The Study of Evaluation and Prediction of China’s Crude Oil’s Safety Based on the Degree of Foreign Dependence

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Abstract. As the blood of industry, crude oil, to a large extent, determines the security and development of a country. China has been importing very much overseas crude oil for a long time, making it strongly necessary to study China's crude oil safety. Therefore, based on the degree of foreign dependence, the regular curves of overseas import crude oil and China's crude oil consumption are computed by numerical fitting to evaluate and predict the safety of China's crude oil, and the results show that (1) the degree of foreign dependence of China's crude oil is higher than the international average value, 20%, for a long time, and (2) it has exceeded the international high security warning line by 50% since 2009 and reached nearly 70% at 2017, probably soaring to 90% in 2020. So, China's overseas crude oil has been in a highly dangerous state for a long time. Therefore, it is necessary to reduce the degree of foreign dependence of China's crude oil to improve the safety of China's crude oil with the following aspects: (1) developing and making use of alternative green energy, and (2) improving the efficiency of crude oil utilization and strengthening secondary and multiple use of the crude oil.

1. Introduction
As a strategic resource, crude oil, which plays a pivotal role in the development of the country, is called black gold, industrial blood, king of commodities, etc. Since reforming and opening up at 1978, China’s economic development has made tremendous progress, and the consumption and consumption rate of crude oil have increased dramatically, with great concerns from business operators and scholars of the consumption of crude oil, overseas supply, supply chain structure, crude oil price, processing technology, and transportation safety. Therefore, the evaluation and prediction of China's crude oil safety are of great significance academically and practically.

There is a significant positive correlation between energy consumption and economic growth, saying that energy consumption can promote economic growth and in turn economic growth promotes energy consumption[1]. In view of this, many scholars have carried out empirical research on the relationship between local energy consumption and economic growth, demonstrated the relationship between them, and put forward corresponding policies based on the actual situation of the local or research countries to reduce energy consumption under the premise of ensuring stable economic development[2–5]. Like most scholars, Yeti believes that terrorism and geopolitics are important factors in the safety of crude oil, especially in the Middle East where crude oil production is huge and local political instability is particularly evident[6]; at the same time, more and more scholars recognizing the important role of China's growing crude oil consumption in global crude oil trade[7, 8]. In China, scholars' discussion on crude oil safety can be divided into different types according to different standards, i.e. single index evaluation research, multi-index evaluation system research,
qualitative analysis, model quantitative analysis, economic analysis, technical analysis, etc., and this paper focuses on the analysis of evaluation indicators. Zhang F. S. and Li Wei believe that China's crude oil has changed greatly, supported by the scenario that the structure of imported crude oil has changed greatly, the quantity of crude oil imports has also soared, and the state needs to adjust the structure of crude oil and establish crude oil reserves to ensure China's security\[9\]. Yue L. Q. believes that, in addition to geographical factors such as the strait, China's crude oil cruise ships and port handling capacity are also insufficient\[10\]. Yan Fei believes that, in addition to geographical factors such as the strait, China's crude oil cruise ships and port handling capacity are also insufficient\[11\]. Li X. X., Ji S. M., Huang Y. C. and Qian Yu adopted external dependence, storage & recovery rate, crude oil import concentration, mining rate, crude oil transportation risk, crude oil strategic reserve ratio, crude oil to energy ratio, crude oil consumption growth rate, the crude oil price volatility, the international crude oil safety situation, the crude oil loss intensity and the energy replacement rate index comprehensively to evaluate the current safety status of China's crude oil\[12\]. Zhu Yong and Wang Y. Q. used analytic hierarchy process, correlation analysis and principal component analysis to quantitatively analyse the factors affecting the performance of Sinopec crude oil supply chain, and then constructed the crude oil supply chain performance evaluation index system with the following indicators, i.e. strategic synergy, resource surplus capacity, demand satisfaction degree, service quality, procurement quantity, financial support and political harmony\[13\]. By analysing the crude oil supply chain, transportation route, capacity and import demand, Song Dan established a target planning model to optimize the network structure of China's crude oil supply chain\[14\]. Tian M. H. explained that China's crude oil demand is high and the degree of foreign dependence is high, showing that China's crude oil security situation is relatively severe\[15\]. Through domestic and foreign research and analysis, it is obviously that (1) China's crude oil consumption has increased rapidly and played an vital role in international crude oil trade, and (2) the degree of foreign dependence has been applied to China's overseas crude oil safety evaluation. However, most scholars have simply mentioned the use of the degree of foreign dependence of crude oil. Although it, to a certain extent, can explain the situation of China's crude oil, the final evaluation results are limited in persuasiveness due to the lack of mathematical models. Therefore, based on the degree of foreign dependence, this paper establishes a comprehensive evaluation model to evaluate China's crude oil.

2. Modelling & Processing
Since it became a net importer of crude oil at 1993, the amount of crude oil of China imported from overseas has increased year by year. China’s net import volume was 337.7 million tons at 2017, accounting for about 20% of the total overseas crude oil imports of all countries in the world. At the same time, China’s the degree of foreign dependence was as high as 69.38%, far exceeding the world average of 20%, significantly exceeding the international crude oil security warning line by 50%, and was in a highly unsafe state. The degree of foreign dependence is determined by the two indicators of overseas crude oil imports and China's oil consumption. Therefore, it is necessary to develop a model with the two indicators to analyse China's crude oil’s safety.

2.1. Hypothesis
The Hypothesis are made as follows,

- H1: During the research period, China's overseas crude oil import have strong regularity and data fitting.
- H2: During the study period, China’s oil consumption has a strong regularity and data fitting.
- H3: During the research period, due to China’s strong ability to maintain stability and manage itself, any event, including world trade wars, natural disasters, strikes, overseas transfer of factories, rising labour costs, military wars, etc., will not affect China's crude oil’s import and consumption dramatically.
2.2. Variables’ Definition

\( t \): time (\( t \geq 2001 \))

\( I(t) \): the amount of China’s overseas crude oil import at \( t \)-year

\( C(t) \): the amount of China’s overseas crude oil consumption at \( t \)-year

\( R(t) \): China’s the degree of foreign dependence at \( t \)-year

\( D_I(t) \): the deviation rate of the predicating amount of China’s overseas crude oil import at \( t \)-year

\( D_C(t) \): the deviation rate of the predicating amount of China’s overseas crude oil consumption at \( t \)-year

\( R^2 \): the accuracy of degree of numerical fitting

2.3. Model Construction

By definition, the degree of foreign dependence of the year is equal to the ratio of overseas crude oil imports to oil consumption, says:

\[
R(t) = \frac{I(t)}{C(t)}
\]

Equation.1

Where \( I(t) \) could be computed by numerical fitting, whose fitness is decided by the accuracy, \( R^2 \) (the higher, the better), and the deviation rate \( D_I(t) \) (the less, the better), and \( C(t) \) could be computed by numerical fitting, whose fitness is decided by the accuracy, \( R^2 \) (the higher, the better), and the deviation rate \( D_C(t) \) (the less, the better). Meanwhile, both \( I(t) \) and \( C(t) \) are translated to the left by 2000 units to improve the fitting accuracy.

2.4. Model Solving

Data can be collected through the BP World Energy Statistical Yearbook and the official website of the National Bureau of Statistics, as shown at Tab.1.

| Year | \( t \) | \( I(t) \) (Million Ton) | \( C(t) \) (Million Ton) |
|------|------|-----------------|-----------------|
| 2001 | 0    | 60.3            | 227.9           |
| 2002 | 1    | 69.4            | 247.5           |
| 2003 | 2    | 91.1            | 271.7           |
| 2004 | 3    | 122.7           | 318.9           |
| 2005 | 4    | 126.8           | 327.8           |
| 2006 | 5    | 145.8           | 351.2           |
| 2007 | 6    | 163.2           | 377.7           |
| 2008 | 7    | 178.8           | 385.5           |
| 2009 | 8    | 203.5           | 400.0           |
| 2010 | 9    | 234.6           | 455.2           |
| 2011 | 10   | 252.9           | 472.1           |
| 2012 | 11   | 271.3           | 494.9           |

Furthermore, all the data from Tab.1 could be used to conduct numerical fitting, and the results are shown at Tab.2 and Tab.3.

| Curve Type       | \( I(t) \)       | \( R^2 \) | \( R^2 \geq 0.99 \) |
|------------------|------------------|-----------|---------------------|
| Exponent         | \( I_1 = 67.259 e^{0.1132t} \) | 0.9643    | ×                   |
| Logarithm        | \( I_2 = 123.25 \ln(t) - 28.048 \) | 0.8113    | ×                   |
| Linear Function  | \( I_3 = 21.378t - 22.459 \) | 0.9830    | ×                   |
| Quadratic Function| \( I_4 = 0.5037t^2 + 12.312t + 51.171 \) | 0.9933    | √                   |
| Cubic Function   | \( I_5 = 0.0567t^3 - 1.0262t^2 + 23.645t + 31.791 \) | 0.9957    | √                   |
| Quartic Function | \( I_6 = 0.0092t^4 - 0.2744t^3 + 2.8828t^2 + 6.9233t + 50.665 \) | 0.9968    | √                   |
| Quintic Function | \( I_7 = 0.0017t^5 - 0.0665t^4 + 0.9568t^3 - 5.8254t^2 + 32.076t + 29.563 \) | 0.9940    | √                   |

According to the data in Tab.2 and Tab.3, the fitting degree of the curve function of both crude oil import and crude oil consumption in China is relatively high (generally, the fitting curve is good if \( R^2 \geq 0.8 \)), meaning that all the fitting curves meet the requirements. Therefore, it is necessary to further
discuss and analyze the curves, whose $R^2 \geq 0.99$, which reflect the changing law of crude oil import and crude oil consumption so that the fittest curves could be found out. Therefore, deviation rates, $D_{(0)}$ and $D_{C(t)}$, are introduced into evaluation. After calculation, Tab. 4 and Tab. 5 are obtained.

Tab.3 China's Crude Oil Consumption Volume Fitting Curve Function List

| CURVE TYPE | $C_{(t)}$ | $R^2$ | $R^2 \geq 0.99$ |
|------------|-----------|-------|------------------|
| Exponent   | $C_1 = 235.18 e^{0.061t}$ | 0.9753 | × |
| Logarithm  | $C_2 = 142.56 \ln(t) + 139.87$ | 0.8749 | × |
| Linear Function | $C_3 = 23.957t + 205.24$ | 0.9949 | √ |
| Quadratic Function | $C_4 = -0.0079t^2 + 24.099t + 204.79$ | 0.9949 | √ |
| Cubic Function | $C_5 = 0.003t^3 - 0.0907t^2 + 24.713t + 203.74$ | 0.9949 | √ |
| Quartic Function | $C_6 = -0.0082t^4 + 0.2977t^3 - 3.5693t^2 + 39.593t + 186.94$ | 0.9956 | √ |
| Quintic Function | $C_7 = -0.0002t^5 - 0.0009t^4 + 0.1507t^3 - 2.5297t^2 + 36.59 + 189.46$ | 0.9956 | √ |

Tab.4 China's Overseas Crude Oil Import Volume Fitting Curve Function Deviation Rate List

| $t$ | No. | O. V. | F. V. | $D_{(0)}$ | O. V. | F. V. | $D_{(0)}$ | O. V. | F. V. | $D_{(0)}$ | O. V. | F. V. | $D_{(0)}$ |
|-----|-----|-------|-------|-----------|-------|-------|-----------|-------|-------|-----------|-------|-------|-----------|
| 2001 | 1   | 60.3  | 64.0  | 6.114     | 60.3  | 54.5  | 9.674     | 60.3  | 60.2  | 0.156     | 60.3  | 56.7  | 5.961     |
| 2002 | 2   | 69.4  | 77.8  | 12.118    | 69.4  | 75.4  | 8.688     | 69.4  | 74.0  | 6.621     | 69.4  | 77.1  | 11.035    |
| 2003 | 3   | 91.1  | 92.6  | 1.691     | 91.1  | 95.0  | 4.304     | 91.1  | 90.7  | 0.421     | 91.1  | 94.2  | 3.428     |
| 2004 | 4   | 122.7 | 108.5 | 11.591    | 122.7 | 113.6 | 7.432     | 122.7 | 109.3 | 10.940    | 122.7 | 110.6 | 9.851     |
| 2005 | 5   | 126.8 | 125.3 | 1.164     | 126.8 | 131.4 | 3.666     | 126.8 | 128.8 | 1.578     | 126.8 | 127.7 | 0.677     |
| 2006 | 6   | 145.8 | 143.2 | 1.800     | 145.8 | 149.0 | 2.171     | 145.8 | 148.6 | 1.947     | 145.8 | 146.0 | 0.143     |
| 2007 | 7   | 163.2 | 162.0 | 0.713     | 163.2 | 166.5 | 2.004     | 163.2 | 168.4 | 3.159     | 163.2 | 165.7 | 1.555     |
| 2008 | 8   | 178.8 | 181.9 | 1.736     | 178.8 | 184.3 | 3.079     | 178.8 | 187.7 | 5.001     | 178.8 | 186.5 | 4.334     |
| 2009 | 9   | 203.5 | 202.8 | 0.354     | 203.5 | 202.8 | 0.340     | 203.5 | 206.8 | 1.624     | 203.5 | 208.0 | 2.198     |
| 2010 | 10  | 234.6 | 224.7 | 4.237     | 234.6 | 222.3 | 5.234     | 234.6 | 225.8 | 3.760     | 234.6 | 229.6 | 2.139     |
| 2011 | 11  | 252.9 | 247.6 | 2.115     | 252.9 | 243.2 | 3.842     | 252.9 | 245.1 | 3.080     | 252.9 | 251.2 | 0.678     |
| 2012 | 12  | 271.3 | 271.4 | 0.054     | 271.3 | 265.7 | 2.051     | 271.3 | 265.5 | 2.147     | 271.3 | 273.0 | 0.641     |
| 2013 | 13  | 282.6 | 296.4 | 4.866     | 282.6 | 290.3 | 2.731     | 282.6 | 287.8 | 1.828     | 282.6 | 296.0 | 4.756     |
| 2014 | 14  | 309.2 | 322.3 | 4.225     | 309.2 | 317.3 | 2.610     | 309.2 | 313.1 | 1.259     | 309.2 | 321.9 | 4.122     |
| 2015 | 15  | 335.8 | 349.2 | 3.986     | 335.8 | 346.9 | 3.316     | 335.8 | 342.8 | 2.083     | 335.8 | 353.6 | 5.290     |
| 2016 | 16  | 382.6 | 377.1 | 1.435     | 382.6 | 379.6 | 0.772     | 382.6 | 378.4 | 1.092     | 382.6 | 395.0 | 3.232     |
| 2017 | 17  | 422.1 | 406.0 | 3.804     | 422.1 | 415.8 | 1.504     | 422.1 | 421.8 | 0.081     | 422.1 | 451.7 | 7.009     |
| Average value / % | 3.647 | 3.730 | 2.752 | 3.944 |

Notes: (1) A.V. is actual value, meaning its original value. (2) F. V. is fitting value, meaning its predicking value. (3) the unit of O.V & F.V. is million ton.

It can be seen from Tab.4 that all the deviation rates of quadratic function, cubic function, quartic function and quintic function curves of all the fitting crude oil imports are all within 4%, indicating that the fitting degree is high and the deviation rate is also low, of whom the curve with the lowest.
shown in Tab.4, the deviation rates of the degree of foreign dependence are all within 2%, showing that the fitting degree is not only high, but also the deviation rate is also very low, and the curve with the lowest deviation rate, 2.752%, is from quartic function. Meanwhile it can be seen from Tab.5 that in all the curves of the fitting crude oil consumption, the deviation rates of linear function, quadratic function, cubic function, quartic function and quintic function are all within 2%, showing that the fitting degree is not only high, but also the deviation rate is also very low, and the curve with the lowest deviation rate, 1.591%, is cubic function. Therefore, for the crude oil import and crude oil consumption, the quartic function curve, shown as Equation.2, and the cubic function curve, shown as Equation.3, are selected for evaluation and prediction. Considering Equation.1, Equation.2, and Equation.3, the curve of China’s crude oil safety’s evaluation is induced as Equation.4.

\[ I = 0.0092t^4 - 0.2744t^3 + 2.8828t^2 + 6.9233t + 50.665 \]
Equation.2

\[ C = 0.003t^3 - 0.0907t^2 + 24.713t + 203.74 \]
Equation.3

\[ R = \frac{I}{C} = \frac{0.0092t^4 - 0.2744t^3 + 2.8828t^2 + 6.9233t + 50.665}{0.003t^3 - 0.0907t^2 + 24.713t + 203.74} \]
Equation.4

All the data of time (No.) into Equation.4, the final results of the degree of foreign dependence are shown in Tab.6.
3. Conclusion

3.1. Discussion
As can be seen from Tab.6, China's overseas crude oil's the degree of foreign dependence has been much higher than the international average value, 20%, for a long time, and the growth rate is very obvious, reaching the international high security warning line by 50% at 2009, since which, it has been much higher than 50%, and the growth rate is very obvious as before, actually reaching about 70% by 2017. In addition, by observing the predicted values, it is likely that by 2020, it will be as high as 90%, indicating that China's overseas crude oil is in an extremely dangerous state. The reason is the continual advancement of China's industrialization process and the popularity of household cars, etc. Although the number of domestic independent exploration and development of crude oil has been steadily increased, the rate of consumption growth is greater than the speed of domestic independent exploration and development, making dramatic growth of the degree of foreign dependence and severely tense of China's crude oil's safety, which need much attention of relevant senior leaders.

3.2. Suggestion
To improve the safety of China's crude oil from the perspective of the degree of foreign dependence, it is obviously unscientific and impractical to suppress domestic crude oil consumption or reduce overseas crude oil imports. Therefore, it’s only rational to reduce the degree of dependence of China's crude oil by increasing domestic crude oil’s supply. However, the quantity and speed of domestic crude oil’s exploration and development are a national strategic decision, which needs to be evaluated and decided in the long run. It may not be the best choice to large-scale explore and develop. Therefore, the following two aspects that we may stick to are, (1) developing and making use of alternative green energy, which the state and society should focus on and invest, such as solar energy, wind energy, electric energy, etc., so that they can be applied to the field of crude oil supply on a large scale. On the one hand, it can reduce energy consumption, and on the other hand, it also reduces pollution to the environment. (2) Improving the utilization efficiency of crude oil and strengthening the secondary and multiple use of crude oil products can reduce the demand for total crude oil and reduce environmental pollution to a certain extent. Both of the two above methods focus on efficiency and environmental protection, which deserve attention and application promotion.

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