data set will be split into developed markets set and emerging markets set. The developed markets set includes Australia, Canada, EU, Singapore, South Korea, United Kingdom, and the United States. The emerging markets set includes Argentina, Brazil, China, India, Indonesia, Mexico, Russia, and South Africa. The sample period is 1999-2019, among which data from 1999-2012 will be in-sample data, while statistics from 2013-2019 will be out-of-sample data. We need the daily exchange rate of G20 to calculate the daily profit and loss.

We collect data of USD based Purchasing Power Parity indicator [12] and the exchange rate of each currency [13] from the Organization for Economic Co-operation and Development (OECD) website. Then use the formula to calculate the real exchange rate to determine which currency is overvalued and which one is undervalued. Therefore, we can decide what to sell and what to buy.

The PPP data from the OECD is in annual frequency, and the exchange rate data is daily. Both of them are using the U.S. dollar as the base currency. Since more than three years' Argentina's historical USD-based exchange rate data cannot be verified, we removed Argentina from our portfolio. We generated all valid trading day dates from January 1, 1999, to December 31, 2019, in an Excel DataFrame through Python, which are dates excluding all weekend days, and these dates are used as indexes for matching data. All PPP data is written into their corresponding year's date, and the exchange rate data is accurately added to the corresponding date. Since different currencies have their unique statutory holidays, some countries do not have valid exchange rate data on certain dates. The data on these dates will be overwritten with previous valid data. After obtaining all the dates with valid data, we divide the PPP of all countries except China by the PPP data of China to obtain the new PPP data based Chinese Yuan (CNY).

In addition, when executing the trade, we need to pay transaction fees and service fees, so they can also affect the profits or loss, so we find the interest rate from the Bank for International Settlements website and the service fee from the Bank of China. We found that there was no interest rate guided by the Bank of Korean until May 1999 in South Korea. Before this date, South Korean interest rates continued to fall from 8.1% since October 1998 due to the Asian financial crisis, and no accurate daily data was recorded. Therefore, we set the Korean interest rate from January to May 1999 at 5% based on the average level. [14] The transaction fee is approximately 0.1% of the trade price. Whenever there is any change in our daily ranking, we consider this to be a transaction. We charge a transaction fee for each transaction. When we do long, interest is earned. When we do short, interest is lost. The interest rate comes from the monthly average interest rate data of the central bank of each country. [15] We convert the annual interest rate to a daily one and use it to correspond to the daily currency change to get the daily profit with the interest rate.

III. IMPLEMENTATION

In the implementation, we created our model with the R language. We select the first two-thirds of the data for the in-sample data test and calculate the real exchange rate of each currency separately. We sort the daily real exchange rates respectively, and we determine the first three in emerging markets and developed markets. We divide the rate of the previous day by the rate of the next day and subtract 1 to complete the rate of the changing table. After that, we complete our quantitative investment in each ranking through the set portfolio construct and multiply the investment ratio after the daily rank real exchange rate by the rate of change to get the daily profit and loss amount. We add the amount of profit or loss of interest rate to the daily profit and loss and pay transaction cost to each transaction. Finally, the Cumulative P&L chart is completed by superimposing daily profits or losses.

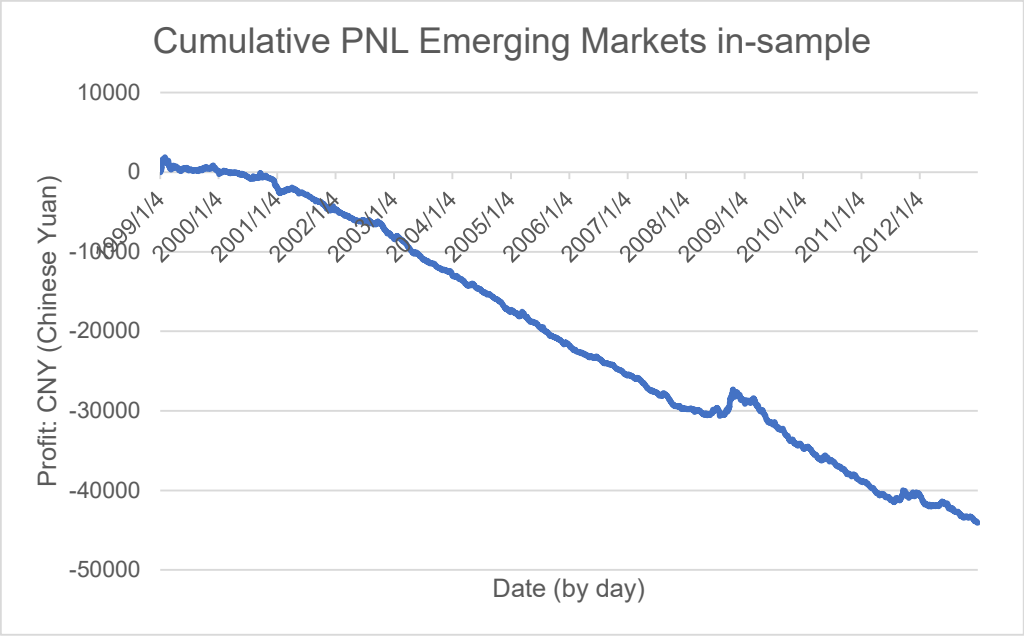

Figure 1. Cumulative PNL Emerging Markets in-sample test

From the daily profit and loss in Figure 1, the daily income in the figure is decreasing. This is to add all gains and losses and divide by the total number of days to get our daily parity gains. The average daily profit rate of cumulative profit and loss from emerging markets in the in-sample data is -0.06%, which is lower than what we expected. We ended up earning a total of -44064.42 in emerging markets.

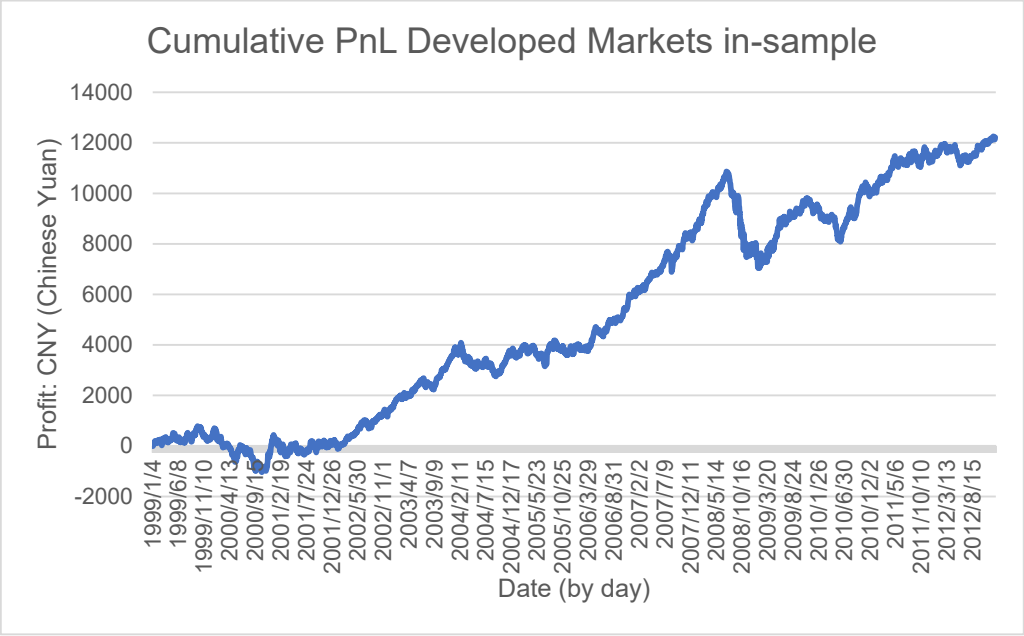

Figure 2. Cumulative PNL Developed Markets in-sample test

From the Figure 2, the daily gains and losses are basically rising. The average daily income in developed markets is more than in emerging markets. The average daily profit rate of cumulative profit and loss from Developed Markets in the in-sample of data is 0.016%; it's lower than what we expected. In the developed market, a total of 12216.8 profits were made.

We completed our idea of the entire portfolio construct in r, and we look forward to using the average daily yield to measure whether our model meets expectations. We compare the daily average profit rate to observe whether our model meets our expectations. Our expectation is 0.02%, and our daily average rate of return in both emerging markets and

developed markets did not meet expectations. With an investment of twenty thousand yuan, the average daily profit rate of emerging markets is -0.06%, while the mean daily revenue rate of developed markets is 0.016%.

A. Refinement 1:

Based on experience, there are some known flaws in using PPP as a currency value judgment. Since the calculation result of PPP originally comes from product prices in the market, market differences will be the main reason that affects PPP results. First, taxation is a factor that directly affects commodity prices. Taxes such as value-added tax and sales tax will increase the price of products. Moreover, different countries have different policies on how to show goods' sales tax. Some countries will add sales tax additional after subtotal prices in receipts while some other countries' goods prices have included sales tax. Therefore, the PPP value associated with countries where sales tax is included in the price of goods will be affected. Second, the production costs of the same product in different countries are different. Non-tradable goods, including utility, insurance, and labor cost, will affect the find goods price. Higher non-tradable goods will increase production cost, and the sale price of the final goods will increase. Third, market competitiveness is also a factor that affects prices. Products with more competitors will have prices closer to cost. However, as mentioned above, the existence of taxation will decrease the accuracy of Purchasing Power Parity. Therefore, we find the taxation rate, including the sales tax rate of each country from the World Bank database in order to eliminate the influence of taxation. We can simply divide the price of those goods that price includes tax by 1+sales tax rate in percentage and the price of goods that without sales tax can be obtained. According to the RER formula, we can deduce that deducting sales tax in the RER formula is equivalent. As a result, a new indicator formula based on RER like this:

$$\text{Optimized RER} = \frac{\text{Original RER}}{1+\text{Sales Tax}} \tag{3}$$

In this refinement, we need to find which countries include their sales tax within goods' marked price and what their sales tax rate is each year. When the country changed the sales tax rate during the year, we decided to calculate the average sales tax of the year based on the ratio of each tax rate period to the number of days in the year. We found the countries that marked price includes sales price, are China, Saudi Arabia, India, Russia, South Korea, South Africa, Mexico, and Australia rom each country's administration of taxation.

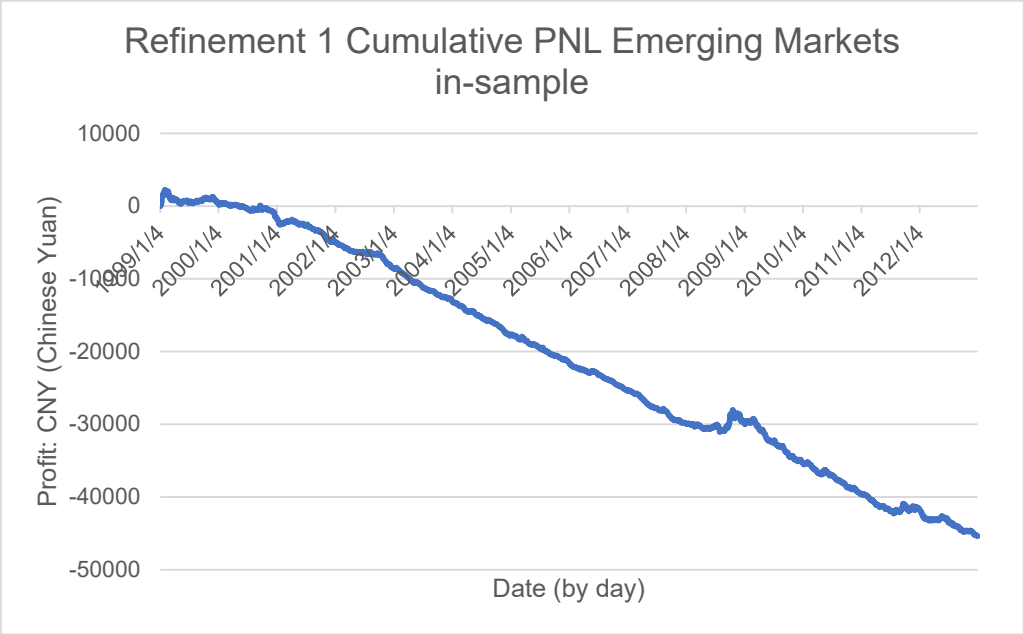

Figure 3. Refinement 1: Cumulative PNL for Emerging Markets in-sample test

From the Figure 3, the cum curve after this optimized data can show the impact of the modified signal on daily income or loss. The average daily profit rate of optimized cumulative profit and loss from Emerging Markets in the in-sample data is -0.062%; it is lower than what we expected. The final profit is -45390.79.

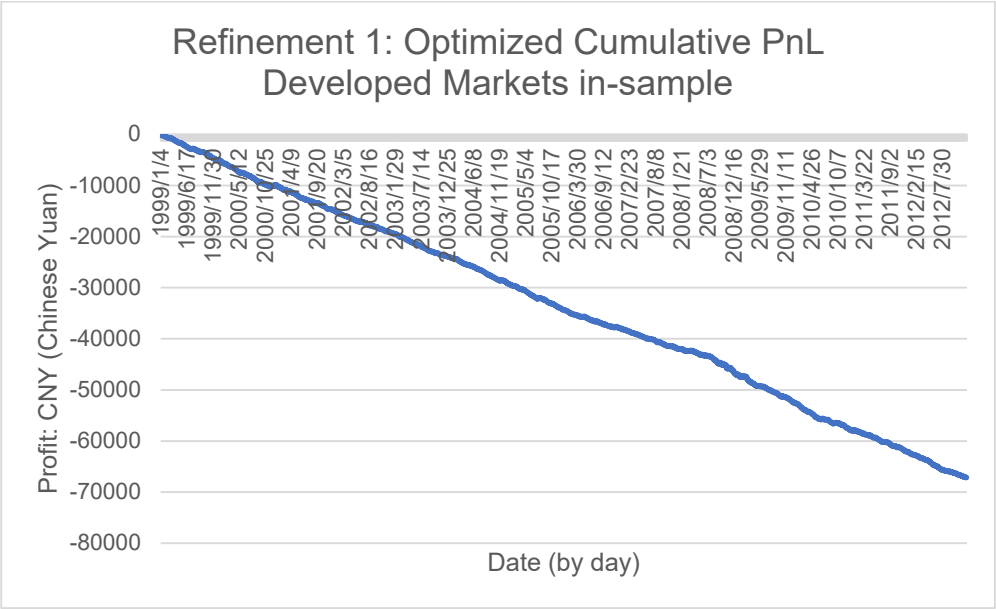

Figure 4. Refinement 1: Cumulative PNL for Developed Markets in-sample test

The Figure 4 shows the state of continuing loss after the exclusion of taxation. The figure presents a declining trend. The average daily profit rate is -0.092%, it is lower than what we expected. We lost 67126.11 in the developed market.

B. Refinement 2: in-sample data test

The second subtle change we made was achieved by changing the investment ratio. Originally, we invested 25% for the first and the last, and the second and third place and last and second to last places invested for 12.5% of the total. This model allows us to invest in each feasibility is seen in the daily profit and loss. We try to use different investment proportions to achieve better profit. We look at the top and bottom rankings of each currency and find that the head rank and tail rank of the real exchange rate calculated by PPP are similar. In other words, the real exchange rate is only slightly different. We plan to use the same investment ratio to invest in the top three and bottom three currencies, and we hope that such an investment ratio can bring better results. We also look at the currencies of developed markets and emerging markets separately. The currencies of each market are reserved for seven currencies. We will also invest in the currencies of the top and bottom rankings but change the portfolio to 1/6 of the investment to each currency.

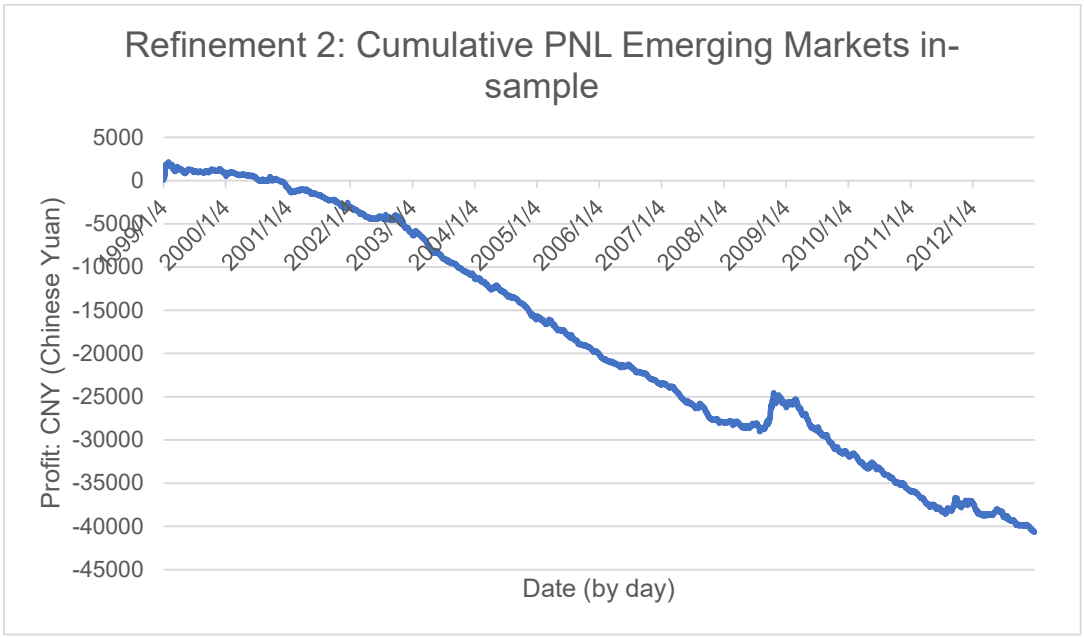

Figure 5. Refinement 2: Cumulative PNL for Emerging Markets in-sample test

The result of Figure 5 shows the investment results in the in-sample data of emerging markets from January 1999 to December 2012. The average daily profit rate of cumulative profit and loss from Emerging Markets in the in-sample data is -0.056%, which is lower than what we expected. The cum curve we can earn a total of -40636.99 profit.

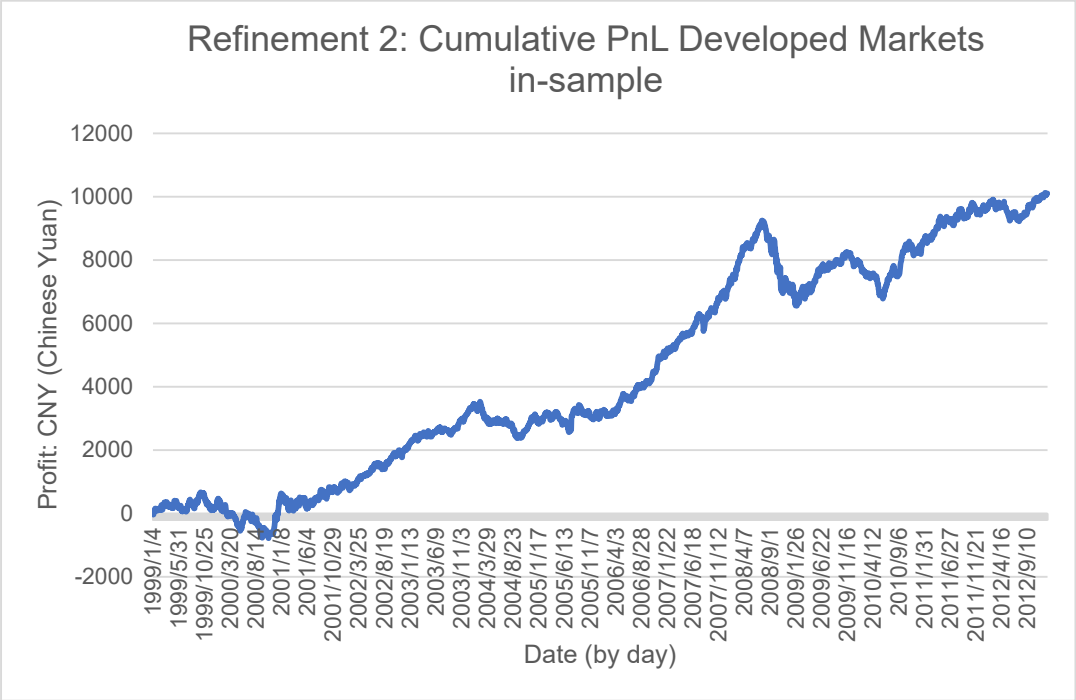

Figure 6. Refinement 2: Cumulative PNL for Developed Markets in-sample test

Through Figure 6, the profitability of currency in the developed market. The average daily profit rate of optimized cumulative profit and loss from Developed Markets in the in-sample data is 0.014%, which is lower than what we expected. In the end, we make a profit by developed market 10106.07.

IV. Our-of-Sample Data Test

A. Cumulative PNL for Emerging Markets out-of-sample test

We choose the statistics from 2013-2019 to be out-of-sample data in order to test the accuracy of the implementation results.

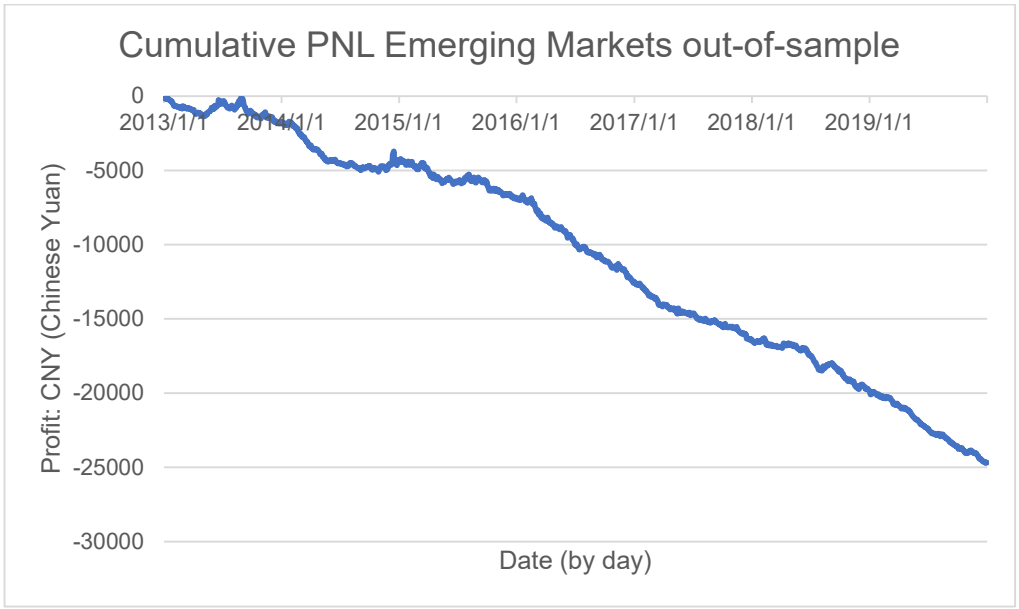

Figure 7. Cumulative PNL Emerging Markets out-of-sample test

From the Figure 7, the overall daily revenue of emerging markets is decreasing. The average daily profit rate is –0.068%. We make a profit by emerging markets from the out-of-sample data test is -24675.61.

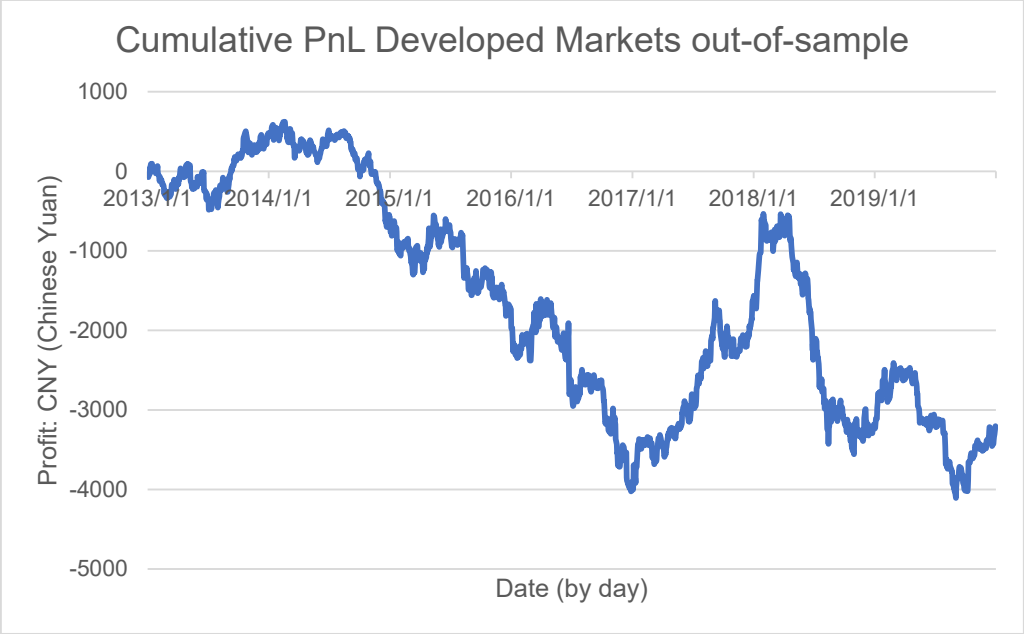

Figure 8. Cumulative PNL Developed Markets out-of-sample test

From the Figure 8, the results of the out-of-sample data test of the developed market changed the graph's direction. Opposite with the in-sample data output, the average daily profit has changed from 3.347 to -1.7549 and the average daily profit rate is –0.009%. The profit changed to -3202.6393.

B. Refinement 1: out-of-sample data

After the exclusion of taxation, the result of refinement 1is: out-of-sample data overall increasing trend with two sharp decreases approximately from February 1, 2014, to April 31, 2014, and from January 1, 2016, to May 31, 2017, while the in-sample output presents a steadily increasing tendency. The average daily profit rate is -0.070%. In the end, we make a profit by emerging markets from the out-of-sample data test is -25689.15.

The output of the out-of-sample test shows a declining trend, basically the same as that of the in-sample data. The average daily profit rate is -0.104%. In the end, we make a loss by developing markets 38067.54.

C. Refinement 2: out-of-sample data

In refinement 2: out-of-sample data, the overall profit is negative and the loss is increasing steadily. The average daily profit rate is –0.061%. The total profit of emerging markets from the out of data test is -22418.85.

After the reallocation of investment in developed markets, the overall profit is negative. The average daily profit rate is –0.006%. Under the superposition of daily profit and loss, the cum curve shows a final loss of 2144.844.

V. CONCLUSION

In the entire study, data from G20 countries from 1999 to 2019 were selected, and the first two thirds of the data were used for in-sample tests, and the latter third for out-of-sample tests. After deleting data from countries that are strongly linked to the U.S. dollar and countries that severely affect the results of the study, the study of 13 countries was completed. There are 6 countries in emerging markets and 7 countries in developing markets. Emerging markets showed losses in all tests, while developed markets showed profitability in the original test and refinement 2. Although the developed markets showed profits, they were still lower than our expected daily average profit. As set in the study, the expected daily average profit is 0.02%.

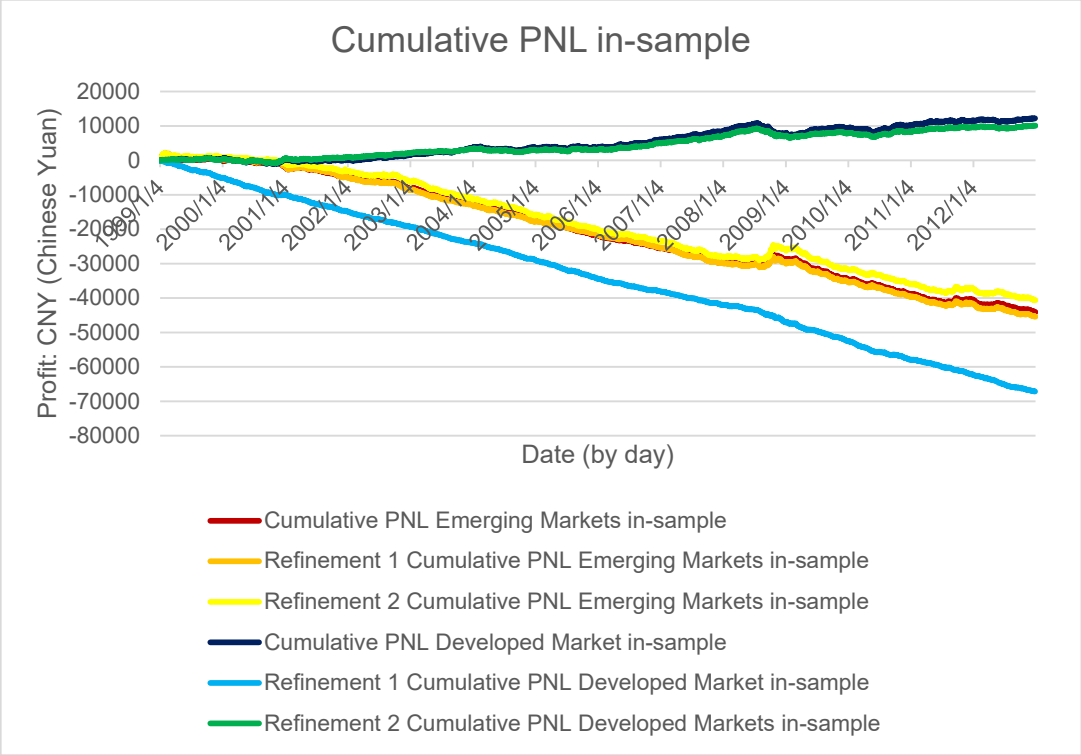

Figure 9. Cumulative PNL in-sample test conclusion

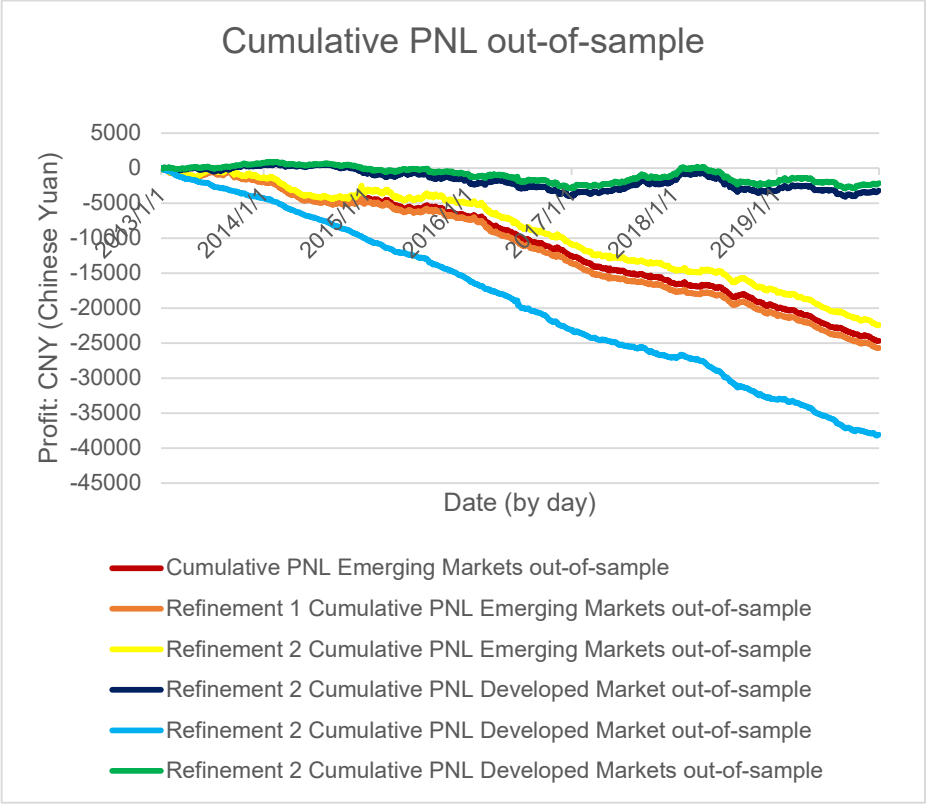

Figure 10. Cumulative PNL out-of-sample test conclusion

In Figure 9, the in-sample test results of emerging markets and developing the market are put together for comparison. Also compared are the conclusions of out-of-sample test, shown in Figure 10. These pictures visually compare the results displayed by each strategy. Refinement 1 has the largest loss in emerging markets and is the least recommended investment strategy. The effect of refinement 1 in the developed of the market has not reached the forecast. It can be seen in both Figure 9 and 10 that refinement 1 is a failed refinement and is not a recommended investment method. However, the original investment strategy yielded better results in the in-sample test of the developed market. The way of changing the investment ratio in Refinement 2 gets more benefits in out-of-sample. It can be concluded that these two investment methods can be used in the developed market, but they did not meet our expectations, so they are still not recommended investment strategies.

Through comparison, it is found that changing the investment ratio can increase the final return. Research shows that the purchasing power parity strategy designed in this research is not a good foreign exchange investment strategy. The researched basically shows a loss status. Two different refinements were designed in the study, one was to optimize the calculation of PPP, and the other was to change the investment ratio. The method of changing the investment ratio has made the purchasing power parity strategy better progress. This research can use time series to predict in the future and use quantitative forecasts to reduce the risk of mergers and find the best matching point. We can expect 3 to 5 years of data on the actual exchange rate of each country, which currency changes the most, and which data is used. Data from previous years can be used to predict the ratio of future cycles. Multivariate analysis can find key correlation coefficients. For currencies that are completely negatively correlated, it is best to make long and short currencies together to be negatively correlated. We hedge against negatively correlated currencies. Analyze the coefficients to form a matrix and hedge each other to achieve the best investment portfolio.

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