Frontiers in Business, Economics and Management
ISSN: 2766-824X | Vol. 6, No. 2, 2022

A Study on the Impact of Macro Uncertainty on the Volatility of China's Carbon Emissions Trading Market

-- Empirical Analysis Based on GARCH-MIDAS Model

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Abstract: This paper selects three carbon emissions trading prices in Tianjin, Guangzhou and Hubei for the period 2019-2021 as the samples and conducts a cross-sectional and longitudinal analysis of their volatility. The study shows that: (1) the price volatility and price level of carbon market in the three places differ significantly, and the difference between the highest and lowest price is significant; (2) the standard deviation of the logarithmic return of carbon trading pilot in the three places is large, and the riskiness of carbon trading is high. Based on this, this paper puts forward suggestions in four aspects: accelerating the improvement of basic system guarantee, accelerating the construction of national carbon market system, steadily promoting the construction of national carbon market, and establishing carbon market risk identification and prevention mechanism.

Keywords: Macroeconomics, China carbon emission trading market, influencing factors, volatility.

1. Introduction and Literature Review

The report of the 19th National Congress emphasizes the need to "accelerate the construction of ecological civilization", suggests that "China's environmental protection still lags behind economic and social development", and emphasizes the environmental construction tasks such as "implementing emission reduction commitments". However, due to the fact that China's carbon emission trading market is still in a state of flux, it is not easy to find a market for carbon emissions. However, since China's carbon emission trading market is still in the construction stage and the number of transactions is small, there is little research literature on the price volatility of the carbon emission trading market. The existing studies mainly focus on the framework of the carbon emission trading market, and believe that the carbon trading market will become a commodity market of great scale in the future, with less research on the price volatility of the carbon market.

As a new financial technology product with special attributes, carbon emission rights will also affect the financial market and enterprise production, and have a significant impact on the achievement of the "double carbon" goal in China. Liu, Hongqin et al. (2021) concluded that the carbon market in China is maturing and prices are generally on an upward trend, and that the price volatility risk is minimal and

Table 1. Guangzhou Carbon Emission Exchange 2019-2021 Trading Information

Date	Species	Opening Price	Closing Price	Highest Price	Lowest Price	Up or Down	Change %	Number of transactions	Transaction amount
20211201	GDEA	45.4	45.28	45.79	44.6	-0.12	-0.26	20832	943371.97
20211101	GDEA	43.36	43.51	44	42.69	0.15	0.35	17708	770439.49
20211008	GDEA	43.7	43.93	44	43	0.23	0.53	12243	537801.69
20210901	GDEA	39.89	38.22	39.8	38.04	-1.67	-4.19	2265	86564.09
20210802	GDEA	40.18	40.25	42.88	40.1	0.07	0.17	156504	5564315.38
20210701	GDEA	41.32	43.22	44	42.6	1.9	4.6	303552	12756159.03
20210601	GDEA	39.44	39.47	39.9	39.3	0.03	0.08	59595	2352316.09
20210506	GDEA	38.26	39.16	39.35	39.1	0.9	2.35	108142	3888848.72
20210401	GDEA	36.28	37.56	37.9	33.6	1.28	3.53	4615	170158.15
20210301	GDEA	31.99	32.12	32.12	29	0.13	0.41	1244	38572
20210201	GDEA	31.35	31.05	31.99	28.66	-0.3	-0.96	39320	1219754.38
20210104	GDEA	28.41	27.94	28.86	26	-0.47	-1.65	22155	617880
20201201	GDEA	27.47	27.71	27.8	27.5	0.24	0.87	83066	2301915.15
20201102	GDEA	27.47	27.81	28	27.21	0.34	1.24	196359	5459788.51
20201009	GDEA	27.53	27.24	28.08	25	-0.29	-1.05	435702	11165113.24
20200901	GDEA	27.5	28.09	28.09	28.09	0.59	2.15	164000	3843260
20200803	GDEA	28.35	28.12	28.48	27.51	-0.23	-0.81	499531	7252840.58
20200701	GDEA	27.55	27.6	27.98	27.26	0.05	0.18	119933	3708924.11
20200601	GDEA	28.66	28.18	28.49	27.8	-0.48	-1.67	308070	7545427.19
20200506	GDEA	27.9	28.32	28.39	27.82	0.42	1.51	5694	161271.96
20200401	GDEA	29.58	29.35	30.25	29.2	-0.23	-0.78	338482	5667549
20200302	GDEA	30.22	30.02	30.85	28.6	-0.2	-0.66	468842	12694782.35
20200210	GDEA	27.15	28.73	29.87	28.21	1.58	5.82	3368	99042.96
20200102	GDEA	27.88	28.03	30	28	0.15	0.54	6225	174505.31
20191202	GDEA	26.95	26.9	27.5	26.55	-0.05	-0.19	11252	302626.92

Table 2. Tianjin Carbon Emission Exchange 2019-2021 Trading Information

		Transaction volume (ton)		Turnover (Yuan)		Average transaction price (yuan/ton)	
Transaction Date	Trading Species	Online Trading	Agreement Transaction	Online Trading	Agreement	Online Trading	Agreement Transaction
2021-05-17	TJEA20	40	-TJEA20	1,160	-	29.00	-
2021-04-13	TJEA20	14,000	-	392,000	-	28.00	-
2021-03-15	TJEA20	28,000	-	630,000	-	22.50	-
2021-02-10	TJEA20	28,400	-	791,792	-	27.88	-
2021-01-22	TJEA20	31,200	-	783,744	-	25.12	-
2020-12-22	TJEA20	3,400	-	76,500	-	22.50	-
2020-11-13	TJEA20	18,760	-	476,504	-	25.40	-
2020-10-15	TJEA20	16,000	-	403,200	-	25.20	-
2020-09-16	TJEA20	195	-	5,015	-	25.72	-
2020-08-19	TJEA19	100,000	315,485	2,650,000	7,872,414	26.50	24.95
2020-07-15	TJEA19	72,980	-	1,945,647	-	26.66	-
2020-06-16	TJEA19	7,424	-	196,736	-	26.50	-
2020-05-15	TJEA19	260	-	5,460	-	21.00	-
2020-04-14	TJEA19	160	-	3,072	-	19.20	-
2020-03-12	TJEA19	350	-	5,950	-	17.00	-
2020-02-12	TJEA19	-	102,363	-	1,555,918	-	15.20
2020-01-14	TJEA19	410	-	6,806	-	16.60	-
2019-12-30	TJEA19	427	-	6,576	-	15.40	-
2019-10-25	TJEA19	170	257	2,385	3,598	14.03	14.00
2019-08-14	TJEA19	-	41,764	-	523,721	-	12.54
2019-07-17	TJEA19	400	-	5,240	-	13.10	-
2019-06-13	TJEA18	-	116,566	-	1,624,290	-	13.93
2019-05-14	TJEA18	-	2,827	-	35,451	-	12.54

Table 3. Hubei Carbon Emissions Exchange 2019-2021 Trading Information

Trading Species	Date	Latest	Up or Down	Highest	Lowest	Volume	Turnover	Yesterday's closing price
HBEA	2019-01-02	31.02	-0.83%	31.95	28.5	10109.0	303130.55	31.28
HBEA	2019-02-01	29.19	-1.39%	32.5	27.62	191.0	5482.92	29.60
HBEA	2019-03-01	28.5	-1.35%	28.89	28.0	5202.0	147558.99	28.89
HBEA	2019-04-01	28.99	2.47%	29.85	25.8	8867.0	245628.18	28.29
HBEA	2019-05-06	32.88	7.84%	33.1	29.13	667.0	21864.93	30.49
HBEA	2019-06-03	52.43	1.63%	56.0	50.0	19340.0	1056744.76	51.59
HBEA	2019-07-01	37.76	-1.87%	42.09	34.63	1123.0	42704.94	38.48
HBEA	2019-08-01	38.6	-5.07%	44.5	38.5	5174.0	200537.77	40.66
HBEA	2019-09-02	34.93	1.04%	35.49	34.12	71121.0	2470959.23	34.57
HBEA	2019-10-08	33.42	2.48%	35.4	31.0	5338.0	170863.23	32.61
HBEA	2019-11-01	30.95	2.96%	31.47	27.5	1523.0	44926.38	30.06
HBEA	2019-12-02	25.16	1.70%	25.95	24.01	99584.0	2450086.12	24.74
HBEA	2020-01-02	27.96	4.88%	27.96	26.52	3005.0	79699.80	26.66
HBEA	2020-03-23	25.59	-6.40%	27.34	24.62	740.0	18465.42	27.34
HBEA	2020-04-01	25.89	-0.27%	27.93	25.01	251.0	6360.44	25.96
HBEA	2020-05-06	25.5	-1.66%	25.99	25.0	46676.0	1169395.39	25.93
HBEA	2020-06-01	25.2	-0.36%	26.88	24.5	2595.0	66472.78	25.29
HBEA	2020-07-01	26.39	5.10%	27.55	23.01	69245.0	1803286.57	25.11
HBEA	2020-08-03	27.8	0.00%	28.16	25.23	112667.0	3129675.97	27.80
HBEA	2020-09-01	29.0	0.00%	29.86	27.5	53966.0	1563457.90	29.00
HBEA	2020-10-09	27.37	-5.26%	29.64	26.01	2131.0	58428.14	28.89
HBEA	2020-11-02	29.41	-0.81%	29.99	28.1	547.0	15829.57	29.65
HBEA	2020-12-01	27.02	-1.71%	27.78	27.02	97753.0	2687687.44	27.49
HBEA	2021-01-04	28.36	1.32%	28.38	28.36	5.0	141.82	27.99
HBEA	2021-02-01	30.99	7.12%	30.99	30.99	5.0	154.95	28.93
HBEA	2021-03-01	29.99	-0.03%	30.0	27.7	452.0	12625.90	30.00
HBEA	2021-04-01	28.99	0.35%	31.24	28.0	323.0	9486.50	28.89
HBEA	2021-05-06	30.99	3.30%	32.98	29.6	948.0	29343.55	30.00
HBEA	2021-06-01	30.98	-6.23%	34.4	30.0	108689.0	3691517.11	33.04
HBEA	2021-07-02	31.75	-3.76%	32.98	31.57	172.0	5510.72	32.99
HBEA	2021-08-02	42.28	5.28%	44.06	41.0	6166.0	262185.14	40.16
HBEA	2021-09-01	40.05	-0.52%	42.89	40.05	6998.0	289734.22	40.26
HBEA	2021-10-08	40.9	0.99%	41.6	39.0	2771.0	110578.59	40.50
HBEA	2021-11-01	41.1	-0.92%	42.44	40.02	7944.0	327624.86	41.48
HBEA	2021-12-22	38.52	-0.98%	39.5	38.51	84106.0	3254930.61	38.90

stability is higher in Ave. Zhou Chang et al. (2020) showed that the implementation of carbon emissions trading does not yet promote Chinese enterprises to increase their R&D investment, and suggested that we should promote active participation in carbon emissions trading and enhance the role of carbon information in enhancing corporate value. Xin Jiang et al. (2018) argue that the carbon trading market is currently at a low volatility stage, with low linkage to other factor markets, as well as the current imperfect system and opaque information in the carbon emission trading market. Economic recovery and sustainable development are important issues of common global concern, and the existing research on the carbon trading financial market should not only focus on the establishment of the basic framework, but also aim to address the analysis of the basic laws of the market.

2. Indicator System Construction and Data Sources

Based on the above research, this paper intends to select three carbon emission exchanges in Tianjin, Guangzhou and Hubei for the period of 2019-2021, and analyze them in a cross-sectional and longitudinal manner, and draw on the GARCH-M model to analyze the data by taking the logarithmic rate of return.

We can find from the table that Tianjin carbon emission trading market is more volatile, with the highest average transaction price and the highest volume among the three trading pilots; Guangzhou carbon emission trading market ranks second in terms of volume and the price is about half of that of Tianjin; and Hubei carbon emission exchange its carbon price is roughly the same as that of Guangzhou, but lower than the carbon price of Tianjin market.

3. Measurement of Volatility in China's Carbon Emission Trading Market

In general, the trend of carbon emission trading pilots in the three regions is consistent. The average price of carbon in the three pilot regions is on an upward trend from 2019 to 2021. Except for Tianjin, which is more volatile in 2020, Hubei and Guangzhou have a stable trend in 2020, and their carbon emission trading prices are low in the late stage of market operation during 2020 because various carbon emission pilot policies have not been fully implemented and the carbon financial market is in its initial stage. From the second half of 2019 onwards, the carbon price will be significantly higher due to the policy tone of national and local governments and the increasing improvement of the carbon market system.

Among the three carbon emission trading pilots, Tianjin has the highest average transaction price, which is related to the fact that Tianjin became a carbon emission trading pilot earlier. It is worth mentioning that there is a decreasing trend of carbon price in Tianjin between the end of 2020 and the beginning of 2021, which is mainly due to the government's promotion of the widespread use of clean energy and the significant increase of production utility of enterprises in Tianjin during the same period, resulting in a lower demand for carbon emissions. Guangzhou has a healthy and stable trend of carbon trading price compared to the other two pilot markets. By 2020, the carbon prices in the three carbon trading markets will gradually stabilize, which is directly related to the continued promotion of national green and low-carbon policies and the increased capacity and efficiency of energy-producing enterprises.

In terms of price, the three regions have different prices in the carbon trading market, with large differences in the highest and lowest prices. Tianjin has the highest carbon trading price, which is more than double that of Guangzhou and three times that of Hubei. The reason for this is that the Tianjin carbon trading market mechanism is more mature, while Hubei is in the initial stage of the market in 2018, and the trading system has not yet been perfected, resulting in the low transaction price and number of transactions. In addition, carbon quotas were issued free of charge at the beginning of the market, without any capital investment by enterprises, which made the carbon price in Hubei continue to be low.

In the following, we conduct an econometric analysis of the three regional carbon trading pilots. To facilitate the data interpretation of price fluctuations and reduce the influence of heteroskedasticity, we adopt the logarithmic rate of return approach with the following formula:

$$R = \ln(sd) - \ln(sd(-1))$$

R is the logarithmic rate of return, and sd is the average daily price of each pilot

According to the above three tables, we can obviously find that all three carbon trading pilots are volatile and aggregated, and there are also differences in the volatility of the three markets.

4. Macro Uncertainty on the Price Impact of China's Carbon Emissions Trading Market

Table 4 shows the descriptive statistics of the log returns of the daily average price of the carbon market.

Table 4. Descriptive statistics of daily average price log returns in the carbon emission market

Region	Mean	Maximum	Min	Standard deviation	Skewness	Kurtosis	J-B statistic
Tianjin	-0.002918	0.105361	-0.095310	0.031231	0.276546	6.287733	83.82637
Guangzhou	-0.000893	0.254991	-0.208055	0.079512	0.644865	4.925268	98.45109
Hubei	-0.001121	0.105361	-0.095532	0.029628	0.149456	6.172196	296.5282

We can observe that the mean log returns of the three pilots in Tianjin, Hubei and Guangzhou are all negative but close to zero, indicating a relatively stable and slightly decreasing trend. Tianjin pilot has the highest standard deviation of log returns, followed by Guangzhou, and Hubei has the lowest; all three pilots are right skewed; kurtosis is higher than the kurtosis value of normal distribution, which proves that the series has the characteristics of spikes and thick tails. Based on the skewness, kurtosis and JB statistic, it can be concluded that the JB statistic is greater than the critical value of 2, which indicates that the hypothesis of normal distribution is not met, and therefore the conclusion that the series is not normally

distributed can be drawn.

Through the above statistical analysis, we can conclude that the three carbon emission trading markets are consistent with the volatility aggregation and non-normal distribution, so we can establish the GARCH model with reasonableness.

4.1. Smoothness test

Before establishing the heteroskedasticity, we need to conduct a stationarity test. The assumption that the time series is not smooth leads to pseudo-regression results, so we use the ADF test for this test. According to the results of the table, the ADF test statistic is less than the critical value at 1% and the P is less than 0.05. Therefore, the original hypothesis is rejected, i.e., there is no unit root in the time series and the time series is proved to be smooth. Therefore, the original hypothesis is rejected, i.e., there is no unit root in the time series and the time series is proved to be stationary.

Table 5. Stability test

Area	T-statistic	P-value	Smoothed or not
Tianjin	-104.9091	0.0001	Stable
Guangzhou	-59.58874	0.0001	stable
Hubei	-15.27989	0.0001	stable

4.2. ARCH effect test

By establishing the autoregressive equation according to the least squares method and performing the ARCH-LM test on the time series with lag order P=1, we can obtain Table 6:

Table 6. ARCH-effect test

Region	F-statistic	P-value
Tianjin	64.88737	0.0000
Guangzhou	48.85057	0.0000
Hubei	147.7215	0.0000

From the above statistical results, it can be concluded that the p-value is less than 5% significant level, which means that the original hypothesis that there is no ARCH effect in the time series is rejected. Thus, we can conclude that there is an ARCH effect in the daily average price of carbon emission trading market in the three regions. Next, we can conduct conditional heteroskedasticity modeling.

4.3. Establishing the GARCH-M model

The above statistical results indicate that there is an ARCH effect in the carbon emission trading pilot in Tianjin, Hubei, and Guangzhou, so we will build a GARCH(1, 1) model for the yield series of the three places.

The estimated equations of the GARCH model are shown in Table 7:

Table 7. GARCH model estimation equation

Region	Constant term	GARCH term	ARCH term
Tianjin	-0.0001068	0.4230356	7.060146
Guangzhou	0.0004692	0.2889304	2.535051
Hubei	0.0000402	-0.2089333	3.082049

According to the results, the GARCH term of the carbon price yield series in Tianjin is the highest, indicating that the historical carbon price level in the previous period has a significant influence on the later carbon price volatility; the GARCH term of the carbon price yield series in Guangzhou is the smallest, indicating that the historical carbon price level in the previous period has less influence on the later volatility. The highest ARCH value among the three pilots in Tianjin indicates that external conditions have a greater influence on the volatility of carbon price in Tianjin. In addition, the coefficient α of the ARCH term is larger than the coefficient β of the GARCH term in all three pilots, suggesting that external shocks have a stronger impact on market volatility than the market's own memory.

4.4. Summary of the volatility analysis of carbon trading prices in the three pilot markets in China

Based on the above empirical analysis, we can draw the following conclusions:

(1) In the descriptive statistical test of the log returns of carbon trading prices, the standard deviation is relatively large, indicating the high riskiness of carbon trading.

(2) The price fluctuations in the carbon trading market in the three regions do not show the same pattern, and the price variability is large, with special and regional characteristics.

(3) The volatile prices of the three carbon emission trading markets do not have dramatic characteristics, indicating that China's carbon emission trading market is in the early stage of development, the market mechanism is not yet perfect, and there is no active operation mode.

5. Conclusion and Policy Suggestions

In the future, China's carbon emission trading market should further improve the market mechanism, and through releasing reasonable price signals, guide the flow of social capital, reduce the cost of emission reduction of the whole society, and then realize the optimal allocation of carbon emission reduction resources, and promote the green and low-carbon transformation of production and life.

5.1. Accelerate the improvement of basic system guarantee

5.1.1. Accelerate the establishment of laws, regulations and institutional systems that are compatible with the carbon market

A good legal foundation provides guarantee for the design and implementation of the carbon market mechanism and is the basis for the effective operation of the carbon market.

A set of "1+N+X" policy and system system should be formed as soon as possible, with the national regulations on carbon emission trading as the foundation, the relevant management system of the Ministry of Ecology and Environment as the focus, and the trading rules of the exchange as the support, so as to guarantee the smooth and long-term operation of carbon market trading.

5.1.2. Introduce national regulations on carbon emissions trading as soon as possible.

Accelerate the promotion of legislation related to improving the climate environment, and ensure the authority of the carbon market with higher-level legislation.

Establish unified legal standards for the qualification of the subjects of the carbon emission market, clarify the rights, obligations and responsibilities of all parties involved in the carbon emission trading market, regulate the conditions, procedures and contents of carbon emission market transactions, and formulate unified regulations for the creation, operation and management of carbon emission exchanges, etc., so as to provide complete laws, regulations and institutional guarantees for the construction of the national carbon market system, so as to stabilize the institutional expectations and market expectations of the trading subjects. Expectations.

5.1.3. Increase the cultivation of carbon finance and encourage the innovation of carbon finance products.

Various carbon financial derivatives and services provide important asset management and risk hedging tools for market participants to explore the real value of carbon assets.

Continuously enrich carbon derivatives and other carbon market trading varieties, encourage financial innovation of trading instruments such as carbon emission allowances, CCERs and carbon forwards, financing instruments such as carbon bonds, carbon asset mortgages/pledges, carbon funds/trusts, and supporting instruments such as carbon indices and carbon insurance, and guide financial resources to boost the development of the national carbon market and build a carbon pricing center with international influence.

5.2. Accelerate the construction of the national carbon market system

5.2.1. Explore the introduction of diversified trading methods.

The existing pilot carbon exchanges are all listed and traded in the mode of over-the-counter non-standardized commodities, which do not allow collective bidding, and there is a risk of price manipulation by knocking a large number of transactions during the short period of opening. It is suggested that on the basis of full demonstration of feasibility, a bidding mechanism should be introduced in due course, and the trading method of free quotation and aggregated transaction should be adopted, with aggregated transaction according to the principle of price priority and time priority, and market maker mechanism and appropriate investor system should be introduced to allow institutions and individuals to participate in the market, so as to enhance trading efficiency and promote price discovery.

5.2.2. Continuously enrich carbon market trading varieties.

On the basis of carbon spot trading, explore carbon futures, carbon options and other derivatives trading.

Derivatives have the functions of hedging and risk transfer, and market participants can effectively hedge the risks caused by the fluctuation of carbon emission rights prices through derivatives.

At the same time, diversified carbon derivatives are also conducive to the optimization of the structure of market participants and the expansion of trading volume, which will also further enhance the pricing efficiency and accuracy of the underlying products in the derivatives market.

5.3. Steadily promote the construction of a national carbon market

Accelerate the formulation of a national carbon market development master plan The construction of a national carbon market is a systematic and long-term work, which requires the formulation of a clear roadmap covering the near, medium and long term, and the promotion of the construction of a national carbon market in steps and phases around the goals of carbon peak and carbon neutral.

The first stage is the policy improvement period. The focus of this phase is to establish and implement laws, regulations and institutional systems that are compatible with the national carbon market. The second stage is the high speed development period. This phase is the key period to achieve the carbon peak target, and is the transition period from relative emission reduction to absolute emission reduction. The national carbon market transitions from relative amount to total amount control, and the total amount target is effectively connected with the target of carbon peaking in each province, so that all regions and industries can optimize the allocation of carbon quota resources and reduce the cost of emission control through the national carbon market.

The third stage is the operational maturity period. The central task of the national carbon market in this stage is to strengthen the total amount of control, continue to tighten the supply of allowances, and form a stable upward trend of carbon price, so as to promote the total amount of carbon emissions to move from "stable" in the plateau period to "down" in the downward period as soon as possible after achieving the carbon peak target. By contracting the total amount of allowances and using carbon price signals to drive emission control enterprises to pay attention to low-carbon technology innovation, it will provide long-term impetus for China's low-carbon transition.

5.4. Establishing a carbon market risk identification and prevention mechanism

5.4.1. Unify market supervision, establish a regulatory synergy mechanism, clarify the division of powers and responsibilities, and implement the main responsibilities.

It is recommended to clarify the boundaries of the various regulatory departments and the powers and responsibilities of the subjects in the national carbon market in accordance with the principle of consistency of powers and responsibilities. The Ministry of Ecology and Environment is responsible for

the comprehensive coordination, organization and implementation, supervision and management of carbon emission management and trading, such as the scope of the main body, quota allocation, carbon emission reporting and verification, etc. It also reviews the relevant business rules formulated by trading institutions and registration and settlement institutions, and provides overall gatekeeping for the relevant processes involved in the participation of enterprises in carbon trading, and specifies the corresponding penalties. The national financial regulatory department is mainly responsible for formulating the relevant carbon finance management system and monitoring the risks of financial institutions involved in carbon trading.

5.4.2. Improve information sharing and strengthen cooperative supervision.

From the current situation of information disclosure in the carbon market, there are large differences in the degree of information disclosure in each local market, and there are also problems such as too conservative public information, little substantive information content, and insufficient information concentration, etc. It is urgent to build a perfect carbon market information disclosure system.

5.4.3. Promote the implementation of responsibility and sound accountability mechanism.

A perfect regulatory system needs a strong law enforcement system to guarantee, to promote the implementation of the main responsibility of all parties and strengthen the accountability mechanism. Explore the establishment of a national credit management system for carbon emissions, and incorporate the transaction behavior records of key emitters, exchanges, verification agencies and other relevant units and practitioners into the credit system.

Acknowledgment

This work is supported by Anhui University of Finance and Economics Undergraduate Research innovation fund project fund, Project number: XSKY22009ZD.

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