Applicability of Efficient Market Hypothesis (EMH) in the Foreign Exchange Market

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1 Introduction

In an efficient capital market, the Efficient Market Hypothesis (EMH) states that market prices fully, correctly, and unbiasedly reflect all available information (Fama, 1970). Typically, in the foreign exchange market, EMH posits that people cannot outperform the forward predictions, since the exchange rate is only affected when new information is presented. This implies that foreign exchange market forwards are unbiased so speculators and arbitrageurs cannot find a steady reliable strategy to profit from the foreign exchange forward discount or premium. However, the currency "carry" trade, a strategy of taking the advantage of the difference in currency exchange rate forwards by using the currency with the lower implied interest rate to fund with a long position in a forward implied high-yielding currency (CFI, 2022), may challenge the validity of EMH. Therefore, this paper will study whether EMH can be applied to the foreign exchange market by constructing a currency carry trade portfolio to determine whether arbitrageurs can find a passive strategy that generates a positive risk-adjusted return over time and hence determine whether the signal in the foreign exchange market is not unbiased and accurate as would be implied by the EMH.

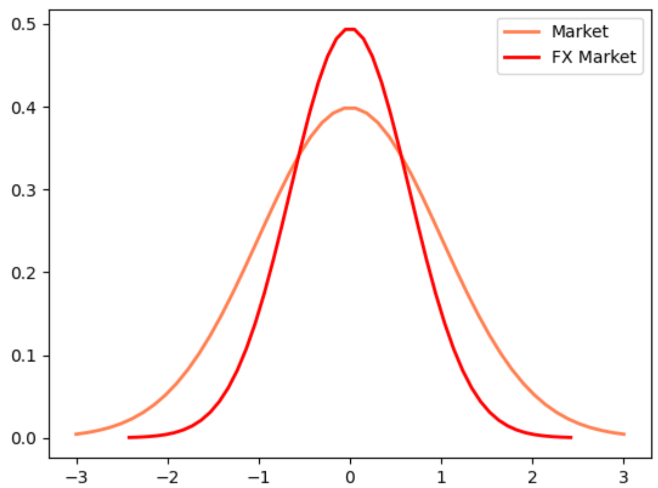

Figure 1 Comparison of revenue distribution in capital market and FX market

It's usually difficult for arbitrageurs to find a passive foreign exchange strategy that can make a risk-adjusted attractive rate of return. This is attributed to the nature of the FX market: symmetrical and unbiased distribution of the probability to gain and loss, which means arbitrageurs have the same probability to gain and lose, therefore deterring them from better forecasting than the forward rate. Another set of characteristics of the typical foreign exchange probability distribution is a fat tail or high kurtosis (the central tendency of the distribution). This implies that an expected net gain of zero due to its high central tendency and the unbiased forward rate in the FX market. Nevertheless, the thicker tail of this distribution makes the investment "riskier", or with high volatility, since arbitrageurs have the probability to gain more and lose more money at the same time. Therefore, this risky but rewarding nature of the FX market pushes people to invest and try to find an optimized strategy. But more importantly, due to the implementation of carry trade, empirical findings show that forward premium on the foreign currency is not an unbiased forecast of the rate of appreciation of the foreign currency (Daniel K., et al, 2017), which may imply that the actual return is going to deviate from what we expected under the efficient market hypothesis.

In terms of the currency carry trade, arbitrageurs may benefit from the forward market by entering a forward contract at a certain future time for a certain exchange rate, which is an immediate action. Through adopting combinations of long (buying the currency at forward discounts) and short (selling the currency at forward premiums) positions in different currencies, arbitrageurs may profit from the difference between the future spot rate and the locked-in forward rate. Typically, for currencies at forward discounts, as long as the spot rate depreciates less than the discount, the position can be profitable, and conversely, this is also applicable for currencies at forward premiums. This paper will analyze whether there exists an optimized strategy to allocate arbitrageurs' investment and hence examine EMH in the FX market.

2 Mechanism of Efficient Market Hypothesis and Gambler Fallacy

With the EMH, we are expecting to get a net gain of zero by using carry trade in the FX market. Also, the distribution of the gain has the skewness of zero. However, we need to be cautious that the final zero-return rate is a long-term result instead of a short-term one. In the short term, the distribution of gain can either be positively skewed (higher chance of receiving net loss) or negatively skewed (higher chance of receiving net gain). With such repetition of investment, if the EMH holds we will finally receive a zero-return rate in the long term.

Nevertheless, the conception of an "unbiased" market usually leads to the confusion of gambler fallacy. Every investment result should be independent from each other, and the continuous gain in the previous investment will not cause arbitrageurs to shortly return back to the loss position to achieve the overall zero-net gain. Moreover, how we define "long-term" is also very crucial to test the validity of EMH in the FX market. This paper will study whether the EMH can be applied to the market with 16 years of annual return and a sharpe ratio based on 3 years of daily return volatility.

Arbitrageurs are rational, which means they are trying to use an optimized strategy to maximize their profits, so in order to simulate their decisions in carry trade, we will test the EMH under the "optimized" strategy used. In the carry trade, our decision can be only made based on the spot rate and forward rate in the same year. Thus, we must generate some threshold by selecting the most seemingly "profitable" currencies and holding a positions on them. This reduces the unnecessary investment in other currencies to maximize our final return. Our "optimized strategy" is merely generated from the previous empirical data, so we cannot ensure the strategy we took can bring us to the best position in the future due to the "unbiased" nature of the FX market. Once we got a strategy that can constantly profit us from within the time span we studied, we should conclude that the EMH cannot be applied to the FX market in this time span, and the "long-term" net gain of zero should be defined in a larger time span than the one proposed in this paper. The following part of paper will establish two portfolios to test the EMH in the FX market.

3 16-year annual-return-based portfolio case

This portfolio includes the annual-based spot rate and forward rate of 23 currencies from 2006 to 2022. Firstly, for our investment plan, we need to determine our position on each currency, whether to hold a long position on it or hold a short position on it. Our positions on each currency are decided by whether that currency is in premium or discount (appreciation or depreciation) by comparing the spot rate and forward rate in the same year. Arbitrageurs are more willing to invest in the currency that is in "great" appreciation or "great" depreciation. By doing so, arbitrageurs can profit from the huge difference between the current forward rate and the future spot rate. Therefore, it's necessary for us to set some threshold to filter out the most "promising" currency, or the currency that can tend to have a very huge gap between the future spot rate and current forward rate, by analyzing the current spot rate and forward rate.

We need to first calculate the relative change $R_{spot\text{-}forward}$ between the current spot rate and forward rate:

$$R_{spot-forward} = \frac{Spot\ Rate}{Forward\ Rate} - 1$$

The future spot rate can only be inferred based on the information we currently have. If $R_{spot\text{-}forward} < 0$, the current spot rate is lower than the current forward rate, which we will infer that the spot rate next year will also be lower than the current forward rate. Therefore, we should hold a long position on this currency. On the other hand, if $R_{spot\text{-}forward} > 0$, we predict that the future spot rate tends to be higher than the current spot rate, so a short position on this currency should be held.

As mentioned above, we need to take the position on the currency with a higher magnitude of $R_{spot\text{-}forward}$, which gives us a higher potential for gain. However, how to select and filter those "promising" currencies should be analyzed thoroughly. This paper provides two different ways to do this: via the absolute-magnitude-threshold method or the maximum-number-threshold method.

To begin with the absolute-magnitude-threshold method, in this model, we set a threshold, L, to filter all the currencies with $R_{spot\text{-}forward}$ that passes the threshold. If the currency has $|R_{spot\text{-}forward}|$ equal or higher than L, we should select it and take the position on it depending on whether it's positive or negative, with the pseudocode presentation below:

$If\ |R_{spot-forward}| \geq L$:

$If\ R_{spot-forward} < 0$:

take the long position on that currency

$If\ R_{spot-forward} > 0$:

take the short position on that currency

By traversing all the possible L, we can find the optimized threshold that gives us the maximized return rate.

Another possible strategy is to set the maximum number of long positions we can take, MAX_{Long}, and the maximum number of short positions we can take, MAX_{Short}. This strategy is intending to select the top N currencies with the highest magnitude of $R_{spot\text{-}forward}$, achieving our aim to allocate our investment to those most "promising" currencies.

Same as the absolute-magnitude-threshold method, we first need to judge our position on each currency by considering the sign of $R_{spot\text{-}forward}$, then choosing the number of currencies as long position and short position within MAX_{Long} and MAX_{Short}.

Pseudocode is presented, $R_{spot\text{-}forward\text{-}i}$ stands for the relative change of the i^{th} currency:

$For\ R_{spot-forward-i}\ in\ all\ currencies$

$If\ R_{spot-forward-i} < 0$:

add i to $Long\ Position\ List$

$If\ R_{spot-forward-i} > 0$:

add i to $Short\ Position\ List$

$Sort(Long\ Position\ List)$

$Sort(Short\ Position\ List)$

$For\ 1st\ to\ MAX_{Long}\ in\ Long\ Position\ List:$

take the long position

$For\ 1st\ to\ MAX_{Short}\ in\ Short\ Position\ List:$

take the short position

After selecting the currency for our long and short position, we need to calculate annual return rate of our investment strategy.

For the currency at long position, we are looking forward to have a future spot rate higher than our current forward rate (appreciation at future spot rate), so we can buy the currency at a lower exchange rate with the current forward rate. Therefore, our percentage gain is measured by the relative change between the current forward rate and the future spot rate (*n* stands for the year):

$$Gain\% = \frac{Forward\ Rate_n}{Spot\ Rate_{n+1}} - 1$$

This percentage gain can either be positive or negative. If the future spot rate depreciates (i.e. future spot rate is higher than the current forward rate), we are getting worse off from it, and the percentage gain should be negative.

For the currency at short position, we looking forward to have a future spot rate lower than our current forward rate (depreciation at future spot rate), so we can sell the currency at a higher exchange rate at the forward rate. Therefore, our percentage gain is measured by the relative change between the future spot rate and the current forward rate (*n* stands for the year):

$$Gain\% = \frac{Spot\ Rate_{n+1}}{Forward\ Rate_n} - 1$$

By combining these two percentages of gain together, we can get final annual return rate, as shown below:

$$Annual\ Return\ Rate = \sum_{Long,n=2006}^{2021} \left(\frac{Forward\ Rate_n}{Spot\ Rate_{n+1}} - 1\right) + \sum_{Short,n=2006}^{2021} \left(\frac{Spot\ Rate_{n+1}}{Forward\ Rate_n} - 1\right)$$

For the absolute-magnitude-threshold method, we are using initial investment of USD10,000 as the numerical calculation example. Figure 2 shows the final return after 16 years at different threshold in percentage (i.e. 0.10% means the magnitude of $R_{spot\text{-}forward}$ should be higher than 0.001):

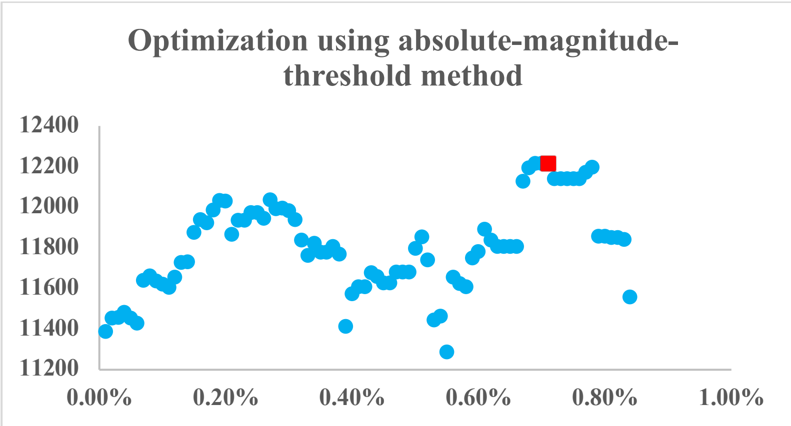

Figure 2 Numerical optimization result for absolute-magnitude-threshold method

Shown in the result, the optimized threshold is $L=0.071$, which we only take position on the currency every year if its $R_{spot\text{-}forward}$ is higher than 0.071. The final return of this portfolio with initial investment of USD10,000 is USD12,218, and the annualized return rate is 1.3%. It should be noted that the USD10,000 is just a notional amount and, in fact, since this is an equal long versus short portfolio there is, in principle, no capital that need be invested so even a marginal positive gain represents and infinite rate of return. In reality some amount of collateral may have to be posted against the traded position but this still would allow a rate of return that is many times the notional return.

For the maximum-number-threshold method, we need to traverse all the possible combination of MAX_{Long} and MAX_{Short} to find a pair of MAX_{Long} and MAX_{Short} that is most profitable for us. Similarly, we are using the initial investment of USD10000 as the numerical calculation example, result shown below:

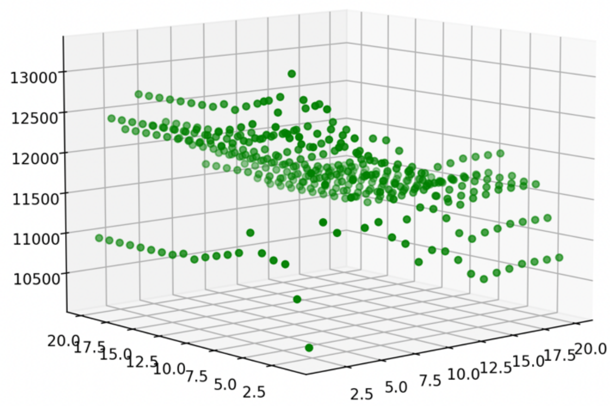

Figure 3 Numerical optimization result for maximum-number-threshold method

Shown in the result, the threshold generates the highest annual return rate when we set $MAX_{Long} = 4$ and $MAX_{Short} = 6$, holding 4 long positions and 6 short positions every year (but the aggregate notional of the shorts and longs is still equal). The optimized return is USD13,214, and the annualized return rate is 1.76%.

4 Discussion of the result

In this portfolio, using either method, we can find a consistently profitable strategy. Moreover, in either Figure 2 or Figure 3, our return is positive in most cases, which proves that using the spot rate and forward rate as the prediction is biased, currency cross rates systematically depreciate less than is forecasted by the forward rates.

Uncovered interest rate parity (UIP) posits that our gain from carry trade would finally be offset, usually by opposite evolution of the exchange rate. However, our case, according to the research (Brunnermeier M. K. et al., 2008), is known as the “forward premium puzzle”, which violates UIP and profit us constantly by utilizing the forward rate as a strong predictor to gain. The only possible explanation to this puzzle is via the empirical data analysis, Matthew’s team in 2017 has revealed that the relationship hypothesized by the UIP doesn’t exist, at least in the past two decades.

Therefore, we cannot find a solid explanation for how to end up getting the net gain of zero in the FX market. Based on the portfolio constructed, we can confidently confirm that EMH is not applicable to the 16-year annual-return-based FX market, which spectators can find the strategy that profit them constantly.

5 Risk evaluation for the optimized strategy

After finding the investment strategy with the optimized return, we need to evaluate the risk of the portfolio by using the Sharpe Ratio, which measures the added returns investors get for taking on added risk (Vincent, 2022).

Sharpe Ratio is composed of three key indicators of the portfolio: annualized return rate of portfolio, risk-free rate of portfolio return, and the standard deviation of portfolio return (volatility).

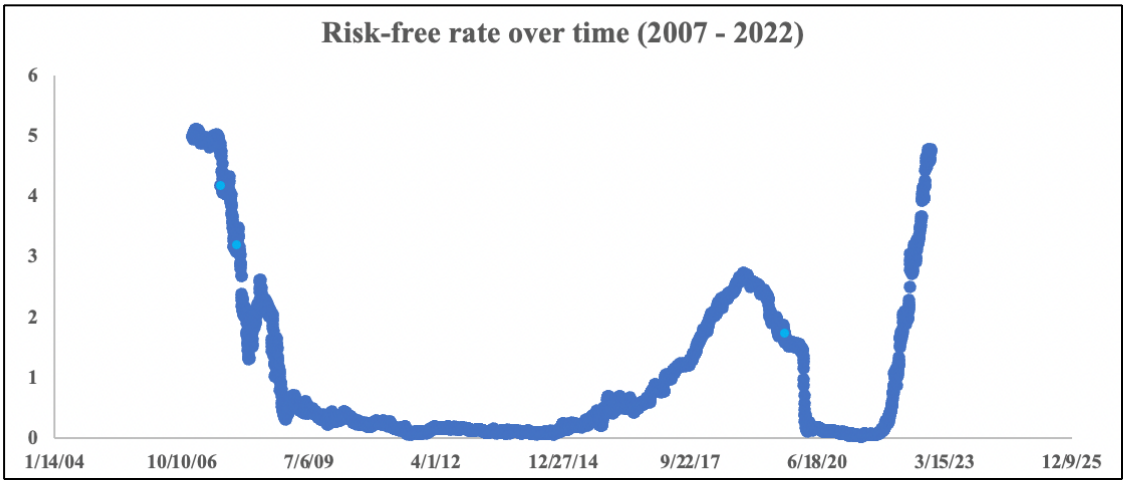

Figure 4 Risk-free rate of portfolio from 2007 to 2022

The risk-free rate of return is the theoretical rate of return of an investment with zero risk (Adam H., 2022). In this portfolio, we are given the daily risk-free rate from 2007 to 2020, and by averaging it over time, we get the risk-free rate of 1.0719%.

For the volatility, we are first to calculate the standard deviation of portfolio by year (using the daily spot rate through a recursive calculation method) and then average all the standard deviations to find the volatility for the entire portfolio. Specifically, for the yearly standard deviation, since arbitrageurs may hold different numbers of currency on short position and long position, we need to weigh each currency in order to make the overall weight on short position and long position to be 1 (0.5 for each):

$$For\ Year\ from\ 2007\ to\ 2022:$$

$$Weight_{Long} = \frac{0.5}{Number\ of\ Currency\ in\ Long\ Position}$$

$$Weight_{Short} = \frac{0.5}{Number\ of\ Currency\ in\ Short\ Position}$$

$$Pre_{Long} = Weight_{Long} * (1 + Spot\ Rate\ of\ Currency_i)$$

$$Pre_{Short} = Weight_{Short} * (1 - Spot\ Rate\ of\ Currency_i)$$

$$For\ Currency_i\ in\ Long\ Position:$$

$$Culmulative\ Change_{i-l} = Pre_{Long} * (1 + Spot\ Rate\ of\ Currency_i)$$

$$Pre_{Long} = Pre_{Long} * (1 + Spot\ Rate\ of\ Currency_i)$$

$$For\ Currency_i\ in\ Short\ Position:$$

$$Culmulative\ Change_{i-s} = Pre_{Short} * (1 - Spot\ Rate\ of\ Currency_i)$$

$$Pre_{Short} = Pre_{Short} * (1 - Spot\ Rate\ of\ Currency_i)$$

$$Culmulative\ Change_i = \sum Culmulative\ Change_{i-s\ and\ i-l}$$

$$Standard\ Deviation = STDEV(Culmulative\ Change_i)$$

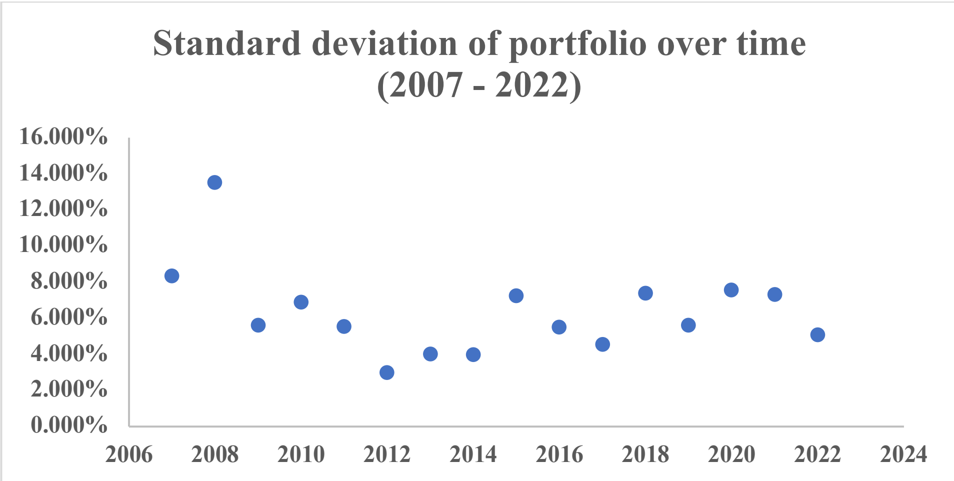

Figure 5 Standard deviation of portfolio from 2007 to 2022

From Figure 5, we get the volatility of portfolio to be 4.971% by averaging all the yearly standard deviation. Therefore, we can calculate the Sharpe Ratio for our portfolio using the results below:

$$Sharpe\ Ratio = \frac{Annualized\ Return - Risk\ free\ rate}{Volatility} = \frac{1.76\% - 1.07\%}{4.971\%} = 0.14$$

A Sharpe Ratio of 1 means that the added value is the same as the added risk for our investment. However, the Sharpe Ratio for this portfolio is very small, which means the added value is much lower than the added risk from each investment. This implies that our optimized strategy is highly risky, with a limit incremental profit as the risk increases.

6 Conclusion

This paper explores the applicability of EMH in the FX exchange market for two portfolios with different return bases and at different periods. Different from conventional literacy and empirical analysis, this paper chooses to use real numerical examples to quantitatively analyze the problem. The result is that arbitrageurs can either find a profitable strategy to hold their positions on different currencies and theoretically, arbitrageurs can achieve the net gain of their investment in the end.

Different from what EMH states, in which the forward rate is unbiasedly presenting the available information, this paper finds that for the currencies we used in the portfolio, the forward rate is strongly biased, and arbitrageurs can infer their optimized position based on the forward rate.

Still, these conclusions can only be drawn based on the period in the portfolio. We definitely cannot extend them to say that EMH does not apply to the FX market in all periods. Currencies have many puzzling natures, one of which is that dramatic exchange rate movements occasionally happen without fundamental news announcements, for example, the large depreciation of the U.S. dollar against the Japanese yen on October 7 and 8, 1998 (Abreu D., M. K., 2003). These sudden changes in the exchange rate may offset our previous gain and lead back to the situation of a net gain of zero. Therefore, one of the shortcomings of this study is the limitation in processing a great amount of data. With a more comprehensive analysis of the previous spot rate and forward rate, the conclusion can be drawn to a broader extent.

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