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ORIGINAL RESEARCH ARTICLE

# The macroeconomic impact of oil price volatility and import volumes

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## ABSTRACT

Nowadays, oil is not only a necessary energy for industrial development but also an important strategic resource for the international economy. Previously, many factors led to a sharp rise in international crude oil prices. Therefore, it is of great significance to explore the influence mechanism between oil price fluctuations and the macroeconomy. In this paper, the VAR model is used to quantitatively analyze the dynamic relationship between oil price, China's GDP, China's CPI, and oil import volume, and the orthogonal impulse response analysis and Granger causality test are carried out. The results show that China's crude oil import volume is the largest factor in GDP; that is, the early changes in China's crude oil imports can effectively explain the changes in China's GDP. China's CPI and GDP show a short-term inverse response, and the change in the data is more dependent on the data of the previous quarter. Given the above problems, this paper proposes that China should attach importance to the long-term stability of oil exploitation, reserves, and the oil market and maintain the stability of the oil trade market by adjusting macroeconomic and gasoline prices when necessary.

***Keywords:*** Chinese oil market; macroeconomic; VAR model

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## 1. Introduction

After the unprecedented impact of economic globalization, the international crude oil market has shrunk seriously. Dai and Shi[1] pointed out that the current crude oil supply and demand are both breaking records, and the market fundamentals are seriously oversupplied, which will have a profound impact on the future oil and gas industry. At present, from the domestic point of view, as the world's largest crude oil importer, China's crude oil prices have continued to fall in line with market expectations, and all aspects of China's economic and social development have been greatly affected. From abroad, factors such as the epidemic among major oil consumers in the United States, exchange rate issues, and international conflicts have led to changes in international oil prices. In addition, the escalation of the conflict between Russia and Ukraine and the mutual sanctions of Western countries such as the United States and Europe have also caused great interference in the rise of international crude oil prices.

Petroleum resources are an indispensable means of production in the process of urban development. Industry, agriculture, transportation, and other sectors are closely related to crude oil and its derivatives. The rise and fall of crude oil prices have a significant impact on modern economies. Smith-Nonini[2] examines the relationship between

America's rapid loss of energy sovereignty in the 1970s and the speculative finance that reshaped global trade relations. The close relationship between U.S. influence on the oil market since the 1973 energy crisis and the continued global hegemony of the United States is presented, with the actual geopolitical control over oil production behind U.S. power. In summary, the natural nature of crude oil and its development from a raw material for industrial production to a key strategic resource in the international economy determine the indispensable role of crude oil in economic growth. Therefore, it is of great practical significance to study the influence of international crude oil prices and oil import volumes on the national economy in both theory and practice.

The structure of this paper is as follows: the second part combines the relevant research papers on oil prices, oil import situation, and macroeconomics, putting forward the theoretical hypothesis. The third part is the research method and data. The fourth part is the result of empirical data analysis. The fifth part summarizes the full text and puts forward some suggestions.

## 2. Literature review

Oil is the lifeblood of industrial development and social life. In the era of high oil prices, the field of research on oil prices and social impacts in various countries is generally popular, and this literature review has combed through relevant papers at home and abroad to elaborate on key arguments on the current status and development of research. In searching for relevant research literature, the team obtained a total of 10,278 articles from journals on "oil and economy" through a precise search of subject terms on the internet. The following is a literature review of typical papers read by the team in three areas: "Oil price volatility and its current situation," "research on the impact of oil price volatility on the macro economy," and "Ways to optimize China's oil import markets."

### 2.1. Factors of oil price fluctuation—There are many factors affecting oil prices, and the uncertainty of oil price change is strong

At the level of causes of oil price changes, Zarubina[3] sorted out and analyzed the key factors affecting the price of refined oil products, proposed the classification of factors, supply factors, and demand factors, allocated objective factors and subjective factors, and analyzed seasonal factors. Kilian[4] believes that, relative to the fundamentals, the actual price of oil is endogenous, and oil price shocks will not occur under other conditions. Yang et al.[5] proposed that economic change is the key factor in determining the long-term change in oil prices. External factors such as inventory changes, political factors, natural disasters, and technological improvements can only affect the short-term trend of oil prices, so they cannot be used to predict the long-term trend of oil prices. Liu et al.[6] argued that supply and demand fundamentals were traditionally crucial to understanding pre-financial crisis oil price dynamics, but these factors are no longer sufficient to explain the post-financial crisis oil market price behavior since 2008. Lu and Umair[7] used a VAR model to reflect the dynamic interaction and interdependence between these two necessities in the context of oil price volatility and COVID-19. The results show that gold has a protective effect on oil price volatility, while COVID-19-gold has a buffer effect on oil price volatility because gold and oil prices have a strong inverse correlation.

To sum up, in addition to the two basic market factors of international oil supply and oil market demand, there is also the exchange rate of the US dollar, national capital speculation, technological progress and development of new energy related to oil, geopolitical factors, and political events such as sudden upheavals. In terms of the current situation of oil price fluctuation, firstly, it should be made clear that large fluctuations in the oil price are not an ideal market phenomenon, and the oil price should be maintained in a reasonable range. Secondly, in recent years, the international oil price has shown an overall trend of decline and frequent recovery. In addition, due to the general uncertainty of factors affecting oil prices, strong uncertainty about future oil prices is likely to prevail.

## 2.2. The impact of oil price fluctuation on macroeconomics—Oil price fluctuation is closely related to macroeconomic development

In terms of commodities and consumption, Li et al.[8] pointed out that the price fluctuation of necessities, durable goods, and other commodities is closely related to the change in oil price. The idealized low oil price has a strong supporting effect on the structure of national consumption expenditure and can promote economic growth, while the rise of oil prices will increase industry costs and consumer spending, hindering social and economic development. However, the results of this study lacked strong data support. Sun et al.[9] used the autoregressive distribution lag (ARDL) constraint test method to estimate the long-term stable relationship between crude oil import volume, household income, and oil price during 1999–2009. The empirical results show that the short-term and long-term price elasticity of imported crude oil is positive and inelastic, and the long-term income elasticity is close to uniform. However, the stationarity of the raw data used in the study may not be ideal.

On the comprehensive macro level, Dudian et al.[10] pointed out that the oil price had a great influence on the economy, and the importance of such influence came from the range of price changes and their diffusion within the economy. This paper studies the effects of oil price changes on industrial production in Romania. The study found that macroeconomic stability is harder to achieve when oil prices rise. Alkhateeb and Sultan[11] analyzed the change in the relationship between oil prices and GDP in the United States from a long-term perspective, and the study showed that when oil prices rose sharply, the negative impact on GDP was greater. Miamo and Achuo[12] used panel vector autoregression to observe that oil prices have a significant positive impact on economic growth in both the short and long term. Kim and Vera[13] propose that the aggregate demand shock and the oil. market-specific shock seems to have positive effects on CPI, while the evidence of the oil supply shock on inflation is very little. The response of GDP and CPI may depend on the source of the shock. But some of the data used in the former study is old, and may not be a good explanation for the link between oil and the economy today. Jiménez-Rodriguez and Sanchez[14] used multivariate VAR analysis to evaluate the impact of the oil price shock on the real economic activities of China, a major industrial country, using linear and nonlinear models and studied the nonlinear impact of oil prices on real GDP. In particular, it is observed that rising oil prices have a larger impact on GDP growth than falling oil prices, which in most cases are not statistically significant. Liu[15] believed that the change in the price of oil would reduce the profit space of enterprises and intensify market competition. At the same time, changes in the residential industrial structure inhibit the transaction. Taken together, the price of oil can significantly affect the price of by-products, which in turn affects the price of a range of necessities and thus people's consumer spending. Therefore, the fluctuation of oil prices is closely related to people's social lives and to economic development. The rise of oil will lead to macroeconomic contraction and the decline of residents' welfare, but it can also limit carbon emissions and other environmental problems. In addition, the fluctuation of oil prices will also affect the profits of various industries, foreign exchange expenditures, trade surpluses, stock market returns, and a series of other economic aspects.

## 2.3. Current situation of China's petroleum import market and its optimization approach—China's oil import trade still needs to be optimized

In terms of the current situation of oil imports, Giraud[16] proposed that since opening to the outside world, China has become a net oil importer rather than a net oil exporter. Under a series of changes such as economic development and industrial structure adjustment, China's oil demand will maintain steady and moderate growth.

Yuan et al.[17] put forward that since Europe and the United States successively joined the sanctions against Russia, the global commodity market prices have fluctuated sharply, and the degree of dependence on oil imports has also been increasing. Therefore, exploring the problems and risks caused by the Russia-Ukraine

conflict from the perspective of energy trade and preventing them from being solved has become a strategic issue. Lu and Umair[7], after studying the correlation between gold prices and oil prices through the VAR model, proposed that investors, policymakers, and market players should consider gold as a means to hedge against oil price fluctuations and economic instability. In terms of the optimization path of the oil import market, Shupletsov and Perelygin[18] proposed that with the sustainable development of China's economy, its energy dependence has gradually increased. Russia is rich in oil resources and is one of the world's major oil exporters. From the perspective of political, resource, market, and geopolitical advantages, it has become the best choice for China to import oil from Russia. Giraud[16] pointed out that China should reduce its dependence on oil and energy for economic development. China should attach equal importance to energy conservation and development, avoid excessive growth of oil demand, and maintain sustainable development. From the perspective of the application chain process, Sun et al.[19] combined the risk of an oil exporting country with the risk of an oil transportation route, quantified the oil risk in China, and analyzed the relationship between China's oil import cost and overseas investment yield.

In conclusion, in terms of the current situation of oil imports, China is currently the world's largest oil importer, while international oil import demand still maintains a rapid growth trend. In addition, China's share of the world's total oil production continues to decline, and China's oil demand gap continues to widen. At present, China's oil dependence is as high as 70.9%, with a high dependence on foreign countries. So the reasonable arrangement of the oil import trade strategy is a major problem in China's oil market. In optimization of China's oil imports, based on good strategic oil reserves China also needs to establish and perfect the legal system of oil imports, develop a diversified oil supply system, and optimize the level of transportation. As oil imports demand the highest voice as a as a separate country, China also needs to seize the opportunity to expand its influence in the international oil supply and trade network by establishing nodes and strengthening the internationalization of RMB.

### 2.4. Summary and prospect—Common research themes and improvements

First of all, in related fields, our common goal is to regulate the oil market and macroeconomics by understanding the factors that affect the change in oil price and the law of oil price change in terms of influencing factors of oil price. The literature selected in this paper provides the research background for this study. There are many factors affecting the price of oil; besides basic supply and demand, there are also the US dollar exchange rate, the gold price, and even some sudden political factors that can affect oil price fluctuations. It is precise because of many factors that lead to the strong uncertainty and unpredictability of the oil price and the market, so this paper takes a new approach, no longer considering the prediction by fitting the past oil change data with the model but considering the adjustment of the oil market by studying the factors related to the oil price and finding out the dynamic relationship between them.

In terms of the impact of oil price fluctuations on the macro-economy, this paper has learned from a lot of relevant studies and found that some studies have certain creativity in the period of data selection. Since the oil market, industrial development, social economy, and politics are significantly different from those of the last century, the timeliness of data should not be ignored in the pursuit of sample size. This paper selects relevant data from the first quarter of 2010 to the second quarter of 2022 as the original data for model establishment.

In addition, we find that many articles lack necessary data analysis and empirical analysis when making recommendations and decisions, and some articles only explain the phenomenon and research results in detail without putting forward relevant suggestions for the research results. This paper will try to put forward corresponding optimization strategies based on the results of data analysis and the existing research in the fields of petroleum and macroeconomics.

# 3. Research methodology

## 3.1. Model selection—Select VAR model to explore the dynamic relationship between endogenous variables

The vector autoregressive model (VAR model, for short) is a generalization of the AR model[20]. The VAR model combines multiple equations to carry out regression for the lag terms of all endogenous variables in the model and can depict the dynamic relationship between all endogenous variables.

Taking the VAR model with $k$-order lag as an example, the model is as follows:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 x_{t-1} + \cdots + \alpha_{2k-1} y_{t-k} + \alpha_{2k} x_{t-k} + \varepsilon_{1t} \quad (1)$$

$$x_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 x_{t-1} + \cdots + \beta_{2k-1} y_{t-k} + \beta_{2k} x_{t-k} + \varepsilon_{2t} \quad (2)$$

Matrix form:

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} y_{t-1} \\ x_{t-1} \end{bmatrix} + \cdots + A_k \begin{bmatrix} y_{t-k} \\ x_{t-k} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \quad (3)$$

where $A_0$ is the constant series vector, $y_t$, $x_t$ is the value of the variable at time $t$, $y_{t-1} \ldots y_{t-k}$, $x_{t-1} \ldots x_{t-k}$ is the value of its lag variable at each period, $A_1 \ldots A_k$ is its corresponding coefficient matrix, $\varepsilon_{1t}$, $\varepsilon_{2t}$ is its random disturbance column vector.

## 3.2. Variable selection and data sources—China's GDP, CPI, gasoline prices, and crude oil imports are selected as variables

Impact on the country's level of economic development. Oil resources are essential factors of production in the process of urban economic development. Without exception, the development of industry, agriculture, transportation, and other sectors is closely related to crude oil and its derivatives. Oil prices are determined by changes in demand and international investment capital, and the fluctuation of oil prices directly affects China's macroeconomic situation. Therefore, this paper uses the quarterly data of China's GDP (unit: trillion yuan) to describe the development level of the national macroeconomic system and adopts a total of 50 quarterly GDP data points from the first quarter of 2010 to the second quarter of 2022 (data source: www.stats.gov.cn, national bureau of statistics).

The impact on the level of national economic growth. The price fluctuation of daily necessities, durable goods, and other commodities is closely related to the change in oil prices. The idealized low oil price has a strong supporting effect on the structure of national consumption expenditure and can promote economic growth, while high oil prices will increase industry costs and consumer expenditure and hinder economic development. Oil price fluctuations will affect our national economy in many ways, and individual consumers are the direct recipients of oil price fluctuations. The CPI, also known as the consumer price index, is data used by the government to measure inflation and is an important economic indicator reflecting the price changes of consumer goods and services generally purchased by households. This paper uses the arithmetic average of monthly CPI data to get the quarterly CPI index as the variable. Consumer price index (CPI): this paper uses monthly CPI data to obtain the arithmetic average of quarterly CPI indicators as variables to obtain a total of 50 quarterly CPI data from the first quarter of 2010 to the second quarter of 2022 in yuan/ton (data source: Oriental Wealth Financial Data: https://data.eastmoney.com).

Influence on Chinese oil import volume change. China is heavily dependent on foreign oil imports and is seriously guided by international oil. Many contradictions in transportation channels are difficult to coordinate and lead to high costs. There are political games among oil powers. These indicate that our oil imports are also closely related to oil price fluctuations. Domestic oil price: since there is no obvious periodic oil price adjustment, this paper uses the average domestic gasoline price, which lasts the longest in each quarter, as an indicator and obtains a total of 50 quarterly data points from the first quarter of 2010 to the second quarter of 2022, in yuan/ton (data source: Oriental Wealth Financial Data: https://data.eastmoney.com).

Oil import volume: this paper uses China's crude oil import volume as the indicator of oil import volume and obtains a total of 50 quarterly data points from the first quarter of 2010 to the second quarter of 2022 from the national import value table of key items (monthly), with a unit of ten thousand tons (data source: the general administration of customs of the national key items imported quantity table, http://search.customs.gov.cn).

### 3.3. Data processing—Logarithmic and differential processing to improve statistical significance of data

To compress the absolute value of the data, increase the stability of the data, and reduce the collinearity and heteroscedasticity of the model for the convenience of later modeling and calculation, logarithmic processing of each variable was carried out. After the unit root test for each variable, variables fail to pass the test completely, and after the difference processing, all variables pass the unit root test, so the data can be used in the model.

## 4. Empirical analysis

### 4.1. Descriptive statistics and modeling—A series of tests and parameter selection to ensure the validity of the model

$$\ln gdp_t = \alpha_0 + \alpha_1 \ln cpi_{t-1} + \alpha_2 \ln import_{t-1} + \alpha_3 \ln prize_{t-1} + \alpha_4 \ln gdp_{t-1} \cdots + \alpha_{4k-3} \ln cpi_{t-k} + \alpha_{4k-2} \ln import_{t-k} + \alpha_{4k-1} \ln prize_{t-k} + \alpha_{4k} \ln gdp_{t-k} + \varepsilon_{1t} \quad (4)$$

$$\ln cpi_t = \beta_0 + \beta_1 \ln cpi_{t-1} + \beta_2 \ln import_{t-1} + \beta_3 \ln prize_{t-1} + \beta_4 \ln gdp_{t-1} \cdots + \beta_{4k-3} \ln cpi_{t-k} + \beta_{4k-2} \ln import_{t-k} + \beta_{4k-1} \ln prize_{t-k} + \beta_{4k} \ln gdp_{t-k} + \varepsilon_{2t} \quad (5)$$

$$\ln import_t = \chi_0 + \chi_1 \ln cpi_{t-1} + \chi_2 \ln import_{t-1} + \chi_3 \ln prize_{t-1} + \chi_4 \ln gdp_{t-1} \cdots + \chi_{4k-3} \ln cpi_{t-k} + \chi_{4k-2} \ln import_{t-k} + \chi_{4k-1} \ln prize_{t-k} + \chi_{4k} \ln gdp_{t-k} + \varepsilon_{3t} \quad (6)$$

$$\ln prize_t = \delta_0 + \delta_1 \ln cpi_{t-1} + \delta_2 \ln import_{t-1} + \delta_3 \ln prize_{t-1} + \delta_4 \ln gdp_{t-1} \cdots + \delta_{4k-3} \ln cpi_{t-k} + \delta_{4k-2} \ln import_{t-k} + \delta_{4k-1} \ln prize_{t-k} + \delta_{4k} \ln gdp_{t-k} + \varepsilon_{4t} \quad (7)$$

The variables include gross domestic product (*gdp*), consumer price index (*cpi*), domestic oil price (*prize*), and oil import (*import*). The subscripts of each variable respectively represent the corresponding quarterly period of the index, $\alpha_0$, $\beta_0$, $\chi_0$, $\delta_0$ respectively represent the constant vector in the four equations, and $\alpha_1 \ldots \alpha_{4k}$, $\beta_1 \ldots \beta_{4k}$, $\chi_1 \ldots \chi_{4k}$, $\delta_1 \ldots \delta_{4k}$ respectively represent the corresponding coefficient matrix of the four equations. Among them is delay order, *t* for the number of quarters, starting from the first quarter of 2010.

#### 4.1.1. Descriptive statistics

Basic statistics such as the mean standard difference of each indicator are shown in **Table 1**.

**Table 1.** Descriptive statistics.

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| *Time* | 50 | 20160.06 | 36.45652 | 20,101 | 20,222 |
| *GDP* | 50 | 191,349 | 60676.32 | 87,500 | 324237.7 |
| *CPI* | 50 | 7.2142 | 3.805678 | 1.01 | 16.8 |
| *Import* | 50 | 9532.44 | 2713.11 | 5668 | 14,725 |
| *Prize* | 50 | 7722.8 | 892.205 | 6130 | 9775 |
| ddln–*gdp* | 48 | −0.0009843 | 0.2108324 | −0.3967352 | 0.4897118 |
| ddln–*cpi* | 48 | 0.0037984 | 0.5012205 | −1.846942 | 2.179543 |
| ddln–*import* | 48 | −0.0021538 | 0.1108157 | −0.2333174 | 0.2993517 |
| ddln–*prize* | 48 | 0.0020547 | 0.1111192 | −0.2757959 | 0.2751074 |

#### 4.1.2. Unit root test and cointegration test

According to **Table 2**, the values of the four variables approximate *p*-value for Z(*t*) is less than 0.01 (the

unit root tests the null hypothesis that there is a non-unit root in the time series, that is, the time series is non-stationary), so we believe that the four variables needed to establish the VAR model pass the unit root test and can be the variables in the VAR model.

To test whether the data after differential processing has economic significance, that is, whether there is a co-integration relationship between variables with their own long-term fluctuation rules. If there is, it is considered that there is a long-term dynamic equilibrium relationship between variables.

**Table 2.** Unit root test.

| **Dickey−fuller test for unit root** | | | | **Number of obs = 47** | | |
|---|---|---|---|---|---|---|
| - | Variable | Test statistic | 1% | 5% | 10% | MacKinnon *p*-value for Z(*t*) |
| Z(*t*) | ddln–*gdp* | −15. 747 | −3. 6 | −2. 938 | −2. 604 | 0. 000 |
| | ddln–*cpi* | −10. 236 | −3. 6 | −2. 938 | −2. 604 | 0. 000 |
| | ddln–*import* | −15. 057 | −3. 6 | −2. 938 | −2. 604 | 0. 000 |
| | ddln–*prize* | −12. 106 | −3. 6 | −2. 938 | −2. 604 | 0. 000 |

As shown in **Table 3**, the test values of each variable in the three significance levels are significantly smaller than the test statistic values, and the Z(*t*) values are all less than 0.01 (cointegration test null hypothesis: residual sequence is a non-stationary process of unit root, that is, sequence non-cointegration). Through the cointegration test, it can be concluded that there is a long-term dynamic equilibrium relationship between each variable.

**Table 3.** Cointegration test.

| **Dickey-fuller test for unit root** | | | | | **Number of obs = 45** | |
|---|---|---|---|---|---|---|
| - | Variable | Test statistic | 1% | 5% | 10% | *P*-value for Z(*t*) |
| Z(*t*) | ddln–*gdp* | −17.366 | −3.614 | −2.944 | −2.606 | 0 |
| | ddln–*cpi* | −4.762 | −3.614 | −2.944 | −2.606 | 0.0001 |
| | ddln–*import* | −5.808 | −3.614 | −2.944 | −2.606 | 0 |
| | ddln–*prize* | −5.668 | −3.614 | −2.944 | −2.606 | 0 |

### 4.1.3. Optimal lag order selection

The optimal index of lag order is selected as shown in **Table 4**: The LR statistic of lag order 2 is the most ideal, while the results of the other four criteria (FPE, AIC, HQIC, and SBIC) all show that lag order 3 is the most ideal. After comprehensive consideration, the VAR model with lag order 3 is selected for this modeling.

**Table 4.** Optimal lag order selection index.

| **AG** | **LL** | **LR** | **DF** | **P** | **FPE** | **AIC** | **HQIC** | **SBIC** |
|---|---|---|---|---|---|---|---|---|
| 0 | 49.1857 | - | - | - | $1.5 \times 10^{-6}$ | −2.0539 | −1.99374 | −1.8917 |
| 1 | 91.2643 | 84.157 | 16 | - | $4.6 \times 10^{-7}$ | −3.23929 | −2.93853 | −2.42829 |
| 2 | 114.308 | 46.087* | 16 | - | $3.4 \times 10^{-7}$ | −3.55945 | −3.01809 | −2.09966 |
| 3 | 225.729 | 222.84 | 16 | - | $4.7 \times 10^{-9}$* | −7.89679* | −7.11483* | −5.7882* |

Note: ***, **, and * represent statistically significant at 1%, 5%, and 10% confidence levels, respectively.

### 4.1.4. Wald test and model stationarity test

The Wald test is used to test the joint significance between equations of various orders. The results are shown in **Table 5**. All equations pass the test at the significance level of 5% (wald test null hypothesis: the

linear constraint holds), and subsequent tests can be conducted.

**Table 5.** Wald test.

| **Wald test** | | | | |
|---|---|---|---|---|
| Equation | Lag | Chi2 | DF | Prob > Chi2 |
| ddln–*gdp* | 1 | 1581.82 | 4 | 0 |
| | 2 | 910.1449 | 4 | 0 |
| | 3 | 1455.839 | 4 | 0 |
| ddln–*cpi* | 1 | 12.9376 | 4 | 0.012 |
| | 2 | 11.85541 | 4 | 0.018 |
| | 3 | 28.34119 | 4 | 0 |
| ddln–*import* | 1 | 131.9123 | 4 | 0 |
| | 2 | 58.81744 | 4 | 0 |
| | 3 | 23.88165 | 4 | 0 |
| ddln–*prize* | 1 | 36.84495 | 4 | 0 |
| | 2 | 13.41372 | 4 | 0.009 |
| | 3 | 3.914062 | 4 | 0.048 |
| All | 1 | 3219.246 | 16 | 0 |
| | 2 | 1920.358 | 16 | 0 |
| | 3 | 3002.739 | 16 | 0 |

Stability test. After VAR modeling, in order to test whether the VAR system is stable, the unit root eigenvalue method is used. As shown in **Figure 1**, the modulus length of the eigenvalues is less than 1, that is, they all fall within the unit circle, so the VAR system can be considered to pass the stability test.

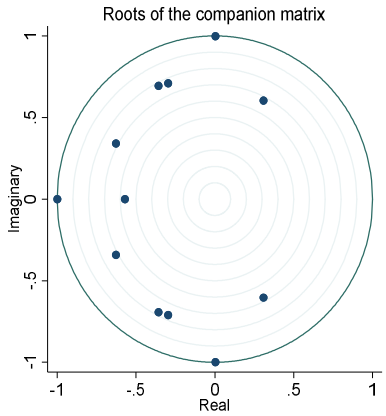


**Figure 1.** Distribution of unit root tests.

### 4.1.5. Residual normality test and residual sequence autocorrelation test

As shown in **Table 6**, the P statistics of ddln–*gdp*, ddln–*cpi*, ddln–*prize*, and all are significantly greater than 0.01, so the null hypothesis cannot be rejected (null hypothesis: sample data obey normal distribution), that is, pass the residual normality test at the significance level of 1%, and the P statistic of ddln–import is greater than 0.01, reject the null hypothesis, that is, fail the residual normality test at the significance level of 1%.

**Table 6.** J–B residual normality test.

| **Jarque Bera test** | | |
|---|---|---|
| Equation | DF | Prob > Chi2 |
| ddln–*gdp* | 2 | 0.66831 |
| ddln–*cpi* | 2 | 0.6906 |
| ddln–*import* | 2 | 0.0109 |
| ddln–*prize* | 2 | 0.30304 |
| All | 8 | 0.2457 |

According to **Table 7**, in the autocorrelation test of residual series with third-order lag, the P statistics of lag orders 1, 2, and 3 are all significantly greater than 0.01, which cannot reject the null hypothesis (null hypothesis: no autocorrelation at lag order), so it can be considered that there is no residual series autocorrelation at the significance level of 1% in the VAR model.

**Table 7.** Residual sequence autocorrelation test.

| **Lagrange multiplier test** | | | |
|---|---|---|---|
| Lag | Chi2 | DF | Prob > Chi2 |
| 1 | 19.2418 | 16 | 0.25633 |
| 2 | 12.2003 | 16 | 0.73008 |
| 3 | 9.5381 | 16 | 0.88961 |
| H0: no autocorrelation at lag order | | | |

## 4.2. Model interpretation—VAR model results and follow-up research

### 4.2.1. VAR model parameter estimation results

The resulting matrix of parameter estimation gives the third-order dynamic VAR model equation among four variables: *gdp*, *cpi*, *price*, and *import*:

$$\begin{bmatrix} dd\ln(gdp)_t \\ dd\ln(cpi)_t \\ dd\ln(import)_t \\ dd\ln(prize)_t \end{bmatrix} = \begin{bmatrix} -1.020161* & -0.0004378 & -0.239172* & -0.0217859 \\ -0.3818669 & -0.3539326* & 0.2956025 & 0.2021533 \\ -0.0806835 & 0.0564448* & -1.316019 & -0.198028 \\ 0.0202657 & -0.526663 & -0.682726 & -0.8163401* \end{bmatrix} \times \begin{bmatrix} dd\ln(gdp)_{t-1} \\ dd\ln(cpi)_{t-1} \\ dd\ln(import)_{t-1} \\ dd\ln(prize)_{t-1} \end{bmatrix}$$
$$\begin{bmatrix} -1.026693 & 0.0160036 & -0.2390663 & -0.0333258 \\ -0.9012357 & -0.263298 & 0.0099723 & 0.5009965 \\ -0.0414567 & 0.0450099 & -1.122033 & 0.0116503 \\ 0.0141498 & -0.0583094 & -0.1989643 & -0.5060219 \end{bmatrix} \times \begin{bmatrix} dd\ln(gdp)_{t-2} \\ dd\ln(cpi)_{t-2} \\ dd\ln(import)_{t-2} \\ dd\ln(prize)_{t-2} \end{bmatrix}$$
$$\begin{bmatrix} -0.9945511 & -0.0029791 & -0.102546 & -0.1122322 \\ -1.169489 & -0.0141472 & -1.097564 & 2.33955 \\ 0.0449283 & 0.0202442 & -0.4620361 & -0.0383304 \\ 0.0025575 & -0.0354736 & 0.0031036 & -0.2363415 \end{bmatrix} \times \begin{bmatrix} \mathrm{dd}\ln(gdp)_{t-3} \\ dd\ln(cpi)_{t-3} \\ dd\ln(import)_{t-3} \\ dd\ln(prize)_{t-3} \end{bmatrix} + \begin{bmatrix} -0.0029243 \\ -0.0058576 \\ -0.0018689 \\ 0.0030694 \end{bmatrix} \quad (8)$$

The results of the above equation show that there is a significant short-term (one quarter) correlation between the indicators: there is a significant negative effect of crude oil imports on GDP and a significant

negative effect of the CPI on crude oil imports, in addition, there is a negative effect of GDP, CPI, and petrol prices on themselves.

### 4.2.2. Orthogonal pulse response analysis

The impulse response function can measure the impact of the unit standard deviation generated by a random disturbance term on the current and future values of endogenous variables and intuitively show the dynamic relationship between variables in the vector autoregressive model. As shown in **Figure 2**.

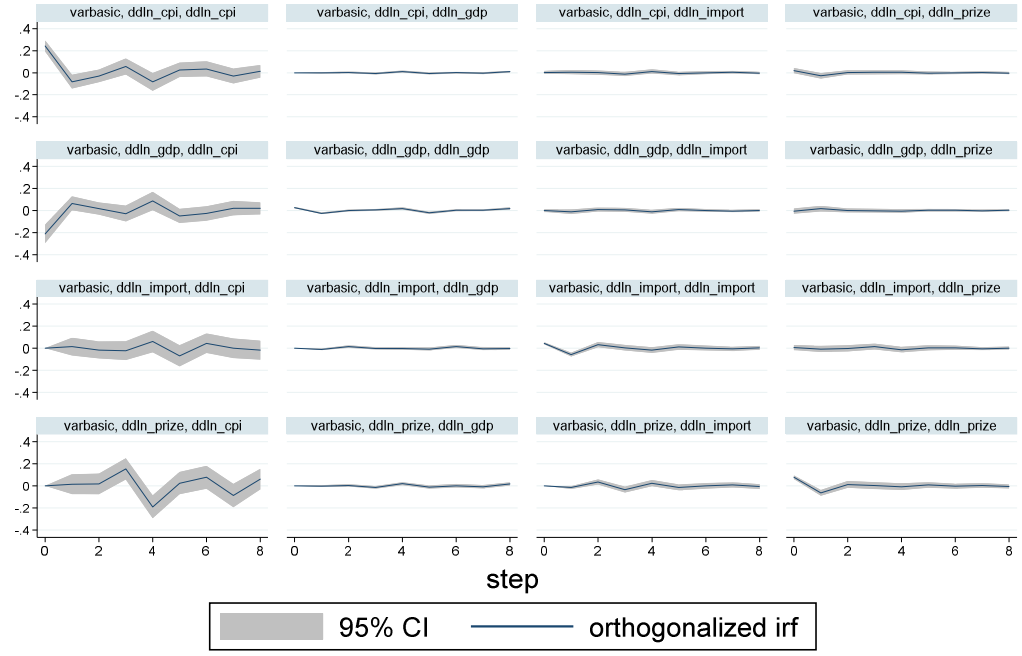


**Figure 2.** Impulse response analysis diagram.

The chart above shows the impact of shocks over eight quarters. The results obtained in the first column are relatively significant. When each factor in the VAR model is impacted by one unit standard deviation, it has a significant impact on the consumer price index (ddln–*cpi*). The first figure shows its response to itself, indicating that there is a decreasing positive response in the first quarter, and then the fluctuation decreases. The second graph shows its response to gross domestic product (ddln–*gdp*). There is a decreasing reverse response on the surface in the first quarter. The other two graphs in the first column all contain axis 0 at time 0, and the response is not significant. In addition, each factor has a certain degree of path dependence, that is, data changes are more dependent on the data from the previous quarter.

### 4.2.3. Granger causality test

The Granger causality test is used to judge whether there are significant causal relationships between variables (Granger causality test null hypothesis: there is no causality between the tested variables). The results are shown in **Table 8**: In China, crude oil import volume is the largest factor in GDP. GDP and total crude oil imports are Granger factors of CPI, and gasoline prices are Granger factors of crude oil imports (at a 5% significance level), and other factors are not Granger factors.

**Table 8.** Granger causality test.

| Equation | Excluded | Chi2 | DF | Prob > Chi2 |
|---|---|---|---|---|
| ddln–*gdp* | ddln–*cpi* | 3.9788 | 3 | 0.264 |
| ddln–*gdp* | ddln–*import* | 11.416 | 3 | 0.01 |
| ddln–*gdp* | ddln–*prize* | 6.0393 | 3 | 0.11 |
| ddln–*gdp* | All | 31.429 | 9 | 0 |
| ddln–*cpi* | ddln–*gdp* | 12.223 | 3 | 0.007 |
| ddln–*cpi* | ddln–*import* | 5.5478 | 3 | 0.136 |
| ddln–*cpi* | ddln–*prize* | 17.2 | 3 | 0.001 |
| ddln–*cpi* | All | 38.253 | 9 | 0 |
| ddln–*import* | ddln–*gdp* | 5.1495 | 3 | 0.161 |
| ddln–*import* | ddln–*cpi* | 13.667 | 3 | 0.003 |
| ddln–*import* | ddln–*prize* | 10.053 | 3 | 0.018 |
| ddln–*import* | All | 31.774 | 9 | 0 |
| ddln–*prize* | ddln–*gdp* | 0.0581 | 3 | 0.996 |
| ddln–*prize* | ddln–*cpi* | 4.427 | 3 | 0.219 |
| ddln–*prize* | ddln–*import* | 1.6952 | 3 | 0.638 |
| ddln–*prize* | All | 7.5688 | 9 | 0.578 |

## 5. Conclusion and suggestion

Taking gross domestic product (*gdp*), consumer price index (*cpi*), crude oil import volume (*import*), and gasoline price (*price*) after logarithmic and differential processing as endogenous variables, this paper establishes a VAR model with a lag order of 3 from the first quarter of 2010. In addition, after establishing the VAR model, this paper conducted orthogonal impulse response analysis to show the dynamic relationship between endogenous variables in the autoregressive model, and conducted the Granger causality test to explore the causal relationship between endogenous variables, respectively drawing the following conclusions and suggestions:

Granger causality test: in China, crude oil import volume is the Granger factor of GDP; GDP and total crude oil imports are the Granger factors of CPI; and CPI and gasoline prices are the Granger factors of crude oil imports.

Impulse response analysis: when each factor in the VAR model is impacted by one unit standard deviation, the response results of the consumer price index (ddln–*cpi*) to the gross domestic product (ddln–*gdp*) show that there is a decreasing reverse response in the first quarter, and the rest of the of the response analysis results all contain the 0 axes at the moment of 0, and the response is not significant. In addition, there are various factors to some extent that contribute to the path dependence, namely data changes, which rely on data from the previous quarter.

Combing the literature review, the current situation of the oil price and the import market in our country is mainly summarized as follows:

1) Factors influencing the fluctuations in the price of oil in addition to the international oil supply and oil demand level in the basic two markets: the dollar, state capital speculation, the related technical progress of oil, sudden political events, etc.
2) In recent years, the international oil price has shown a trend of decline and frequent recovery. In addition, the strong uncertainty about the future oil price may be widespread.
3) The fluctuation of oil prices is closely related to residents' social life and economic development.

The rise of oil prices will lead to macroeconomic contraction and the decline of residents' welfare, but it can also limit carbon emissions and other environmental problems.

4) Oil price fluctuations will also for other industries' profit, foreign exchange expenditure and the trade surplus, stock market returns, and a series of economic impacts.
5) China is currently the world's largest oil importer, and its demand for international oil imports still maintains a rapid growth trend. In addition, the proportion of China's oil production in the world's total production continues to decline, which makes the gap in China's oil demand continue to expand.
6) Based on making good strategic oil reserves, China also needs to develop a diversified oil supply system and realize the optimization of transportation. At the same time, China also needs to seize the opportunity to expand its influence in the international oil supply trade network by establishing nodes and strengthening the internationalization of the RMB.

Given the serious problem of the oil import dependence of China, which is the largest oil importer in the world, it is proposed that while focusing on domestic oil strategic reserves and improving oil exploitation and processing technology, China also needs to optimize the structure of the international trade market and improve the influence of the international oil trade market because of its market status as the largest oil demand country.

In addition, there are some limitations and potential errors in this study. First of all, in terms of data selection and processing, due to the tradeoff between the amount of data mined and its timeliness, the sample size selected in this study is not ideal, which may lead to insufficient accuracy of parameter estimation. In addition, to increase the stationarity of the data, reduce the collinearity and heteroscedasticity of the model, and make the data pass the unit root test, we carried out logarithmic and differential processing on the original data. However, since the difference eliminated the long-term economic information of the variables, the VAR model could not well reflect the long-term causality between the variables at this time. Secondly, disadvantages of the VAR model: since the VAR model maintains the assumption of the distribution obtained from the observed data, if China's oil market or the macroeconomic situation changes dramatically in a short period, the estimated results of the VAR model will seriously deviate from the facts. In addition, the VAR model is subjective to some extent. The calculation method, time range of data selection, significance level, and lag order selection will all affect the modeling effect of the VAR model.

## Author contributions

Conceptualization, ZY; methodology, ZY; software, ZY; validation, YS (Yuping Shang); formal analysis, ZY and YS (Yuping Shang); investigation, YS (Yujiao Shang); resources, YS (Yujiao Shang); data curation, ZY; writing—original draft preparation, ZY; writing—review and editing, ZY and YS (Yujiao Shang); visualization, ZY and YS (Yujiao Shang); supervision, YS (Yujiao Shang); project administration, YS (Yuping Shang); funding acquisition, ZY. All authors have read and agreed to the published version of the manuscript.

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## Conflict of interest

The authors declare no conflict of interest.

# Reference


1. Dai J, Shi H. The COVID-19 pandemic has severely affected the world economy and exacerbated the contradiction between supply and demand in petroleum and petrochemical markets. *International Petroleum Economics* 2021; 29(1): 39–40.
2. Smith-Nonini S. The role of corporate oil and energy debt in creating the neoliberal era. *Economic Anthropology* 2016; 3(1): 57–67. doi: 10.1002/sea2.12044
3. Zarubina YV. Analysis of factors affecting pricing in the oil market. *Bulletin of the Angarsk State Technical University* 2018; 1(12): 258–262. doi: 10.36629/2686-777X-2018-1-12-258-262
4. Kilian L. Oil price shocks: Causes and consequences. *CEPR Discussion Papers* 2014; 6(1): 133–154. doi: 10.1146/annurev-resource-083013-114701
5. Yang CW, Hwang MJ, Huang BN. An analysis of factors affecting price volatility of the us oil market. *Energy Economics* 2002; 24(2): 107–119. doi: 10.1016/S0140-9883(01)00092-5
6. Liu Z, Ding Z, Lv T, et al. Financial factors affecting oil price change and oil-stock interactions: A review and future perspectives. *Natural Hazards* 2019; 95: 207–225. doi: 10.1007/s11069-018-3473-y
7. Lu Y, Umair M. The protective nature of gold during times of oil price volatility: An analysis of the COVID-19 pandemic. *The Extractive Industries and Society* 2023; 15: 101284. doi: 10.1016/J.EXIS.2023.101284
8. Li H, Xie Q, Zhang A. Impact of international oil price fluctuation on China's oil enterprises. *Modern Management* 2011; 1(2): 59–68. doi: 10.12677/mm.2011.12010
9. Sun W, Qi Z, Jia N. Import demand of crude oil and economic growth in China: Evidence from the ARDL model. In: Proceedings of the 2010 Third International Conference on Business Intelligence and Financial Engineering; 13–15 August 2010; Hong Kong, China. pp. 314–318.
10. Dudian M, Mosora M, Mosora C, Birova S. Oil price and economic resilience. Romania's case. *Sustainability* 2017; 9(2): 273. doi: 10.3390/su9020273
11. Alkhateeb T, Sultan Z. Oil price and economic growth: The case of indian economy. *International Journal of Energy Economics and Policy* 2019; 9(3): 274–279. doi: 10.32479/ijeep.7602
12. Miamo CW, Achuo ED. Can the resource curse be avoided? An empirical examination of the nexus between crude oil price and economic growth. *SN Business & Economics* 2022; 2(1): 5. doi: 10.1007/s43546-021-00179-x
13. Kim G,Vera D. The effect of oil price fluctuation on the economy: What can we learn from alternative models? *Journal of Applied Economics* 2022; 25(1): 856–877. doi: 10.1080/15140326.2022.2053940
14. Jiménez-Rodriguez R, Sanchez M. Oil price shocks and real GDP growth: Empirical evidence for some OECD countries. *Applied Economics* 2005; 37(2): 201–228. doi: 10.1080/0003684042000281561
15. Liu Q. Impacts of oil price fluctuation to China economy. *Quantitative and Technical Economics* 2005; 3: 17–28.
16. Giraud PN. The equilibrium price range of oil: Economics, politics and uncertainty in the formation of oil prices. *Energy Policy* 1995; 23(1): 35–49. doi: 10.1016/0301-4215(95)90764-x
17. Yuan S, Chen L, He Z. Based on the conflict between Russia and Ukraine under the background of China's oil imports problems and countermeasure analysis. *China Business Theory* 2023; 880(9): 62–65. doi: 10.19699/j.carol carroll nki issn2096-0298.2023.09.062
18. Shupletsov A, Perelygin A. Risk hedging tools: Efficiency and significance of their use in the processes of forming development strategies of Russian oil and gas companies. *Bulletin of Baikal State University* 2020; 30(2): 318–325. doi: 10.1016/0140-6701(95)92692-5
19. Sun M, Gao C, Shen B. Quantifying China's oil import risks and the impact on the national economy. *Energy Policy* 2014; 67: 605–611. doi: 10.1016/j.enpol.2013.12.061
20. Obalade AA, Ebiwonjumi A, Adaramola AO. VAR modelling of dynamics of poverty, unemployment, literacy and per capita income in nigeria. *Folia Oeconomica Stetinensia* 2019; 19(1): 73–88. doi: 10.2478/foli-2019-0006