**Understanding the Dynamics of Exchange Rates: Interest Rates, Inflation, and Volatility**

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**Abstract:**

The Foreign Exchange (Forex) market is extremely important in today’s increasingly globalized economy. It plays a crucial role in international trade and investment, as it is where foreign currencies are exchanged and traded. The Forex market is the largest financial market in the world with trillions of dollars exchanged daily (average daily trading volume was $6.6 million across all OTC FX instruments and $1.99 trillion for the global spot FX market in April 2019).[[1]](#footnote-1) This project investigates the relationship between exchange rate movements, and interest rate and inflation differentials while focusing on the USD/JPY and USD/EUR currency pairs. Using statistical analysis, we look at the impact of these factors on the change in exchange rate. This project employs both standard and robust regression techniques to try and improve the overall accuracy, significance of the results, and explanatory power of our model.

**1. Introduction**

The Forex market is more crucial now than it has ever been before. It helps facilitate international trade by allowing businesses to convert one currency to another. This is fundamental in the globalized world that we live in because so many companies must engage in international trade to stay competitive. The United States plays a massive role in this as the world’s largest economy, and the U.S. dollar is also the most held reserve currency in the world.[[2]](#footnote-2) For perspective, the U.S. exported $80,180 million of goods to Japan in 2022 and imported $148,064 million from them. The U.S. dollar usually in high demand as well because it is the most used currency in international trade. This paper focuses on trying to better understand the relationship between exchange rates, inflation differentials, and interest rate differentials. Theories of exchange rate determination have long been a topic of interest and debate for economists and financial analysts. One thing that most economists and theorists agree on is that inflation and interest rate differentials largely impact exchange rates. Two of the more popular theories around exchange rate determination are relative Purchasing Power Parity (relative PPP) and Uncovered Interest Rate Parity (UIP). These theories suggest that exchange rates should adjust to inflation and interest rate differentials over time, respectively. Relative PPP suggests that exchange rates and inflation rates should be equal over time, stating that exchange rates are expected to adjust to inflation rate differentials so that PPP holds true. UIP is one form of Interest Rate Parity (IRP) that is used to show the relationship between exchange rates and interest rates. It states that the difference in interest rates between two countries is expected to equal the change in exchange rates over the same period. The motivation for this study comes from wanting to have a better understanding of exchange rates and the economic factors that impact their change. Having a sound understanding of what effects exchange rates can help a company engaging in international trade minimize costs and risk, while maximizing profits. For the study, we looked at two pairs of currencies: USD/JPY and USD/EUR. We then did a linear regression (OLS) with the change in exchange rates (one regression for each of the currency pairs) as the dependent variable (y) and change in interest rate and inflation differentials as the independent variables (X1 and X2). Our goal was to model (explanatory) the relationship between exchange rates and our variables of interest. We then looked at improving the model by adding other variables and using outlier removal techniques to trim our data. The goal of this project was to gain more knowledge about the complex dynamics of exchange rates and the main variables that affect them, specifically inflation and interest rate differentials. We expect that interest rate differentials will be significant, but we don’t expect inflation differentials or the model to be statistically significant.

**2. Hypotheses**

The hypotheses for our project stem from the question of whether certain economic indicators can explain the changes in exchange rates. We feel that this is an important place to start, and it sets us up to take our research a step further and see if certain economic factors can help predict changes in exchange rates. Both the Efficient Market Hypothesis (EMH) and the Random Walk Theory suggest that is extremely difficult and unlikely to accurately predict future changes in exchange rates.[[3]](#footnote-3) Despite the rationale behind these two theories, we believe it is within reason to believe that some macroeconomic indicators can help accurately forecast exchange rates to some extent. We also believe that certain indicators will hold a large amount of explanatory power, though we are not sure how this will translate to predictive capabilities. Again, the focus of our research is around studying these contemporaneous variables and coming up with an explanatory model. We believe that the coefficients for interest rate differentials will be statistically significant in our explanatory model. We believe that they will be significant because of Uncovered Interest Rate Parity (UIP), meaning that an increase in Japan or the Euro Area interest rate (relative to the U.S. rate) should lead to an appreciation of each currency against the USD (USD/JPY and USD/EUR). We are not sure what to expect for the change in the Nikkei Volatility Index (JNIV), though we are leaning towards it not being significant. The last hypothesis we have is that dealing with outliers and robustness will not improve the significance of our models.

**3. Data and Methods**

The data for this project was collected from various sources across the internet, and all of it is in monthly intervals. We cleaned and processed the data, eventually combining everything into one data set, so that we could do statistical analysis on it. We made sure to check the data to ensure its integrity before doing any analysis. We gathered data on the price of the Yen (USD/JPY) and the Euro (USD/EUR) from the CRSP database. The data on the Yen and Euro go back to1984 and 1999, respectively. However, the Euro wasn’t publicly available until 2002, as it was only used for accounting purposes for the first three years. [[4]](#footnote-4) The inflation data we gathered for Japan and the Euro Area goes back to 1980 and 2000. The inflation data variable is the Consumer Price Index (CPI) level for the U.S. and Japan. The Euro Area uses a metric called Harmonized Index of Consumer Prices (HCIP). One thing to note about HCIP is that it differs from CPI, and therefore can pose some problems when using it to compare variables and do analysis. A paper that talks about this is titled “Comparing U.S. and European inflation: the CPI and the HICP” and it discusses this topic in depth. They come with an experimental CPI that is built in a similar manner to HICP and tracks the index much better than normal CPI.[[5]](#footnote-5) We came across this paper towards the end of our research, though we thought it was important to mention that. The interest rate variable data is the 10Year bond yield for the U.S., Japan, and the Euro Area (USD, JPY, EUR), and the data goes back to 1980, 1980, and 1989, respectively. Both inflation and interest rate data are from the FRED (Federal Reserve Economic Data) database. After data the data was collected, we processed and cleaned it so that it would be ready for statistical analysis. The processing and cleaning included merging the datasets together, converting dates to a consistent format, and then calculating the interest rate and inflation differentials for both currency pairs. For Japan, we take the Japan 10Y yield and subtract it from the U.S. 10Y yield. Then we took the CPI level for Japan and subtracted the U.S. CPI level from it, and we did the same steps for the Euro Area. We then calculated the change of the differentials, saving them in the data frame to use in our analysis. The last thing we calculated was the change in JNIV, and we used the percent change for it (decimal format i.e., 0.73 in our data represents 73%). At this time, we ran a regression on the two currency pairs with the following equations:

**JPY/USD Exchange Rate Δt =**

**β0 + β1 × Inflation Diff Δ JPYt+ β2 × Interest Rate Diff Δ JPYt+ β3 × JNIV Δt +ϵt**

**EUR/USD Exchange Rate Δt =**

**β0 + β1 × Inflation Differential Δ EURt + β2 × Interest Rate Differential Δ EURt + ϵt**

Here is the summary output of those two regressions:

**Figure 4.1**

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**Figure 4.2**

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After running these regressions, we cleaned the data once again to take care of outliers. We did this first with the IQR method (IQR = Q3 – Q1, [Q1 – 1.5IQR, Q3 + 1.5IQR]). We then ran the same regressions on the updated data. We used the same variables as the equation before, but with the trimmed values for the variables of interest. Here are the results of those regressions:

**Figure 4.3**

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**Figure 4.4**

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We also want to note that we fit our models using a robust covariance matrix (cov\_type=’HC3’) since we had issues with heteroskedasticity in our data.[[6]](#footnote-6)

**4. Results**

**4.1**

R2 of 0.124, meaning 12.4% of the variation in the model is accounted for, and an adjusted R2 of 0.112. F-statistic of 6.898 and an F-stat probability of 0.000183, suggesting significance of the model. “Interest\_Rate\_diff\_change\_JPY” was the only significant variable with a coefficient of negative 0.0493 (-0.0493). The high Omnibus value indicates that the residuals may not be normally distributed.

**4.2**

R2 of 0.033, meaning 3.3% of the variation in the model is accounted for, and an adjusted R2 of 0.024. F-statistic of 2.892 and an F-stat probability of 0.0575, suggesting that the model is very close to being statistically significant. “Interest\_Rate\_diff\_change\_EUR” and “Inflation\_diff\_change\_EUR” were significant with a coefficient of negative 0.0238 (-0.0238) and positive 0.0058 (0.0058). The high Omnibus value indicates that the residuals are likely not normally distributed.

**4.3**

R2 of 0.101, meaning 10.1% of the variation in the model is explained, and an adjusted R2 of 0.087. F-statistic of 5.642 and an F-stat probability of 0.087, suggesting that the model is not statistically significant, though it is close. “Interest\_Rate\_Diff\_JPY\_trimmed”, representing the interest rate differential change in the trimmed data, was the only significant variable with a coefficient of negative 0.0578 (-0.0578). The high Omnibus value of 10.394 indicates that the residuals are likely not normally distributed.

**4.4**

R2 of 0.016, meaning 1.6% of the variation in the model is explained, and an adjusted R2 of 0.006. F-statistic of 1.422 and an F-stat probability of 0.244, suggesting that the model is not statistically significant. None of the variables were significant, and the high Omnibus value of 5.734 indicates that the residuals are likely not normally distributed.

**5. Conclusion and Discussion**

Our study aimed to look at the explanatory power of some important economic factors that theories of exchange rate determination have largely been built around. Though we got significant and close to significant models in 4.1 and 4.2, the R2 values show that the model accounts for very little of the variation in the change in exchange rates. Though these models provide some valuable information about the relationships between interest rates, inflation, and exchange rates, our models do not suggest that there is a likely way to forecast changes in exchange rates using interest rate and inflation differentials alone. The lack of variation explained in our models suggests that though our variables of interest are important to exchange rates, there are likely many more factors influencing them. Further research into potential macroeconomic variables that could influence exchange rates is a good place for us to continue our research. This would then allow us to explore more complex models with greater explanatory power, which would hopefully allow us to start research on a predictive model for changes in exchange rates.

**6. Back Matter**

**6.1 Bibliography**

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**6.2 Figures:**

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A graph showing the growth of the stock market

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