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Volatility of Treasury Bond Futures Price: Evidence from Tick-by-Tick Data

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Abstract
In order to find the causes of price volatility in bond futures market, we consider the potential impact of trading properties and construct a multivariate linear model between realized volatility and Behavioral variables included the strategies of Open, Close, Long, Short and turnover. Then through an empirical analysis of tick-by-tick data, we found that realized volatility is negative respectively related to Long, Double-close and turnover, and positive correlated to Long-Close, Shot and shot-Close. The double-turnover has weakly influence, and both sides explain differences. The volume is not significantly explaining the price volatility. Therefore, our findings will be helpful to manage the risk of bond futures transactions.

Keywords
Treasury bond futures; Transaction attributes; Realized volatility; Systematic Risk

国债期货价格波动分析——分笔数据的经验证据

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摘要：为探明国债期货市场日内价格波动的微观原因，考虑到分笔交易属性的潜在影响，构建了日内价格已实现波动率与分笔交易属性变量的多元线性模型，接着选取国债期货分笔交易数据进行实证分析。结果表明：分笔交易属性变量中多开、换手和双平等与日内价格已实现波动率负相关；多平、空开和空平等与日内价格已实现波动率正相关；双换影响较弱，而开仓、平仓等影响较强；多空双方同一交易属性的解释能力差异较大；成交量不能显著地解释日内价格波动。这有助于国债期货交易行为的风险管理。

关键词：国债期货；交易属性；已实现波动率；系统性风险

1. Introduction

As the interest rate risk management tools, bond futures originated in mid 1970s in the United States. Global turnover about 2 billion 400 million hands, and turnover value amounted to $1026 trillion, accounting for 47%. Single large transactions cause the market price volatility. For example, on the morning of August 16, 2013, it is that

Oolong event involving more than 150 stocks trading losses 194 million Yuan. This shows that microcosmic reason of price volatility is of great significance to the risk management of futures market.

In this paper, some reasons for the futures prices volatility sums up as follows. On the one hand, the foreign scholars study the correlation between the volume and the positions. Crouch (1970) found that turnover was positively related to absolute return. Karpoff (1987) believes that correlation between volatility and turnover is weak. Bessem binder (1993) selects positions as market depth, and finds that positions and turnover are positively related to volatility. Chan (2000) found positive relationship between price and volume, and the trading positions and order flow interpretation ability is limited. This is confirmed by Huang (2003). Chevallier (2012) use high-frequency data to test linear correlation between realized volatility and trading volume, transaction volume and trading position. On the other hand, domestic scholars mainly study the Grainger causality between volatility and volume of futures market (Hua Renhai, 2004; Dai Yu, 2009; Zhang, 2013). Furthermore, Cao Lingling et al. (2016) based on the DCC-GARCH model, studied the linkage between Treasury bond futures and spot prices.

In general, scholars mainly study the correlation between positions, volume and price volatility, but ignoring empirical analysis of transaction tick-by-tick data to confirm the correlation between transaction behavior and volatility. Therefore, building a linear model of behavior variables and realized volatility, we show that trading behavior of bond futures and realized volatility have significant linear correlation, and the price volatility caused by the trading for variables. Therefore, regulatory authorities may be controlling the trading behavior to avoid systematic risk in the futures market. As lacking of ultra-high frequency data, we use intraday tick-by-tick data to doing empirical analysis to reveal the microscopic reason for price volatility from transaction behavior. It is importantly significant to improve the risk management of bond futures market.

2. Theoretical model

According to effective market theory, the price contains all the information, so based on the "days return square" measurement method (Andersen and Bollerslev, 2005 and 2011), we derived the calculation method of volatility, and construct a multivariate linear model of the volatility and behavior variable, turnover, and test their relations.

2.1. realized volatility method

According to the theory of continuous time finance, daily price obeys the Brown semi martingale process (Brownian Semi-Martingale, BSM in short):

$$p_t = \int_0^t \mu(s)ds + \int_0^t \sigma(s)dw_s \qquad (1)$$

Where $\lambda = \underset{i \in \{1,2,M\}}{Sup} \{\lambda_i \mid \lambda_i = \tau_{i+1} - \tau_i\} \to 0$ in (1), and sum squares of the daily price is as below

$$\lim_{\lambda \to 0} \sum_{j=0}^{n-1} (p_{\tau_{j+1}} - p_{\tau_j})^2 = \int_0^t \sigma^2(s)ds \qquad (2)$$

Where $\int_0^t \sigma^2(s)ds$ defined as Integral volatility (IV in short). It approximately approximates the sum of instantaneous volatility for a period of time. Therefore, the intraday volatility converges to the integral volatility in probability.

$$RV_t = \sum_{i=1}^{M_0} r_{t,i}^2 \xrightarrow{p} \int_{t-1}^t \sigma^2(s)ds \qquad (3)$$

Where M_0 is the total number of transactions in one day. Due to the volatility is the observed distribution of the theoretical value, so the integral volatility called realized volatility (RV in short). Then we have extracted each behavior corresponding to tick-by-tick price, so the behavior contribution of realized volatility is defined as follows:

$$RV_t^j = \sum_{i=1}^{M_j} r_{t,i}^2 \xrightarrow{p} \int_{t-1}^t \sigma_j^2(s)ds \qquad (4)$$

Where RV_t^j is realized volatility on $j \in \{1,2,3,\cdots,11\}$, $r_{t,i} = \ln p_{t,i}^j - \ln p_{t,i-1}^j$ is the behavior return, M_j is a tick number of the same behavior and total tick number is up to $M_0 = \sum_{j=1}^{11} M_j$ each day.

2.2. A multivariate linear model

According to (1), realized volatility is an unbiased estimate of integral volatility. Taking into account influence of market microstructure, a multivariate linear model is constructed for trading strategy with realized volatility

$$RV_t = \beta_0 + \sum_{j=1}^{11} \beta_j RV_t^j + \varepsilon_t \qquad (5)$$

Where β_0 is a constant, β_j is the coefficient of behavioral variables j, displayed the behavior to explain the extent of realized volatility, ε_t is the realized volatility caused by other factors, which is supposed to obey a standard normal distribution.

According to the existing literature on the relationship between price and quantity, the linear model after introducing other explanatory variables in formula (5) is

$$RV_t = \beta_0 + \sum_{j=1}^{11} \beta_j RV_t^j + \beta_V V_t + \varepsilon_t \qquad (6)$$

Where $V_t = (Vol_t - Vol_{t-1})/Vol_{t-1}$ indicates the range of volume within t days.

3. Empirical analysis

This section tests the linear model of volatility, and analyzes the impact of transaction attributes and trading volume on realized volatility. Our purpose is to ascertain the potential explanatory power of transaction behavior variables.

3.1. data selection and analysis

In order to explore the micro-reason of futures price volatility, this section selects the Treasury bond futures as a sample. Variables including transaction time, transaction price, volume, and transaction behaviors. Because the bond futures re-listed in September 6, 2013, from September 6, 2013 to November 4, 2016, so acquisition of each trading day tick-by-tick price from morning 9:15-11:30 to 13:00-15:15 PM, get a total of 767 trading days, we sum price data

(Figure 1). The realized volatility including RV1(DH), RV2 (DK), RV3 (DP), RV4 (HS), RV5 (KC), RV6 (KH), RV7 (KK), RV8 (KP), RV9 (PC).
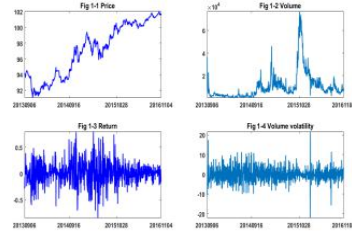

Figure1. Treasury futures trading price, volume, Return and Volatility

Figure 1 shows that bond futures prices decline in 60 days after the listing contract, this time in 60 days after shrinking down; to 180 days, prices, volume consolidation, the overall trend has not been rising, fluctuating trend between the two variables; but the return is random and aggregation features and characteristics of volume fluctuations obviously, there is a linear relationship between the two variables.

3.2. Realized Volatility Analysis

Based on the realized volatility model, the expected volatility (Figure 2-12) is obtained. The realized volatility reflects evolution characteristics of intraday risk of bond futures. As to how to find out relevant factors, we classify the transaction data in the order of time and calculate the realized volatility of transaction attributes (Figure 2-1~11).

As seen from Figure 2, the realized volatility of behavior presents a common evolutionary feature. The early resumption of the market realized volatility is smaller and smaller, then realized volatility is larger, and the days of realized volatility characteristics are very similar, so the trading behavior and realized volatility have cooperative movement characteristics.

3.3. stepwise regressions

Based on the linear model of trading behavior variables, turnover volatility and realized volatility (Table 1), the results showed that

some behavioral variables can significantly explain the realized volatility. Therefore, our linear model is the best fitting method (Table 2)
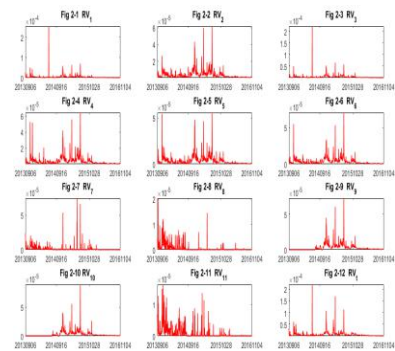

Figure2. Realized volatility of transaction behavior.

Table1. Estimation results of linear model with all variables

variable	coefficient	standard error	T statistic	P value
Constant (β_0)	0.00005	0.000023	2.2	0.029
RV_1 (β_1)	-0.18284	0.06325	-2.89	0.004
RV_2 (β_2)	0.99245	0.05431	18.27	0
RV_3 (β_3)	0.5668	0.1354	4.19	0
RV_4 (β_4)	0.0818	0.08048	1.02	0.311
RV_5 (β_5)	0.03776	0.05718	0.66	0.51
RV_6 (β_6)	-1.0439	0.1331	-7.84	0
RV_7 (β_7)	0.77174	0.04984	15.48	0
RV_8 (β_8)	0.4567	0.1137	4.02	0
RV_9 (β_9)	-0.24571	0.08165	-3.01	0.003
V_t(β_{10})	0.00521	0.00361	1.44	0.151
	S=0.00000221	R^2 =98.15%	R^2(Adjusted)=98.1%	F=1297.71

Table 1 shows: (1) T statistics RV4 and RV5 is less than 2, that influence of HS and KC on days of realized volatility is not significant; (2) according to the T statistic of RV1, RV6 and RV9, trading behavior is KH and PC for the negative impact of DH; (3) T statistics of V_t is 1.44, and display the volume did insignificantly explain volatility; (4) F statistics show a significant linear relationship, R^2 means volume causes intraday volatility more than 98.15%.

Table2. Stepwise regression results

step	1	2	3	4	5	6	7
β_0	2.6E-04	6.99E-05	1.03E-04	9.8E-05	5.2E-05	4.43E-05	5.38E-05
β_1	-	-	-	-	-0.199	-	-0.201
T-statistics	-	-	-	-	-3.17	-	-3.25
β_2	0.8961	0.8597	0.8665	0.8531	0.8404	1.0098	1.01
T-statistics	56.12	82.25	86.39	88.7	84.45	18.6	18.78
β_3	-	-	-	-	0.44	0.52	0.639

Table 2, cont.

step	1	2	3	4	5	6	7
T-statistics	-	-	-	-	3.7	4.36	5.08
β_6	-0.346	-0.952	-	-	-1.068	-0.938	-1.05
T-statistics	-4.89	-7.73	-	-	-8.64	-7.34	-7.9
β_7	0.602	0.82	0.829	-	0.787	0.774	0.779
T-statistics	17.56	14.85	16.13	-	15.35	15.39	15.69
β_8	0.6	-	-	-	0.51	0.37	0.438
T-statistics	5.82	-	-	-	4.89	3.29	3.88
β_9	-	-	-	-	-	-	-0.184
T-statistics	-	-	-	-	-	-	-2.65
S	0.000004	0.000003	0.000003	0.000002	0.000002	0.000002	0.000002
R^2	93.61	97.38	97.65	97.97	98.09	98.18	98.24
Mallows CP	546.6	100.3	70.9	34.3	21.5	13.2	8.2

Table2 shows: (1) T statistics of RV3, RV7,RV2 and RV8 are greater than 2, shows significantly the influence of DP, DK, kk and KP on days of realized volatility; (2) according to the T statistics the size of transactions on the realized volatility has positive effect in order; (3) discrimination value is 0.15 and the variables in the stepwise regression model; S value decreased from 0.000004 to 0.000002, R2 increased from 93.61 to 98.24 Mallows, CP value decreased from 546.6 to 8.2, which shows that the best linear stepwise regression fitting model was better than before; (4) R2 explaining realized volatility reached more than 98.24%.

Both table 1 and table 2 shows that the T statistics of both hand change and double Ping are smaller, while the other 4 trading strategies have higher t values. It shows that the selection steps of attribute variables in stepwise regression are reasonable and the obvious explanatory variables do not enter the best linear model. Through the comparative analysis found that: (1) DK, and HS and realized volatility are negatively correlated, and DP, KC and PC have a positive correlation to realized volatility; (2) DK, HS and SP reduce the days of realized volatility, and DP, KK and KP

increase of realized volatility. Volume change is not the micro cause of price fluctuation.

3.4. result analysis

This section explains the following conclusions. First, the 3-behavioral variables in linear model exclude turnover, opening, and trading volume volatility. Turnover trading accounted for more than 30% of all turnovers, turnover increased, but there was no significant impact on volatility. Volume volatility has no significant effect on the realized volatility, so it can be seen that turnover will not directly affect the intraday volatility of Treasury bond futures.

Second, a linear model between behavioral variables and realized volatility is established. Model coefficients of DH, DP, HS, KK, KP and SH are less than 0.5, and have weak influence on realized volatility. The absolute value of coefficient of KK is above 0.5, moderate impact on the intraday price realized volatility; the absolute value of the coefficient of KC and KP was more than 1, which has strongly effect on realized volatility.

Third, the HS and SP behavior is weakly impact on volatility. Four positive related behavioral variables are divided into both sides, compared with the effect on volatility, has a strong impact on the fluctuation. two kinds of

behavior caused by fluctuations in the market in the same direction, the risk of fluctuations in the direction of KK; and two kinds of behavior to the market brought about by the contrary, multi-level amplification of the market volatility, more stabilize market volatility. The magnification is far greater than the magnification of market volatility. Therefore, the price fluctuation of Treasury bond futures is dominated by many parties. This has a certain relationship with the bear market and the bull market during the sample period.

4. Conclusion

Through a linear model of volatility and trading behavior variables, we found that regression coefficient of behavior variables included DH, DP, HS, KK, KP and SH are significant, and different extent explain the realized bond futures intraday price volatility; and the DH, KC, KH and PC provide a insignificant explanation. Therefore, it is found that the effect to the trading behavior is not obvious; many transactions small changes will lead to fluctuations in the market; many behaviors are the dominant force in realized volatility.

This paper provides a new empirical support for monitoring the risk of Treasury bond futures transactions. Then we get the following enlightenment: trading behavior is a key factor in addition to the positions, micro volume and price index; the influence due to trading behavior was significantly larger than the volume of transactions. Therefore, we recognize clearly conducive to the management of futures trading behavior risk, and actively safeguard the stable operation of the market; and the investors should fully consider the impact of transaction acts, take good control of the investment risk trading behavior.

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