Using Search Index to Predict the Volatility of Exchange Rate Based on HAR Model

Zhao Wang[1,*]

[1]*Irvine Valley College, Irvine California, US*
[*]*Corresponding author. Email: zwang84@ivc.edu*

ABSTRACT

The exchange rate is crucial to global financial markets. However, the existing literature rarely considers the impacts of the search index effects on the volatility of the exchange rate. With the gradual improvement of the realized volatility theory, researchers have found that the realized volatility has the characteristics of sharp peaks, thick tails, right-side deviation, and long memory, indicating that the Efficient Market Hypothesis is invalid. Based on Heterogeneous Autoregressive (HAR) theory, the new type HAR models are established by incorporating a search index to forecast the volatility. The new model's predicting efficiency is better than the original one. Then, the RMB to U.S. dollar exchange rate (ERMB) and RMB exchange rate (RMB) has no impact on daily volatility. But the USD has a negative impact on daily realized volatility. In the weekly and monthly model, the search indexes all perform significantly to the volatility. This research would help the investor to identify more impacts factor to the exchange rate market.

Keywords: Exchange rate, HAR, Search index, Volatility

1. INTRODUCTION

Exchange rates are the main indicator influencing the pricing of goods and services, as well as the volume of international trade and capital movement between countries. [1]The economic performance of a country depends on the level of international trade. Foreign economic theories hold that trade openness is beneficial for economic growth. The development of international trade promotes capital formation and accelerates technical progress that in turn enhances factor productivity [2].

A consideration of the empirical studies has shown the effect of the fluctuation of exchange rates on exports, trade, investment, capital market, inflation, and employment growth—in developing and developed countries[3]. The exchange rate is a key macroeconomic factor that affects international trade and the real economy of each country. The Effect of Exchange Rate Volatility on Economic Growth: Case of the CEE Countries Fatbardha Morina [4] Theoretical literature on exchange rate volatility nexus economic growth is still a big debate among economists. The study by Obstfeld and Rogoff [5]. Many financial firms, such as New York Stock Exchange, Shanghai Stock Exchange, Toronto Stock Exchange, publish annual exchange rate reports that analyze the investment opportunities of the exchange rate. The transaction cost of international trade has become more expensive and reduces the gains of investors as it constrains their decisions to develop their activity. The economists believed that floating rates may be harmful to the economy because every country uses the currency as an intermediate to purchase products and services in international trade. When the exchange rate becomes volatile, they are faced with uncertainty regarding the agreement with other countries [6]. The volatility is generally perceived as negatively affecting international trade. While theoretical predictions and empirical outcomes appear mix [7]. A series of studies claimed that exchange rate volatility leads to a contraction in international trade.[8] while other studies argued that exchange rate volatility leads to an expansion in international trade [9].

Furthermore, a small number of studies observed that exchange rate volatility had either a very slight effect on international trade or no statistically significant effect at all [10-11]

This research uses empirical data to examine the different effects of volatility and the impact of search indexes on different volatility. We select the thirty-

minute high-frequency data of the Shanghai Stock Exchange from January 1, 2020, to April 10, 2020. The RMB exchange rate (RMB), RMB to U.S. dollar exchange rate (ERMB), and U.S. dollar to RMB exchange rate in the Baidu Index during the same period (USD) and other search indexes are used as research objects to establish the HAR-RV model and HAR-RV-ERU model. The results of the HAR-RV model show that the daily volatility, weekly volatility, and monthly volatility in the 1-day, 1-week, and 1-month volatility forecasts include market forecast information; in the daily model, the daily volatility is The forecast of the next day has a negative impact, and the daily volatility also harms the weekly volatility, but the impact is small compared with the daily model; in the weekly model, the monthly volatility has a positive impact on the weekly volatility, reaching 0.0435; The influence of weekly volatility on future monthly volatility is 0.028. The estimation results of the HAR-RV-ERU model are similar to those of the HAR-RV model. Most of the coefficients of daily, weekly and monthly volatility are positive and significant; different search indexes can also predict the exchange rate market, in which foreign exchange reserves and The renminbi has no effect on daily volatility; but the US dollar has a negative impact on the daily realized volatility; for the weekly model and the monthly model, the three search indexes have a significant impact on the volatility, and foreign exchange reserves have a negative impact on predicting future volatility Impact, and the RMB has a positive impact.

The remainder of the paper is organized as follows. Section 2 introduces the data description. Section 3 presents the economic model. Section 4 investigates the detailed results of the HAR model and search index. Finally, the results are shown in the conclusion part.

2. DATA

In financial markets, the sampling frequency has a significant impact on volatility prediction. Microscopic noise will result if the sampling frequency is set too high. If it is too low, it will not provide all of the daily volatility statistics. According to the 30-minute sampling frequency, the high-frequency data are selected to be demonstrated and to be the most accurate. Therefore, following the relevant researches from Chinese scholars [11]. To calculate the exchange rate's price volatility, 30-minute-frequency trading data are used.

The sample consists of data from Shanghai Stock Exchange. The sample period starts from January 1, 2020 and ends on April 10, 2020, many items of data on. After calculating the RV and eliminating the vacancy value, the data of 100 trading days are extracted from January 1, 2020, to April 1, 2020. The search index such as the RMB exchange rate, the exchange rate of the

RMB versus the US dollar, and the USD to RMB exchange rate are also collected from January 2020 to April 2020 from the Baidu index. Some figures are presented to describe the trend.

Fig. 1 shows that the trend of volatility. Since January 1st in 2020, RVD fluctuations have been relatively small and have remained at a low level. The RVD fluctuated sharply from March 3 to April 4 in 2020, the volatility of March 3, 2020 owes the highest volatility in the whole period. Besides, In April 2020, the exchange rate volatility stabilized gradually.

From Fig. 2, the index of the USD to RMB exchange rate differs significantly over time, in some periods. It has been shown that the RMB exchange rate has the highest index among the other two indexes, such as the exchange rate of the RMB versus the US dollar, and the USD to the RMB exchange rate. On March 21, 2020, it reached 25000 points in the observation period. Besides, the exchange rate of the RMB versus the US dollar is the lowest. Also, these three indexes have the same trend performance from January 2020 to April 2020.
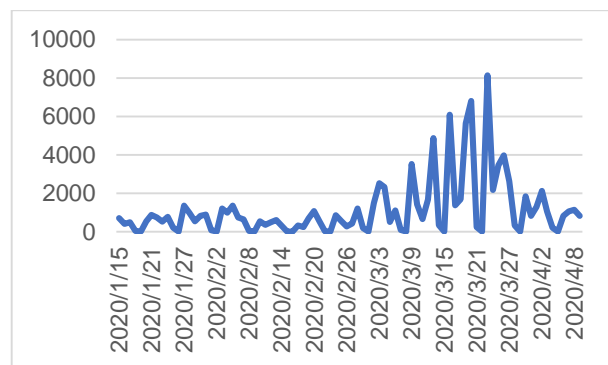

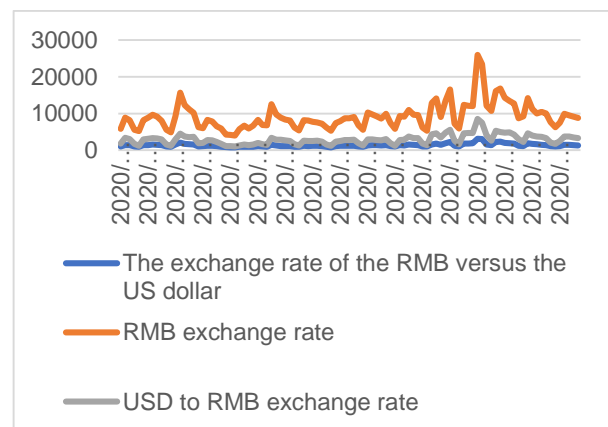**Figure 1**. The volatility of exchange rate

Figure 2. The different performance of three related indexes

3. METHOD

In recent years, with the rapid development of technology and the Internet, the cost of recording and storing high-frequency data has been effectively reduced. Therefore, the measurement based on the

volatility of high-frequency data has once again attracted broad attention in academia. With the gradual improvement of the realized volatility theory, researchers have found that the realized volatility has the characteristics of sharp peaks, thick tails, right-side deviation, and long memory, indicating that the Efficient Market Hypothesis is invalid.

The HAR-RV model is proposed based on the Market Heterogeneity Hypothesis, which mainly describes the different aspects of the impact of different market participants on the financial market. For example, according to the asymmetry of information, traders in the market can be divided into noise traders, positive feedback traders, and informed traders. The statement is precise. These three types of traders respond to the same information differently from the predictions. The stock price fluctuates within the fundamentals. If the number of heterogeneous traders increases, the difference in the response of different traders to information will also increase, leading to an increase in price volatility. This research considers the HAR-RV model to investigate the impact of the search index on the exchange rate volatility. Following the method of Li et al., [12], the basic models are established as follows.

The return of exchange rate is presented as follows

$$R_{t,exchange} = ln\frac{P_t}{P_{t-1}} \quad (1)$$

Where, P_t is the exchange rate of time t, P_{t-1} is the exchange rate of time t-1. $R_{t,exchange}$ is the return of exchange rate among time t-1 to time t.

Then the volatility is introduced as follows.

$$V_{t,exchange} = R_{t,exchange}^2 \quad (2)$$

Where $V_{t,exchange}$ means the volatility among time t-1 to time t.

Thus, the daily volatility, RV_t^d satisfies the following.

$$RV_t^d = \sum_{t=1}^{M} V_{t,exchange} \quad (3)$$

According to the HAR-RV model theory, the weekly volatility and the monthly volatility are required to be calculated.

$$RV_t^w = \frac{RV_t^d + RV_{t-1}^d + RV_{t-2}^d + RV_{t-3}^d + RV_{t-4}^d}{5} \quad (4)$$

$$RV_t^m = \frac{RV_t^d + RV_{t-1}^d + \cdots + RV_{t-20}^d + RV_{t-21}^d}{22} \quad (5)$$

Therefore, daily, weekly, and monthly realized volatilities are used to represent the time scales of three different stages of short-term, medium-term, and long-

term, and the HAR-RV model is as follows. H could be a substitute to daily, weekly, or monthly.

$$RV_{t+1}^H = \beta_0 + \beta_1 RV_t^d + \beta_2 RV_t^w + \beta_3 RV_t^m \quad (6)$$

The different impact of the search index is also considered. For instance, the RMB exchange rate (RMB), the exchange rate of the RMB versus the US dollar (ERMB), and USD to RMB exchange rate (USD). Then the HAR-RV-ERU model is established. It is as follows.

$$RV_{t+1}^H = \beta_0 + \beta_1 RV_t^d + \beta_2 RV_t^w + \beta_3 RV_t^m + \beta_4 ERMB + \beta_5 RMB + \beta_6 USD \quad (7)$$

The empirical data are considered to investigate the different impacts of volatility and the search index's impact on different volatility. It is important to study the finance problem using the above model [13].

4. IN-SAMPLE ANALYSIS

This section describes the data collected and gives regression results based on the above analysis. The results of the basic HAR-RV model and the new model, the HAR-RV-ERU model are summarized.

4.1. Summary Statistics

According to the following descriptive statistical analysis (Table 1) of the main variables, the volatility of the exchange rate of the RMB versus the US dollar futures' prices ranges from 752.00 to 3157.00, with a wide range and intense volatility. As for the price volatility of the RMB exchange rate, the range exceeds 26001.00, whereas, for the price volatility of USD to the RMB exchange rate, the range is relatively small, at approximately 8455. The results support the notion that the volatility of the exchange rate of the RMB versus the US dollar futures market fluctuates more dramatically than do the USD to RMB exchange rate and RMB exchange rate prices. The mean and variance of the exchange rate of the RMB versus the US dollar price volatility are much larger than is USD to RMB exchange rate volatility, indicating that the average daily RV of The exchange rate of the RMB versus the US dollar is much higher than is that of USD to the RMB exchange rate. Additionally, the difference in daily the exchange rate of the RMB versus the US dollar volatility is far greater than is that of USD to the RMB exchange rate. Moreover, the mean and variance of RMB exchange rate volatility are slightly larger than are those of the exchange rate of the RMB versus the US dollar, and the difference between average volatility and daily RV is greater than is that of The exchange rate of the RMB versus the US dollar.

Table 1. statistical description of variables

Variable	Mean	Std.dev.	Min	Max
RV_t^d	1138.508	1554.481	0	8140.466
RV_t^w	1132.512	932.9435	283.679	3776.877
RV_t^m	1165.005	667.4864	450.926	2181.586
The exchange rate of the RMB versus the US dollar	1359.594	418.903**	752	3157
RMB exchange rate	9167.307	3577.772	3965	26001
USD to RMB exchange rate	2921.782	1314.842	1065	8544

4.2. *Regression Results*

According to the results (Table 2), for the HAR-RV model, it has been shown that in 1-day, 1-week, and 1-month volatility forecasting, the daily, weekly, and monthly volatility are all contain the market forecasting information. For the daily model, RV_t^d has a negative impact on the future day's forecasting. The weekly model present that RV_t^m has a positive impact on weekly volatility and it reaches 0.0435. The daily volatility also has a negative impact on weekly volatility but its impact is smaller compared to the daily model. The weekly volatility has a 0.028's impact on the future's monthly volatility. The results reveal that the medium-term (weekly) and long-term (monthly) volatility of the exchange rate market contain a large amount of forecasting information on the RV, but only short-term (daily) volatility can forecast the 1-week exchange rate market.

The estimation results of the HAR-RV-ERU model show that most coefficients of daily, weekly, and monthly volatility are significant and positive, which is similar to the findings of the HAR-RV model. Then, the coefficients of the different search indexes are examined. It shows that the ERMB and RMB have no impact on daily volatility. But the USD hurts daily realized volatility. For the weekly model and monthly model, the three search indexes all perform significantly to the volatility. The ERMB has a negative impact on forecasting the future's volatility, and the RMB has a positive impact. Thus, the search index could also be considered as a factor to forecast the exchange rate market.

Table 2. Regression Analysis

	1-day	1-week	1-month	1-day	1-week	1-month
β_0	-26.55754	9.760859	25.9901	-1334.346***	-78.14307***	41.98933
	-0.1	0.23	1.38	-1.61	-0.61	0.75
RV_t^d	-0.1880669*	-0.0086425***	-0.0093728***	-0.2511785***	-0.0319227***	-0.002133***
	-1.69	-0.51	-1.25	-1.72	-1.43	-0.22
RV_t^w	1.164878	0.9597161	0.0284911**	0.9702045	0.9498305	0.0226953**
	4.17	22.56	1.51	3.29	20.96	1.14
RV_t^m	0.0465237	0.0435061**	0.964145	0.1843853	0.0294046**	0.9863816
	0.13	0.81	40.18	0.48	0.5	37.85
ERMB				2.0333	-0.0073395***	-0.0683881***
				1.11	-0.03	-0.55
RMB				0.1252242	0.012105**	0.0200889**
				0.67	0.42	1.58
USD				-0.8468037***	0.0131148**	-0.0465697***
				-1.72	0.17	-1.4

Note: t statistics in parentheses.*   *p<0.1,**p<0.05,***p<0.01

5. CONCLUSION

The exchange rate market is crucial to investors. The scale and daily trading volume of the global foreign exchange market make the foreign exchange market the largest financial market. In 2019, the daily trading volume reached 6.6 trillion US dollars. The scale of the foreign exchange market is three times that of the derivatives market and 35 times that of the stock market. The currencies of more than 170 countries around the world are traded in the foreign exchange market, and the US dollar has the largest trading volume, accounting for more than 73%. The euro is second, accounting for 39.7%. The yen is third, accounting for 25.7%. The British pound (20.7%), Australian dollar (11.48%), Canadian dollar (8%), Swiss franc (7%), New Zealand dollar (5.7%). It is important to research the exchange rate's volatility. This article investigates the impacts of search index on exchange rate volatility forecasting.

Based on the Heterogeneous Autoregressive (HAR) theory, this article uses thirty-minute high-frequency data to predict exchange rate volatility by combining structural mutations and weekday effects and establishes six new Heterogeneous Autoregressive (HAR) models. The empirical results show that the prediction accuracy of the new model is better than that of the original HAR model, and the structural mutation and weekday effect contain a lot of exchange rate forecast information. In addition, structural mutations have a positive impact on exchange rate fluctuations; the weekday effect has a significant negative impact on the price fluctuations of exchange rate futures, especially in medium- and long-term forecasts.

The limitation of this paper includes the following. Firstly, the data used is not such large. It may lead to little difference in forecasting results. Secondly, this research did not consider more complicated models to conduct sample predicting. In the future, the influences of structural break and leverage effect on exchange rate forecasting could be investigated. And the sample forecasting could also be considered in the future.

REFERENCES

[1]Morina, F., Hysa, E., Ergn, U., Panait, M., & Voica, M. C. (2020). The Effect of Exchange Rate Volatility on Economic Growth: Case of the CEE Countries. Journal of Risk and Financial Management, 13(8), 177

[2]Romer, P. M. (1986). Increasing returns and long-run growth. Journal of political economy, 94(5), 1002-1037.

[3]Schnabl, G. (2008). Exchange rate volatility and growth in small open economies at the EMU periphery. Economic Systems, 32(1), 70-91.

[4] Morina, F., Hysa, E., Ergn, U., Panait, M., & Voica, M. C. (2020). The Effect of Exchange Rate

Volatility on Economic Growth: Case of the CEE Countries. Journal of Risk and Financial Management, 13(8), 177

[5]Obstfeld, M., & Rogoff, K. (1998). Risk and exchange rates (No. w6694). National bureau of economic research.

[6]Morina, F., Hysa, E., Erg 眉 n, U., Panait, M., & Voica, M. C. (2020). The Effect of Exchange Rate Volatility on Economic Growth: Case of the CEE Countries. Journal of Risk and Financial Management, 13(8), 177.

[7]Senadza, B., & Diaba, D. D. (2017). Effect of exchange rate volatility on trade in Sub-Saharan Africa. Journal of African Trade, 4(1-2), 20-36.

[8]Arize, A. C., Osang, T., & Slottje, D. J. (2000). Exchange-rate volatility and foreign trade: evidence from thirteen LDC's. Journal of Business & Economic Statistics, 18(1), 10-17.

[9]Kasman, A., & Kasman, S. (2005). Exchange rate uncertainty in Turkey and its impact on export volume.

[10]Haile, M. G., & Pugh, G. (2013). Does exchange rate volatility discourage international trade? A meta-regression analysis. The Journal of International Trade & Economic Development, 22(3), 321-350.

[11]Wen, F., Gong, X., & Cai, S. (2016). Forecasting the volatility of crude oil futures using HAR-type models with structural breaks. Energy Economics, 59, 400-413.

[12]Li, W., Cheng, Y., & Fang, Q. (2020). Forecast on silver futures linked with structural breaks and day-of-the-week effect. The North American Journal of Economics and Finance, 53, 101192.

[13]Cheng, Y., Wu, D. D., Olson, D. L., & Dolgui, A. (2020). Financing the newsvendor with preferential credit: bank vs. manufacturer. International Journal of Production Research, 1-20.