

An Empirical Study on the Day-of-the-Week Effect of China's Iron Ore Futures Based on the HAR-RV Model

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Abstract. Iron ore future has an extreme influence on global financial markets. Thus, we are supposed to consider the day-of-the-week effect, which is important to the volatility of iron ore future price, although less existing literature considers it. The day-of-the-week effect is added to the basic heterogeneous autoregressive (HAR) model so that a new type of heterogeneous autoregressive (HAR) model is established. The empirical results show that the new model has higher accuracy in forecasting the volatility of iron ore future price and the day-of-the-week effect contains much forecasting information. Moreover, the day-of-the-week effect has a positive influence on iron ore futures' price volatility, and the influence is more significant in the short and medium-term. This paper considers the day-of-the-week effect and uses an improved HAR model to predict the volatility of iron ore future.

Keywords: component; Volatility forecasting, HAR-type models, Iron ore futures market, Structural breaks, Day-of-the-week effect.

1. Introduction

As Iron ore is the fundamental steel production resource, predicting its price is strategically important for risk management at related enterprises and project [1]. Besides, iron ore was subsequently opened to investors outside mainland China as part of the government's larger plan to internationalize its commodity futures markets. By the end of 2021, foreign investors will likely have access to more than ten commodity futures products [2].

With regard to the strategic status of iron ore in international economics, it is universally acknowledged that iron ore is at a crucial state mainly due to its characteristics. Anticipating long-term trends in the steel cycle is hence of great importance both for investment decisions and the transition to sustainable metal use [3]. Meanwhile, in the field of industry, manufacturing and daily life, iron can be used as catalysts, pharmaceuticals, pesticides and nutritional supplements, which all indicates the importance of iron ore. Considering the status of iron ore in China, it has the largest import volume, the import amount is only crude to crude oil, which has an important impact on my country's national economic development. Compared with crude oil, iron ore is less impacted by geopolitical factors, and most countries stress less political sensitivity to iron ore than crude oil, which contribute to its expansive market. Due to the characteristic financial properties of iron ore, it is widely adopted to control risk and optimize asset allocation. In recent years, affected by the increasing labor costs, political conditions and supply-side structural reform, China's iron ore prices have been fluctuating, partly resulting in the severe and frequent price fluctuations influencing company profits and investment plans, especially in the downstream enterprises associated with metallurgy, construction, and automotive manufacturing. As an important kind of safe-haven asset, the price of iron ore is also affected by seasonal factors, influencing the available import quantity.

The price of iron ore operates as a crucial signal of the market because it can not only reflect the circumstances of the global political and economic, environment but demonstrates investors' sentiments as well. In fact, domestic and foreign researchers have already discovered that the day-of-the-week effect demonstrated different modes, which plays a crucial role in aggrandizing the earning of the portfolio. In the previous period of the US stock market, negative effect on Mondays and positive effect on Fridays have been studied [4]. In this day and age, an increasing number of researchers continue to conduct researches into the day-of-the-week effect. A lot of literature researches have shown that the day-of-the-week effect exists in most of the developed markets and the new industrial markets. The presence of calendar anomalies has been documented extensively for the last two decades in financial markets. The findings show that the day of the week effect is present in both volatility and return equations [5]. Under this circumstance, the day-of-the-week effect is one of the market anomalies that tend to show more performance and may give the possibility for investors to make extra stock returns [6]. Therefore, it is of great significance to put the day-of-the-week effect, which is demonstrated in the paper, into consideration when managing portfolios in the stock market in order to maximize the returns.

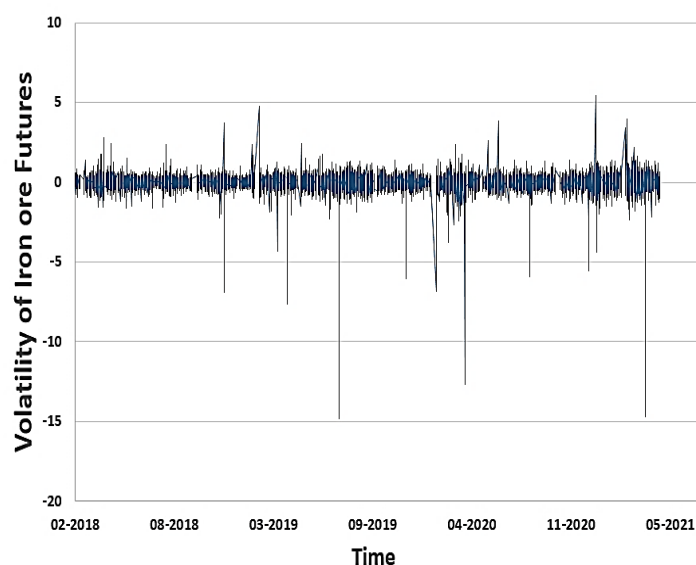


Fig. 1 Five minutes high-frequency price dynamics of iron ore futures.

This research uses two HAR models to predict the iron ore futures market and use 5-minute high-frequency data from the iron ore futures market to improve the accuracy of the iron ore futures market. We considered the impact of the day-of-the-week effect and proposed the HAR-RV-W model with historical transaction prices and the day-of-the-week effect to predict the price fluctuations of iron ore futures. Compared with the HAR-RV model, the prediction accuracy of this model has been improved and contains much forecasting information, and the influence caused by the day-of-the-week effect is positive for iron ore futures' price volatility, which is more significant in the short and medium-term.

The rest of this article is arranged to serve: section 2 describes the sample and data; section 3 introduces the HAR-RV model and its extended model; section 4 analyzes the sample regression results; the last section summarizes and gives our conclusion

2. Data.

In the financial market, the sampling frequency has an important influence on volatility prediction. However, if the sampling frequency is too high or too low, it will cause microscopic noise or will not contain all the information which is about daily volatility. Accordingly, the accuracy of 5-minute sampling frequency is the highest so that 5-minute-frequency trading data is selected to measure the

price volatility of the iron ore futures. The sample only includes China iron ore futures. The sampling period starts on January 2, 2018, and ends on April 29, 2021, and contains 5553 China iron ore futures data. When the RV is calculated and the vacant value is eliminated successfully, the data of 784 trading days (February 5, 2018~April 29, 2021) are obtained.

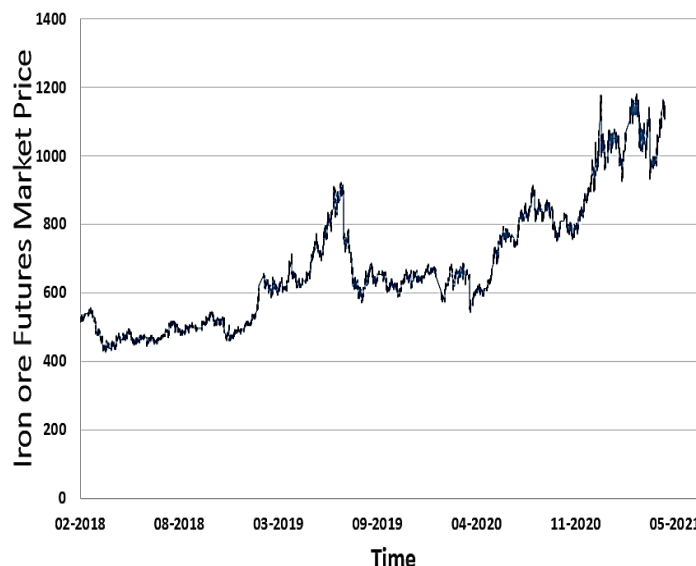


Fig. 2 Daily price volatility dynamics of iron ore futures

Fig.1 indicates that the volatility of iron ore futures market prices was stable between February 2018 and January 2019, though there was a severe fluctuation in March 2018. In February 2019, the prices fluctuated sharply and reached a higher level, and then the volatility gradually increased until May 2019. However, in May 2019, iron ore futures market prices had a sharp fluctuation. From September 2019 to April 2020, the fluctuations remained slightly before iron ore futures market prices volatility started to rise severely in May 2020. During the period of September 2020 to November 2020, the fluctuations were still relatively large. Iron ore futures market prices volatility has become larger and maintained unchanged at a high level since December 2020.

According to Fig.2, it is obvious that there are volatility asymmetry and volatility in the iron ore futures market. The volatility of iron ore futures also appears in the market. Moreover, the volatility of iron ore futures varied so greatly over time that the volatility can become large when compared to other times in certain periods. For instance, the period of November 2018 to May 2019 witnessed big volatility in the daily price of iron ore futures, although iron ore daily prices fluctuated even more from November 2019 to June 2020 and from January 2021 to April 2021.

3. Model

In the Heterogeneous market hypothesis proposed by Muller, each trader does not influence the other, but they have the different risk appetite and trading characteristics [7-8]. Traders will trade with their preference, which will lead to deviations between the price and the value of the asset [9]. Therefore, the preference of different traders should be fully considered when measuring the iron ore futures market.

3.1 HAR-RV model

According to the method for calculating the RV [10], the day should be divided by every 5 minutes, the i^{th} closing price in the day t is denoted as $P_{t,i}$. The RV of the trading day t is denoted as RV_t^d , which is

$$RV_t^d = \sum_{i=1}^M r_{t,i}^2 \quad (1)$$

Where $r_{t,i}$ denotes the logarithmic rate of return for the i^{th} period of the trading day t

$$r_{t,i} = (\ln P_{t,i} - \ln P_{t,i-1}) \quad (2)$$

$r_{t,i}$ is magnified 100 times to have an easy observation, which can be expressed as

$$r_{t,i} = (\ln P_{t,i} - \ln P_{t,i-1}) \times 100 \quad (3)$$

Then the weekly, and monthly realized variance can be calculated, denoted as RV_t^w and RV_t^m , defined as following

$$RV_t^w = \frac{1}{5} \sum_{i=0}^4 RV_{t-i} \quad (4)$$

$$RV_t^m = \frac{1}{25} \sum_{i=0}^{24} RV_{t-i} \quad (5)$$

The average RV from the day t to $(t+H)$ is defined as

$$\overline{RV}_{t+H} = \frac{1}{H} \sum_{i=1}^H RV_{t+i}^d \quad (6)$$

Then they are used in the HAR-RV model. The model of RV_t writes then as:

$$\overline{RV}_{t+H} = \beta_0 + \beta_1 RV_{t-1} + \beta_2 RV_{t-1}^w + \beta_3 RV_{t-1}^m \quad (7)$$

Among them, RV_t is the explained variable, which is also the data we want to predict. RV_{t-1} is the daily realized variance, RV_{t-1}^w is the weekly (6 days) realized variance, and RV_{t-1}^m is the monthly (25 days) realized variance. The least-squares method is used for multiple linear regression to determine the value of each coefficient.

3.2 HAR-RV-W model

New variables are introduced in the realized volatility model in this section—day-of-the-week effect. As known, in the capital market, returns can be significantly different from zero on a certain day of the week, or different from other trading days in the week. In iron ore trading, there will also be such an effect. So the model is modified to:

$$\overline{RV}_{t+H} = \beta_0 + \beta_1 RV_{t-1} + \beta_2 RV_{t-1}^w + \beta_3 RV_{t-1}^m + \theta_1 \text{Mon} + \theta_2 \text{Tue} + \theta_3 \text{Wed} + \theta_4 \text{Thu} + \theta_5 \text{Fri} \quad (8)$$

Mon, Tue, Wed, Thu, Fri are the variables describing the day-of-the-week effect. Sunday is set as a basis. When the trading day is Sunday, then $\text{Mon} = \text{Tue} = \text{Wed} = \text{Thu} = \text{Fri} = 0$. When the trading day is Monday (Tuesday, Wednesday, Thursday, Friday), Then $\text{Mon}(\text{Tue}, \text{Wed}, \text{Thu}, \text{Fri})=1$, and the other four variables will be 0. By linear regression, the preferences of traders can be described at a different time of the week, which can guide our investment strategy.

4. result analysis

Part 4 conducts the descriptive statistical analysis of the main variables (RV_{t-1} , RV_{t-1}^w , RV_{t-1}^m) in part 4.1, and then in part 4.2, regression analysis is done based on Table 2.

4.1 Descriptive statistical analysis

If you have an odd number of affiliations, the final affiliation will be centered on the page; all previous will be in two columns. The descriptive statistical analysis (Table 1) of the main variables shows that the wide and violent range of the daily volatility of iron ore futures prices is from 0.457 to 222.99. On the contrary, the weekly volatility of iron ore futures prices ranges smaller from 1.09 to 42.85, although the range of the monthly volatility of iron ore futures prices is narrowest (1.73~17.88). The results indicate that when the RV_{t-1} sampling time becomes longer, the volatility of iron ore futures prices is decreasing and the prices of iron ore become more stable

Table 1. Descriptive statistics of variables.

Variable	Mean	Std. Dev.	Min	Max
RV_{t-1}	5.347766	13.54759	0.4567208	222.9858
RV_{t-1}^w	5.339414	5.911745	1.093494	42.84916
RV_{t-1}^m	5.265119	3.358783	1.733249	17.8771

Table 1 supports that the mean and the variance of the daily volatility of iron ore futures prices are the biggest, compared with the mean and the variance of the weekly and the monthly of iron ore futures and showing that the average daily RV_{t-1} of iron ore and the difference in daily iron ore volatility are also the biggest. Furthermore, when it comes to the mean and the variance of the weekly volatility of iron ore futures prices, the table shows that they are bigger than the monthly volatility of iron ore futures prices. Thus, it can be proved that the average RV_{t-1} of Iron ore and the difference in iron ore volatility will become increasingly smaller if a longer sampling time is adopted.

4.2 Regression analysis

Table 2 summarizes HAR-RV and HAR-RV-W model on forecasting the iron ore futures' price on three aspects (daily, weekly, monthly).

Table 2. Regression results

	HAR-RV			HAR-RV-W		
	1-day	1-week	1-month	1-day	1-week	1-month
β_0	3.59*** (4.00)	0.617*** (3.08)	0.106** (2.29)	1.18** (2.20)	0.200 (0.50)	0.0684 (1.44)
RV_{t-1}	0.0161 (0.41)	0.0369*** (4.18)	0.000252 (0.12)	0.0226 (1.04)	0.0391** (2.37)	0.000855 (0.68)
RV_{t-1}^w	0.0138 (0.13)	0.807*** (33.77)	0.0122** (2.21)	0.0119 (0.23)	0.805*** (9.45)	0.0118** (2.02)
RV_{t-1}^m	0.304* (1.73)	0.0422 (1.08)	0.970*** (107.47)	0.301** (2.01)	0.0416 (1.33)	0.970*** (60.01)
Mon				1.31*** (3.41)	-1.89 (-0.51)	-0.107* (-1.65)
Tue				3.54** (2.09)	0.766* (1.88)	0.108 (1.50)
Wed				1.33** (2.47)	0.480 (1.54)	0.0290 (1.00)
Thu				1.65*** (3.44)	0.126 (0.34)	0.0284 (0.94)

Fri	4.55** (2.79)	0.946** (2.35)	0.130* (1.87)
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Note: t statistics in parentheses. $p^* < 0.1$, $p^{**} < 0.05$, $p^{***} < 0.01$.

The results of the HAR-RV model shows that only monthly volatility is enough significant on predicting 1-day volatility. The daily and monthly volatility are significant positive on 1-week volatility forecasting. The daily volatility is useless in predicting 1-month volatility.

The results of the HAR-RV-W model shows that more than half of the volatility (daily, weekly, monthly) are significant and positive. As for the day-of-the-week effect, the coefficients are positive and significant for 1-day, and the daily coefficient of Wednesday and Thursday are positive but insignificant in predicting 1-week and 1-month volatility. Besides, it is obvious that there is a strong positive and significant effect of the daily coefficient of Friday in iron ore futures market prediction, which means that the day-of-the-week effect plays an important role in predicting the future market of iron ore futures.

5. Conclusion

In summary, this article has a certain practical significance in management practices. Based on HAR-type models, high-frequency data of the iron ore futures market is considered first. Additionally, the day-of-the-week effect is introduced into research to improve the models' forecasting accuracy. This research mainly focus on volatility forecasting in the iron futures market by using 5-minute high-frequency data from 2018 to 2020 and in the meanwhile establish HAR-RV and HAR-RV-W models to look into the influences of the day-of-the-week effect. Specifically, this paper takes 5 minutes of high-frequency data from 2018 to 2020 as an example, using more strict test methods, empirical methods that have compared the above high-frequency volatility models to the stock market fluctuation rate prediction.

It can be seen from the fitting results that at this time, the t statistic of the daily realized volatility is 1.04, which is significant at a confidence level of 70%; the t statistic of the realized volatility weekly data is 0.23, which is at the confidence level. It is significant at the 20% level; the t-statistic of the monthly data of the realized volatility is 2.01. Significant at the 95% confidence level. Therefore, it can be concluded that the weekly explanatory variable does not have a particularly significant correlation with the explained variable. The fitting effect is not good.

From the regression analysis, the models hold with day-of-the-week effect perform better than do those without day-of-the-week effect. Except for Monday, the day-of-the-week effect has a positive impact on the price of iron ore but is not significant. The monthly volatility has a positive and significant effect in predicting future daily volatility. The weekly volatility also has a positive and significant impact on the monthly volatility prediction.

In addition, from the perspective of the day-of-the-week effect, in daily volatility predicting, the day-of-the-week effect has the most significant impact, and both have positive effects. The influence of the weekday effect on weekly and monthly volatility is not so significant, only Friday's trading will have a significant positive impact on them. As results, the weekday effect contains more information about the iron futures market. Finally, in terms of model stability, the HAR-RV-W model, its R-squared is the most significant, reaching 0.9582.

This paper mainly has two shortcomings. First, the HAR-type and the improved HAR-type models that take the day-of-the-week effect in this paper do not consider the structural breaks or other factors, making the accuracy of forecast decreased to some extent. Second, the sampling time of Iron ore futures is a little short. In the future, the structural breaks and other factors should be added to the HAR-type model to forecast Iron ore futures' prices more accurate.

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