Article

Prediction of crude oil price based on quantum model

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Abstract: This paper constructs a quantum model to solve the problem of international crude oil market price prediction. The price movement in the market is compared with the movement of particles in the micro world, and the probability of its existence is calculated by quantum mechanics algorithm. In the process of calculation, fuzzy mathematics and spectrum filtering are used to process the original data. Then the volatility function is introduced to describe the market energy. According to the simultaneous equation of market energy, the existence probability and transition orbit of market price in the future are solved. Finally, on the basis of the probability of price existence and transition orbit, the future price path is predicted. In addition, this paper also designs a practical trading strategy, the actual results show that the model can achieve good results, and provide reference and guidance for individual, institutional and corporate investors. The innovation of the research work in this paper is that the price movement is compared to the particle movement, the market price transition phenomenon is calculated by quantum mechanics algorithm, and the consistency of micro and macro is unified in the model.

Keywords: Crude oil price; Quantum model; The wave function; Price forecasting;

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1. Introduction

In recent years, the use of statistical physics methods, especially the quantum mechanical algorithm to solve economic and financial problems, has attracted more and more attention because of its economic value, novelty and efficiency. As an interdisciplinary subject of economics and physics, it involves not only stock market, futures market and foreign exchange market, but also investment portfolio, investor psychology research and asset risk measurement.

Many scholars have demonstrated the feasibility and prospect of quantum model in the economic field[1–7]. Quantum mechanics solves the non-linear problems in the micro world, while the problems in the field of economy and finance are often non-linear. They have something in common. First of all, some scholars studied the quantum game decision-making, financial market path integral method, financial market wave function and financial market volume price behavior[8–14]. These works lay the foundation for the construction of quantum model. With the development of the theory, the stock market has been paid more and more attention, and a number of quantum models[15–23] of the stock market have been born. Quantum models also deal with some problems in bond, lottery and option markets.[24–26]. Secondly, the quantum mechanics algorithm, neural network algorithm and Brownian motion are combined to construct the quantum model, which has achieved good results. [27–31]. Thirdly, with the development of electronic equipment, quantum circuits and calculators have been widely used. Due to the high efficiency of the algorithm, it has a certain prospect in solving option pricing and financial risk measurement[32,33].

Some scholars construct the model from the psychological factors of market participants [34,35], and the quantum model from the perspective of market risk measurement, stochastic theory and supply-demand relationship[36–39]. This paper makes some innovations in previous scholars' ideas, improves Zhang and Huang's idea of constructing market wave function[40], so as to better reflect the essence of the market. Then, using the methods of data processing in economics and the algorithm of quantum mechanics, a quantum model is constructed and the practical strategy is formulated. Compared with other papers, the work of this paper is more comprehensive and practical. The main features of this paper are as follows:

1. A quantum model is established from the perspective of price transition, which unifies the micro and macro consistency in the model. 2. The fuzzy function and spectrum filtering method are used to extract and quantify the original market data. Compared with the other models, the data has been processed more reasonably. 3. The calculation method of price jump position is proposed and verified with the actual data. The calculation results show that it has a certain relationship with the golden section position of traditional technical analysis. 4. According to the theoretical model, we can make practical trading strategies. The results also prove the validity and practicality of the model from another aspect.

The first part of this paper summarizes the previous research results and introduces the characteristics and innovation of this model. The second part is the establishment of the model. the candle line is fuzzy quantified, the price center is defined, and the quantum mechanics algorithm is introduced to calculate the price trajectory. The third part selects the data of recent two years to verify, and the results are basically consistent with the theoretical values. The trading strategy based on the model also has certain profitability. The fourth part summarizes the research work and puts forward the direction of improvement in the future.

2. Materials and Methods

This section is the establishment stage of the model. Based on certain assumptions, a quantum model is established to simulate the investment, loss and income in the market. The algorithms used in this section refer to the algorithms of quantum mechanics in physics. Due to the complexity of the development process of quantum mechanics, the proof process of operators is not described in detail.

2.1. Conditional hypothesis

Condition hypothesis 1: the prices in the market are continuous, including horizontal time continuity and vertical space continuity, that is, there will be no similar black swan event and fuse event.

Condition hypothesis 2: The capital movement in the market has energy and obeys the law of conservation of energy.

2.2. Defining the price hub

Just as electrons in the micro world revolve around the nucleus, the market can be regarded as the central force field formed by the price fluctuation around the price center. When things move regularly, there will be a center, and its range of motion will not deviate from this center.

The price P of "nucleus" is defined by the average price of candle line. Just as the mass of molecules is concentrated on the nucleus, the volume corresponding to different prices in the market is different. Define the price hub.

$$P = \sum_{n=1}^{N} \frac{x + w + y + z}{4} / N, \tag{1}$$

Where x is the highest price of the nth candle line in the past; y is the lowest price of the nth candle line in the past; w is the opening price of the nth candle line in the past; z is the closing price of the nth candle line in the past; P is the price corresponding to the price center; n is the sum of the number of candle lines taken.

2.3. Candle line fuzzy quantization

In 1965, Professor Zadeh[43] of the Electrical Engineering Department of the University of California, Berkeley, founded the fuzzy set theory, and then gradually developed fuzzy mathematics on this basis. The basic idea of fuzzy mathematics is to describe and model a large number of fuzzy concepts and phenomena in the real world with accurate mathematical methods, so as to achieve the purpose of correctly handling them.

Different lengths of candlelight lines correspond to different volumes. Generally speaking, the longer the length of the candle, the larger the volume. Due to the great difference of candle lines in the market, it is necessary to fuzzy quantify the candle light in order to facilitate modeling and calculation.

According to the length of candle line, candle line is divided into four categories by fuzzy function, which is convenient for modeling and calculation. Candle line originated from the Tokugawa Shogunate era of rice market transactions, including the opening price, closing price, the highest price and the lowest price. Candle line is the result of the game between long and short funds, which reflects the strength of price rising energy and falling energy.The length of candle line is calculated as follows:

$$body = [max(open(t), close(t) - min(open(t), close(t)]/open(t) * 10 \tag{2}$$

Where *body* represents the length of the candle entity, and $open(t)$, $close(t)$, $low(t)$, $high(t)$ are the opening price, closing price, lowest price and highest price of period t respectively.

The first step of quantification is to divide the candle into four fuzzy lengths. Fuzzy semantics is used to describe the length of candlelight line entity and shadow line: "extremely short", "short", "medium" and "long". In this paper, four parameters a, b, c, d are used to describe the length of candlelight.

The membership function of fuzzy subset corresponding to "long" is defined as follows (see Figure 2-5), and parameters (a , b) are defined as (0.35 , 0.5) respectively,

$$leftlinear\ (x : a, b) = \begin{cases} 0 & x < a \\ (x-a)/(b-a) & a \le x < b \\ 1 & x > b \end{cases} \tag{3}$$

The membership functions of "short" and "medium" fuzzy subsets are as follows: the parameters (a, b, c, d) are defined as (0.15 , 0.25 , 0.35 , 0.5), respectively,

$$trapezoid\ (x : a, b, c, d) = \begin{cases} 0 & x < a \\ (x-a)/(b-a) & a \le x < b \\ 1 & b \le x < c \\ (d-x)/(d-c) & c \le x < d \\ 0 & x \ge d \end{cases} \tag{4}$$

The membership function formula of "extremely short" fuzzy subsets is as follows: parameters (a , b) are defined as (0 , 0.05) respectively,

$$rightlinear\ (x : a, b) = \begin{cases} 1 & x < a \\ (b-x)/(b-a) & a \le x < b \\ 0 & x > b \end{cases} \tag{5}$$

Different weight coefficients are given to different length candle lines, and the weight coefficients 0, 0.3, 2 and 3 are defined, and the weight coefficient μ of "length" in candle thread is defined $\mu_1 = 3$, the weight coefficient μ of "medium" is $\mu_2 = 2$, the weight coefficient μ of "short" is $\mu_3 = 1$, the weight coefficient μ of "extremely short" is $\mu_4 = 0.3$, Because the quantum model assumes that there is energy in the capital, the long solid candle usually contains more capital than the short solid candle, so the weight coefficient of the solid length candle is greater than that of the short solid candle.

2.4. Quantum model algorithm

This section first introduces the calculation formula of current market energy. Since most financial markets follow the standard Gaussian distribution, cosine function is introduced to describe the energy state of current market price[40] , because the frequency attribute of cosine function is similar to the fluctuation frequency of market, and its function image is also similar to Gaussian distribution.

$$\varphi(r) = \cos\left(\frac{wr}{d}\right), \tag{6}$$

Among them, $\varphi(r)$ is the wave function describing the market state and represents the energy state of the current market. ω is the inherent fluctuation frequency of the market, in which each trading variety has its own inherent fluctuation frequency. This frequency is determined by the nature and influencing factors of the trading variety. The value of the market natural frequency is extracted by spectrum filtering method.r represents the distance between the price and the center price, that is, the difference between the current price and the center of the orbit is the potential energy d is one-half of the price difference between the highest price and the lowest price in the past period of time. The total energy of the current market can be expressed as

$$E = \frac{1}{2}\mu\omega^2 d^2, \tag{7}$$

Where μ represents the weight coefficient after the candle line is blurred, which has been defined in Section 2.3. If there is price center P in price, the capital will move around the center, and the price will fluctuate around the value. The candle line with mass μ moves around the central force field, and the energy operator can be expressed as

$$H = -\frac{\hbar^2}{2\mu}\nabla^2 + V(r), \tag{8}$$

$$V(r) = \mu\omega r, \tag{9}$$

Where H is a function of the spatial state in which the price is located; $\hbar$ is the capital dimension of the market, which specifically represents the amount of capital traded in the market every second. The value of crude oil market can be found from the United States Energy Administration. $V(r)$ represents the gravitational potential energy of the price center on which the fund is subjected at the current moment. ∇^2 is a differential operator, representing the evolution state of price Strict proof has been given[41].

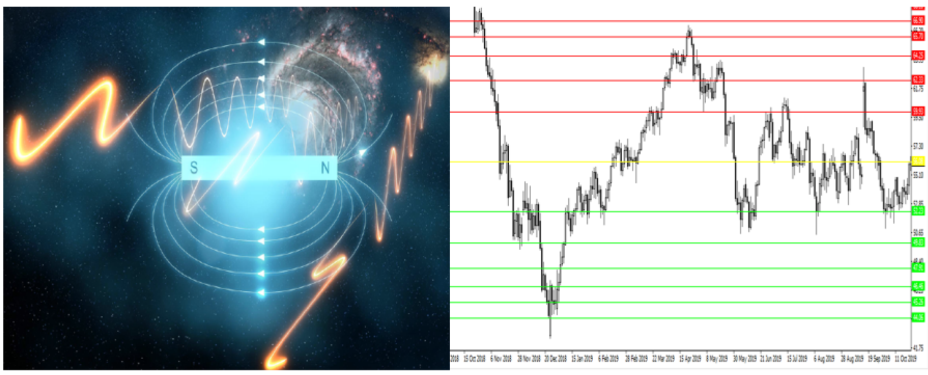


Figure 1. Price is similar to the motion around the central magnetic field.

The next step is to use the spherical harmonic function in quantum mechanics to do the specific operation, that is, to coordinate the spherical equation 8. The spherical harmonic function is used to calculate because the quantum model compares the price motion to a space field motion. Because the field in physics is three-dimensional, the spherical coordinate is used. In a sense, price movement is about time, space, and people's psychology and so on, which is multi-dimensional. As shown in Figure 1, prices fluctuate around a central force field. Figure 2 shows the candle line in three dimensions.

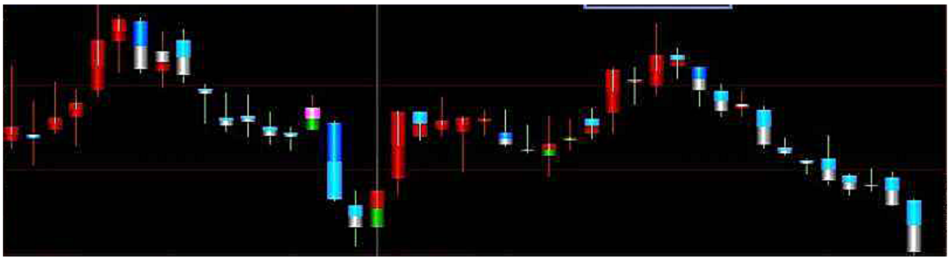


Figure 2. Three dimensional candle line.

The following are three spherical coordinate operators $\hat{L}^2, \hat{L}_z, \nabla^2, L$ in quantum mechanics[41]. In the spherical coordinates (r, θ, ψ), the operator can be expressed as follows:

$$\hat{L}^2 = -\hbar^2 \left(\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\sin\theta\frac{\partial}{\partial\theta} + \frac{1}{\sin^2\theta}\frac{\partial^2}{2\varphi^2} \right), \tag{10}$$

$$\hat{L}_z = -i\hbar\frac{\partial}{\partial\varphi}, \tag{11}$$

$$\nabla^2 = \frac{1}{r^2}\frac{\partial}{\partial r}r^2\frac{\partial}{\partial r} + \frac{1}{r^2}\left(\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\sin\theta\frac{\partial}{\partial\theta} + \frac{1}{\sin^2\theta}\frac{\partial^2}{\partial\varphi^2} \right), \tag{12}$$

$$L^2 = l(l+1)\hbar^2, \quad l = 0, 1, 2, \cdots \tag{13}$$

Equation 10-13 is an operator in quantum mechanics, and its source history is too complex. This paper tries to make it concise and not repeat. For details, please refer to reference [41]. Finally, the total energy operator of formula 8 can be simplified as follows

$$\hat{H} = -\frac{\hbar^2}{2\mu}\frac{1}{r^2}\frac{\partial}{\partial r}r^2\frac{\partial}{\partial r} + \frac{1}{2\mu r^2}\hat{L}^2 + V(r). \tag{14}$$

The first term is traditionally called the radial kinetic energy operator, and the second term is the centrifugal potential energy operator. That is to say, the "quality" of the candle line of capital movement in the market is subject to both the potential energy of return of value itself and the kinetic energy of market psychological speculation inertia. For equation14, the quantum mechanical operator and the energy equation $H\Psi = E\Psi$ are further simplified

$$H\psi = E\psi, \tag{15}$$

Replace the above equation 10 with 14 to obtain the equation

$$\left[\frac{\hbar^2}{2\mu}\frac{1}{r^2}\frac{\partial}{\partial r}r^2\frac{\partial}{\partial r} + \frac{l(l+1)\hbar^2}{2\mu r^2} + V(r) \right]\psi(r) = E\Psi(r), \tag{16}$$

$$\frac{1}{r^2}\frac{\partial}{\partial r}r^2\frac{\partial}{\partial r}\psi(r) \equiv \frac{1}{r}\frac{\partial^2}{\partial r^2}[r\psi(r)], \tag{17}$$

By introducing equation17 into equation16, the result is simplified so equation16 is simplified to

$$\frac{\hbar^2}{2\mu}\frac{\partial^2}{\partial r^2}+\frac{l(l+1)\hbar^2}{2\mu r^2}+V(r)=E, \tag{18}$$

The equation16 is similar to the stationary Schrodinger equation, but the real $V(r)$ is replaced by the equivalent potential energy$V_t(r)$,Where l is the angular momentum operator in the micro world, and different values represent different energy states. In the financial market, different l values can be used to solve different orbital parameters.

$$V_t(r)=V(r)+\frac{l(l+1)\hbar^2}{2\mu r^2}, \tag{19}$$

Besides the radial equation, the radial wave function $\psi(r)$ must satisfy the normalization condition, which means that the price will not produce black swan and fuse time.

$$\int_0^\infty |\psi(r)|^2 dr=1. \tag{20}$$

In the financial market, when $r\to\infty$, $V(r\to\infty)=0$ is usually taken as the standard of market energy. In this case, equation18 is simplified to obtain the market energy state.

$$\frac{\partial^2}{\partial r^2}\psi(r)+\frac{2\mu E}{\hbar^2}\psi(r)\approx 0, \tag{21}$$

The solution of $E>0$ equation is

$$\psi(r)\approx C_1\sin kr+C_2\cos kr,\quad k=\frac{\sqrt{2\mu E}}{\hbar}, \tag{22}$$

At this time, if the normalization condition is not satisfied, it belongs to continuous energy spectrum in quantum mechanics[41], that is to say, the price in the rising trend is likely to be continuous. $E>0$, presents the continuous inflow or outflow of a large number of funds. In reality, with the influx of a large number of funds, there will be a large-scale trend market, which is the price center is moving slowly. When $E<0$, the solution of the equation is

$$\psi(r)\approx C_3e^{-\alpha \mathrm{r}}+C_4e^{\alpha t},\quad \alpha=\frac{\sqrt{-2\mu E}}{\hbar}, \tag{23}$$

In order to satisfy the normalization condition, Under this condition of $c_4=0$, the energy level can be quantized, and the corresponding wave function is obviously square integrable and can be normalized.The short jump in the market is often faster than the rise, which can be interpreted as discontinuous. The negative oil price event of international crude oil in the first year of 2020 can be explained by this equation.

2.5. Probability distribution of price

In physics, the square of wave function is used to represent the distribution probability in space. Similarly, the probability of price in the market is

$$\mathrm{P}(r)=\int_0^{+\infty}\left|\psi(r)^2\right|\mathrm{d}r. \tag{24}$$

Where 0 represents the lowest price of the commodity to be traded is 0, $+\infty$ means that the price has no upper limit, and the state of the financial system is completely determined by the wave function ψ. The probability of price distribution corresponding to the corresponding price level of each "orbit" is

$$P(n)=\psi^2(n)\quad l=0,1,2\ldots, \tag{25}$$

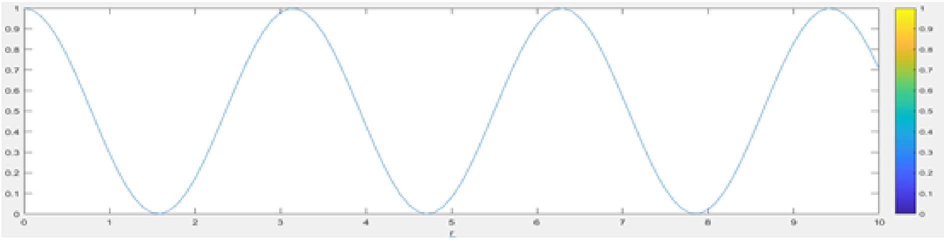


Figure 3. Wave function squared image

Figure 3 The abscissa r is the distance between the price and P in the price, and the ordinate represents the distribution probability of the price. It can be seen that the price moves periodically. The farther the price is from the central P, the lower the corresponding probability is. Because the price is moving in a trend, so its function image is periodic, but in each cycle, the probability of the overall phenomenon is that the farther away from the price center, the smaller the distribution probability. The overall probability within a center is shown in Figure4.

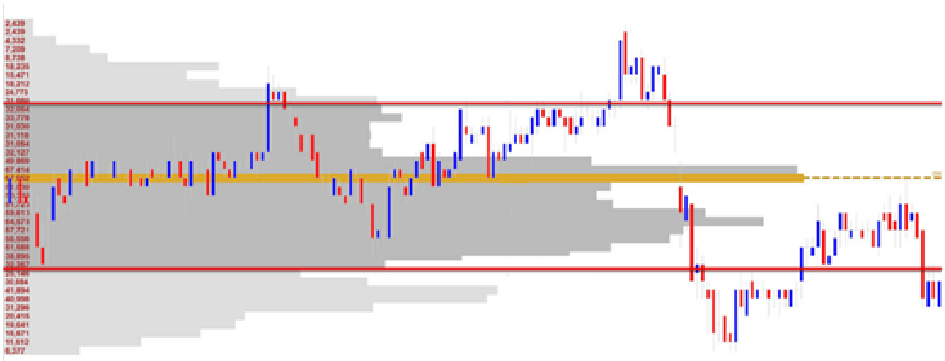


Figure 4. Probability distribution of prices

The middle line in Figure 4 is equivalent to the price center P. the scatter concentration in the figure represents the probability of price distribution, and the greater the scatter density, the greater the probability distribution. It can be seen from the figure that the farther the price is from the center, the lower the probability of distribution. The rarity is the most valuable thing. The point with small probability in the market is often the trading opportunity, which is also in line with the trading theory of Soros, the investment master. The probability of the market in some critical states is extremely unbalanced, and it can be traded.

In order to satisfy the normalization condition, Under this condition of $c_4 = 0$, the energy level can be quantized, and the corresponding wave function is obviously square integrable and can be normalized.The short jump in the market is often faster than the rise, which can be interpreted as discontinuous. The negative oil price event of international crude oil in the first year of 2020 can be explained by this equation.

2.6. Calculating the transition orbit of price

Because this paper is from the perspective of price transition modeling, the price in the market is quantized and discontinuous. Only the probability distribution function is used to predict the price position, which is not accurate enough to implement the strategy,If the energy is absorbed or released, the price will jump to the given orbit Equation16 is finally expressed as

$$-\frac{\hbar^2}{2\mu}\frac{\partial^2}{\partial r^2}\psi(r) + \frac{l(l+1)\hbar^2}{2\mu r^2}\psi(r) + \mu\omega r = \frac{1}{2}\mu w^2 d^2. \tag{26}$$

In order to simplify the calculation, different l values corresponding to different orbital radii are taken as $w = 1, \hbar = 1,$, and different orbital radii are obtained by different angular momentum (see table 1).

Table 1. Orbital radius corresponding to angular momentum

l	1	2	3	4	5	6	7	8	9	10
r	-0.93	2.62	3.18	3.49	1.62	3.86	3.99	-1.49	2	-0.9
$\lvert r\rvert$	0.93	2.62	3.18	3.49	1.62	3.86	3.99	1.49	2	0.9
$\lvert r\rvert/2$	0.47	1.31	1.59	1.745	0.81	1.93	2	0.745	1	0.45

Since the value $d = 1$, the calculated value of $|r|/2$ is equivalent to a coefficient of the distance between the upper and lower price centers. As can be seen from table 1, the values of r are very close to the golden section values of 1.618 and 2.618, and 1.5 and 2 are important figures considered by Wall Street investment master Gann. It can be seen that there is a certain relationship between quantum model algorithm and natural phenomena.

2.7. Trading rules

As shown in Figure 5,the line in the middle is the price center P. the transition from the price center up or down to the corresponding orbit will take place, and each orbit corresponds to a different probability. Simply understood as the farther the price is from the center, the greater the force of its return to the center. In order to simplify the verification process, automatic trading procedures are set up. When the price reaches the bottom track, the price will be bought and sold at the top track.

Figure 5. Entry and exit rules

3. Empirical analysis

Based on the model established in Section 2, this section selects the historical data of one hour cycle of crude oil price from February 1, 2018 to January 1, 2020, and the data is from the official website of the United States Energy Administration for empirical analysis.

3.1. Data processing

In this paper, the time series of influencing factors are extracted using the spectral analysis method in economics. The basic idea of spectrum analysis is to divide the time series into different sequences and stack them. By studying and comparing the changes of each component, the wave characteristics in different frequency domains can be fully displayed. With the help of Eviews software, the short-term fluctuation level of time series data, such as international crude oil benchmark average price, nominal effective exchange rate of US dollar, commercial inventory of us energy administration and net position of non-commercial traders are separated.

The function of spectrum filtering is to remove the clutter in the market and extract the fluctuation frequency in the trend market. According to the frequency spectrum filtering on the cycle period of Figure 6-9, four dimensions w are taken respectively w_1, w_2, w_3, w_4, corresponding to 12.5, 1.3, 12.5, 12.5 wave dimensions respectively.

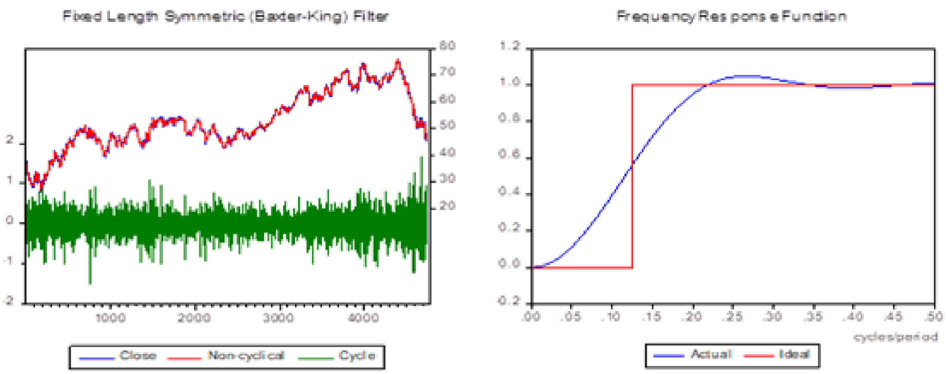


Figure 6. 30 minute filter chart of crude oil price

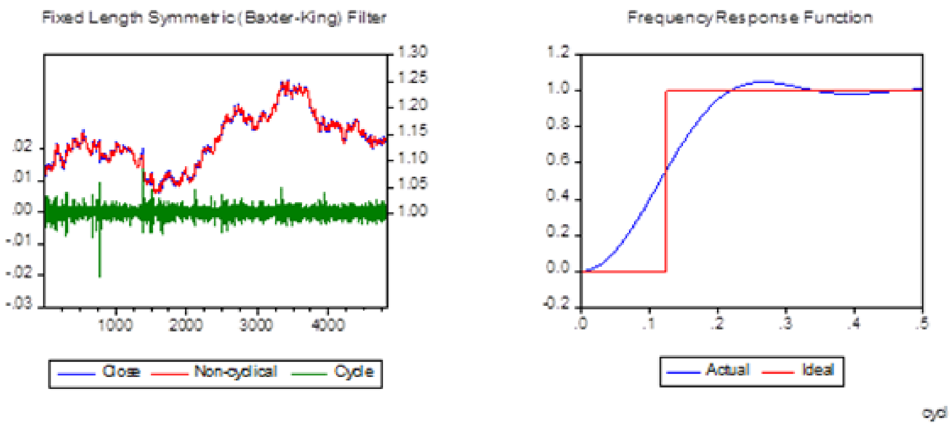


Figure 7. Filtering analysis chart of 30 minute period of US dollar exchange rate

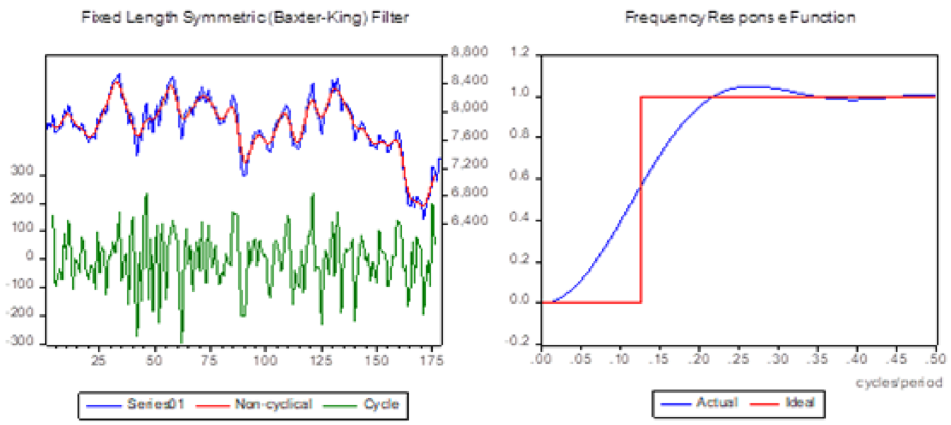


Figure 8. Filter analysis chart of crude oil inventory with 30 minute cycle

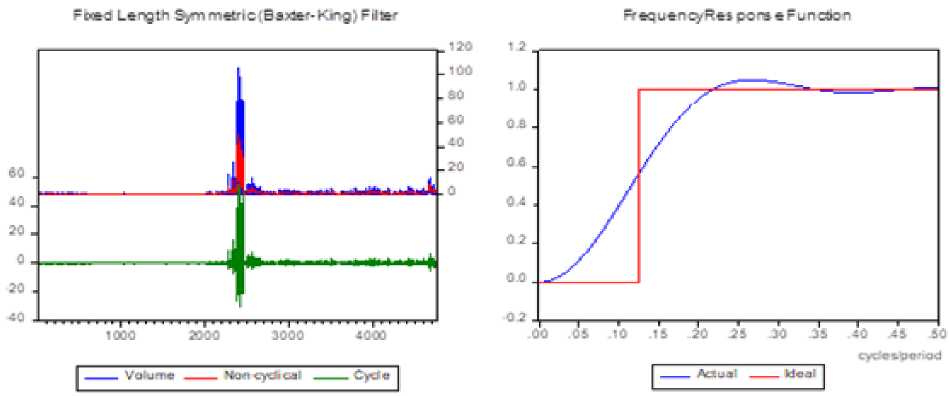


Figure 9. Filtering analysis chart of 30 minute period of crude oil position

Through the spectrum filtering, the fluctuation frequency w of four main factors is extracted w_1, w_2, w_3, w_4 then the main fluctuation frequency of the model is $w = \sqrt{w_1 w_2 w_3 w_4} = 50.39$. The reason for taking the geometric square root is to consider the influence of various factors comprehensively[42].In fact, w is the frequency of the four influencing factors, the benchmark average price of international crude oil, the nominal effective exchange rate of the US dollar, the commercial inventory of the US Energy Administration and the market position. Among them, three of them are the attributes of crude oil, and their values are the same. There is also an attribute of the US dollar exchange rate, which links several attributes together through geometric average to reflect the nature of the market.

3.2. Forecast future price

The trading mechanism behind the financial market is that the buying and selling orders at different prices are changing all the time, so it is impossible to predict the current or future price changes strictly and accurately. In the price coordinate system, the uncertainty relation in the stock market can be expressed as

$$(\Delta p)^2(\Delta t)^2 \geq \hbar^2/4\pi^2 \tag{27}$$
$$(\Delta p)(\Delta t) \geq h/2\pi \tag{28}$$

Where Δp and Δt are the standard deviations of the price of financial subject matter and its change trend, respectively. In quantum mechanics, $\hbar/2\pi$ is a reduced Planck constant. Similarly, there is a Planck constant in the financial market, which represents the trading volume per unit time in the market. The value taken in this paper is the trading dimension of the market per second, according to the amount of capital in a certain period (official website of the United States Energy Administration) eia.gov.cn The data are available) and then divided by the total time of the period. From the perspective of investment expectation, it is the profit value of the minimum expected return on investment. Due to the unpredictability of a certain range, the price range $d = \hbar/2\pi$, that is, the minimum range that can be predicted is selected.

$$p_t = P \pm \sum_{i}^{t} d \quad t = 1, 2, 3 \ldots \tag{29}$$

p_t represents the price of the candle line at time t. since the candle line in the market is counted in an integer, t is taken as an integer. D is the minimum range to select the forecast price. Suppose that in a trend market, the price does not reach 90% reversal probability, the trend will not reverse. When the price is in an upward trend, it is an addition operation; when the price is in a downward trend, it is a subtraction operation.

Put all the points in the market (p_t, t) a line formed by connecting lines. The price at t time in the future predicted according to the past.

$$\left\{ p_1, p_2, p_3......p_t \mid \psi^2 \left(\sum_1^t d \right) > 0.9 \right\}. \tag{30}$$

$$\left\{ p_t, p_{t+1}, p_{t+2,...} p_\infty \mid \psi^2 \left(\sum_t^\infty d \right) > 0.9 \right\}. \tag{31}$$

The market is composed of countless rising and falling stages. Add up all the stages to form figure 10 .The expression of the upward trend is equation30; the expression of the downward trend is equation31.

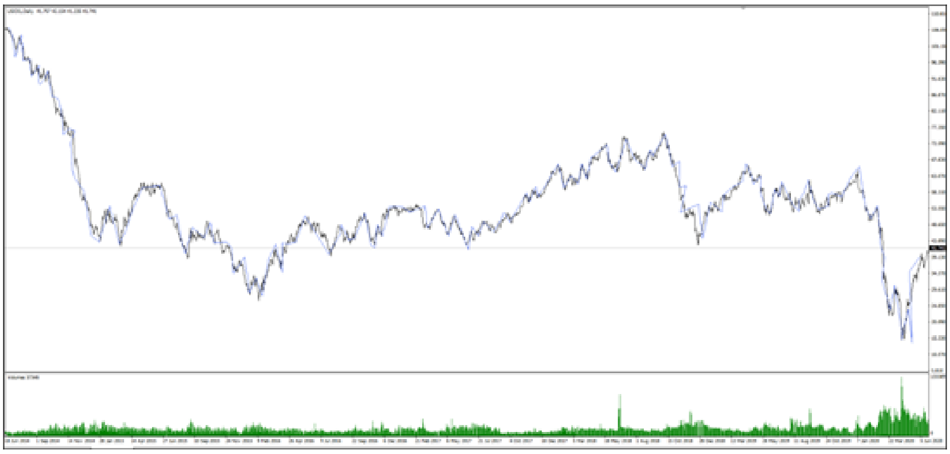


Figure 10. Theoretical and real prediction data

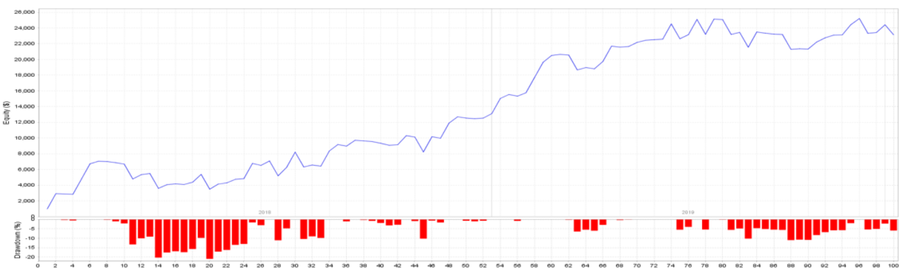
As shown in Figure 10, the blue line is the forecast data, the black line is the real data, and the price fits the real market well. Because the force fields of price orbits with different periods influence each other, only the minimum period is considered in order to simplify the calculation, so the prediction data will have errors.

3.3. *Empirical effect*

The 30 minute crude oil data from February 1, 2018 to January 1, 2020 is selected as the sample data, and the actual data is verified according to the import and export strategy of this model. Because the probability of entering and leaving the market is too large, it only involves a fixed price.

Figure 11. Changes in net worth, volume and pullback

246 As shown in Figure 11, the main profit time of the market is the opening time of the United States. During this period, a large number of funds entered the market, the market was active, and the market absorbed or released energy, so the price jumped. The implementation strategy of this paper is based on 30 minutes cycle, so the profit difference between daily cycle and monthly cycle is not very obvious. Most positions are held in 48 hours, that is to say, an average of two days to complete a price cycle. Considering that the international crude oil market operates all day and the market is highly active, it is in line with the reality of the market to complete the price fluctuation every two days. In addition, from the hourly profit and loss chart, we can see that the market is in a non transition equilibrium state most of the time, and this change occurs at a certain time node, that is to say, the market needs to accumulate energy for a period of time to achieve price transition.



Results

History Quality:	99%				
Bars:	23714	Ticks:	92346	Symbols:	1
Total Net Profit:	21 346.71	Balance Drawdown Absolute:	140.91	Equity Drawdown Absolute:	709.17
Gross Profit:	48 447.63	Balance Drawdown Maximal:	3 379.53 (10.62%)	Equity Drawdown Maximal:	4 051.74 (26.05%)
Gross Loss:	-27 100.92	Balance Drawdown Relative:	20.39% (3 083.85)	Equity Drawdown Relative:	26.05% (4 051.74)
Profit Factor:	1.79	Expected Payoff:	195.84	Margin Level:	2011.00%
Recovery Factor:	5.27	Sharpe Ratio:	0.23	Z-Score:	1.18 (76.20%)
AHPR:	1.0118 (1.18%)	LR Correlation:	0.95	OnTester result:	0
GHPR:	1.0105 (1.05%)	LR Standard Error:	2 530.20		
Total Trades:	109	Short Trades (won %):	43 (65.12%)	Long Trades (won %):	66 (43.94%)
Total Deals:	218	Profit Trades (% of total):	57 (52.29%)	Loss Trades (% of total):	52 (47.71%)
		Largest profit trade:	1 815.66	Largest loss trade:	-919.38
		Average profit trade:	849.96	Average loss trade:	-521.17
		Maximum consecutive wins ($):	5 (3 342.57)	Maximum consecutive losses ($):	4 (-2 940.63)
		Maximal consecutive profit (count):	4 338.18 (4)	Maximal consecutive loss (count):	-2 940.63 (4)
		Average consecutive wins:	2	Average consecutive losses:	2

Figure 12. Crude oil profit effect chart

256 As shown in Figure12,The two-year return rate is 113.46%, which proves that the model is effective. Sharpe ratio is an index to measure the return risk. It represents that investors can get several excess returns for every extra risk they take. Because the selected parameters are the most profitable of all portfolios, and if you take more risks, the profitability will not increase significantly, so the Sharpe ratio is 0.23, which is not a very high value. Ahpr and ghpr are indicators to measure the quality of

each transaction. If the value is greater than 1, it means that the transaction is profitable and of high quality. The ahpr and ghpr of the model are both greater than 1, indicating that the transaction quality of the model is very high. LR measures the stability of account profit growth, the more close to 1, the more stable the growth. The model value is 0.95, close to 1, which shows the correctness of the theory. From the perspective of net worth withdrawal, the scope of net worth withdrawal is within 20%, and the strategy adopted is feasible. From the perspective of trading loss, there is a small part of the loss, because the market is dynamic, especially in a small period, it is impossible to make an absolutely accurate forecast, as long as the forecast effect reaches a certain reasonable range.

3.4. Data results

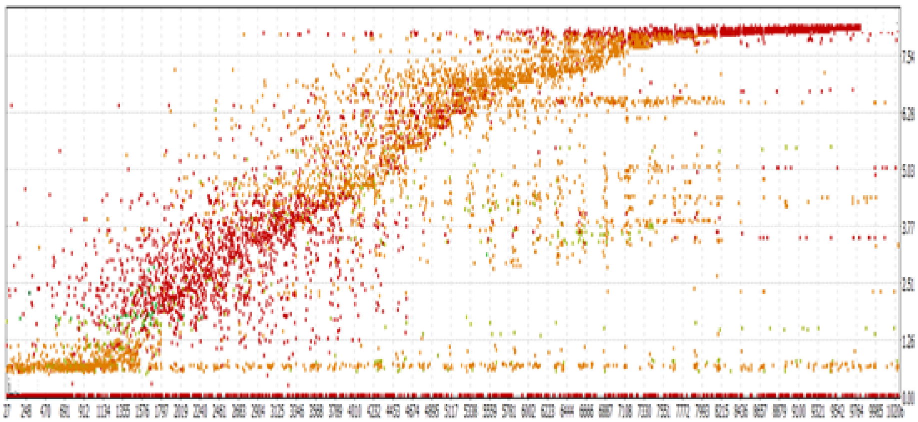


Figure 13. Aggregation effect of profit factors

Set up a trading program, choose to trade randomly in the market, and the result of each transaction is expressed in dots.As shown in Figure13, the abscissa represents the number of transactions, and the ordinate represents the profitability. The larger the ordinate, the greater the profitability.It can be seen from the figure that the points in the figure are not evenly distributed, but are aggregated in some areas.The position of point aggregation in the graph can be understood as the position of transition orbit in the market, because the probability of price transition near each orbit is higher than that of non orbit position.It also indirectly proves the correctness of the price transition orbit calculated by the model.

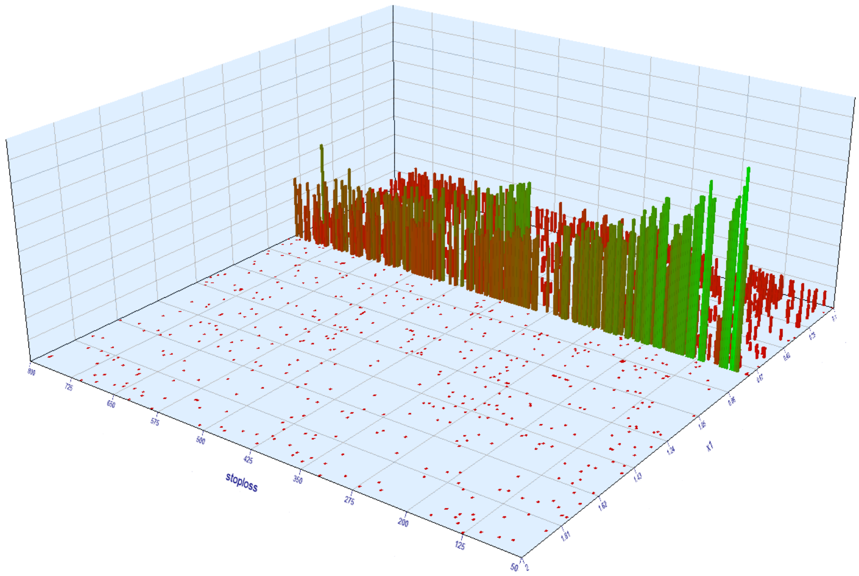


Figure 14. Profitability under different parameters

As shown in Figure 14 , the three-dimensional column in the figure represents the rate of return of different track parameters selected by the model. The higher the column is, the higher the rate of return it represents. On the plane, the two abscissa represent the fluctuation range of the price around the center. It can be seen from the figure that the rate of return is also concentrated in some cases. There is a row of parameters with the largest return rate, which can be understood as the derivative of probability distribution function $d\psi/dr = 0$ in the model to form the parameter corresponding to the radius of the ground state.Where $\varphi(r)$ is the energy function of the market price, which is related to the fluctuation range of the price.Here, it is equivalent to the turning point of market energy depletion

Figure 15. Profitability under different parameters

As shown in the figure 15, there are four situations in which representative profit curve is selected, and the situation that conforms to the transition degree from top to bottom is becoming smaller and smaller. The fourth graph at the bottom is directly from the most unfavorable situation of the strategy, which can be understood as the implementation against the direction of the transition. It can be seen from the figure that its net value is decreasing and finally is 0. Moreover, its net value status is discontinuous and presents a broken line. It proves the existence of price jump from the reverse side and the feasibility of the model in this paper.

4. Conclusions

In order to achieve the goal of forecasting the international crude oil price, this paper compares the price movement with the movement of particles in the micro world, and establishes a financial quantum model. Using fuzzy mathematics and spectrum filtering to process the original market data, and then introduces wave function, Schrodinger equation and related quantum mechanics algorithm to predict the future price of international crude oil, and formulates a practical trading strategy.

Then, using the crude oil data of the past two years, the model is verified by the MetaQuotes Software. By choosing different parameters, the stability, effectiveness and profitability of the model are verified. The empirical results show that the results of quantum mechanics calculation and the results of traditional analysis in the financial market have a certain connection, and have the same essence. It also proves that the theory of this paper is effective, and the basis of modeling is reasonable, which provides guidance for investors, enterprises and institutions to make investment decisions.

The research work of this paper can not only provide a broader perspective for scholars, but also provide some insights and Enlightenment for enterprise decision-making. Because this study describes market energy from the perspective of wave function, the limitations of the study are also related to wave function. In the future work, we will consider more realistic characteristics and design a more suitable model for the market, such as: (1) constructing a more suitable wave function to describe the energy system of the market; (2) using a more suitable algorithm to predict the future price path of the market; (3) introducing more reasonable parameters to make the model more effective and practical.

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Sample Availability: Samples of the compounds ...... are available from the authors.