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Dynamic Pass-through Effect of Global Oil Price on China's Gasoline and Diesel Market: Empirical Analysis Based on the Structural Vector Autoregressive Models

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Abstract: *The paper attempts to assess the dynamic effect of global oil price shocks on China gasoline and diesel markets. Using responses of these two markets to international oil price fluctuations, we establish structural vector autoregressive (SVAR) models respectively, estimating the impulse response functions (IRF) and variance decomposition results. Base on monthly data on global oil prices, Chinese gasoline and diesel prices, consumption and production from January 2014 to March 2022, we found that: (i) Both two markets responded relatively fast to global oil price shocks, peaking statistically within two to three months, with the gasoline market being more sensitive to oil price fluctuations. (ii) The impact of oil price fluctuations on the markets can last for two to three years, and the impact on the gasoline market last significantly longer than that on the diesel market while the pass-through effect of international oil prices on China's diesel market is stronger, reflected in the variance decomposition results. The above results show that diesel market is more able to withstand the impact of oil price fluctuations than the gasoline market, and it is also more stable from the previous period. Based on the existing policy and market environment, we believe that this situation will not change in the short term.*

Keywords: *Oil price pass-through, Fuel markets, Heterogeneity, Structural vector auto-regression model, JEL classification: C32; D40; Q41*

1. Introduction

The economic consequences of world oil prices fluctuation have been a topic at the forefront for decades, especially given the recent volatility in oil prices. Studying the heterogeneity of oil price pass-through effect on economy, Jie Lin (2023) [1] finds that the impact of oil price shock on Chinese market is second only to Japanese. Wenbei Zhang (2023) [2] illustrates that the jet fuel and diesel of America have long-run equilibrium relationship with oil price. However, current studies rarely comprehensive explored China's fuel market. China's fuel market is regarded as a government-regulated market. In such a government-led fuel market, the impact of global oil price fluctuations can be mitigated through policies such as fuel subsidies [3] and may not last for long. However, we observed that during the oil price crashes, China's fuel market had very large fluctuation. Therefore, we need to rethink the relationship between oil prices and the Chinese fuel market. Based on the Dallas research, we take the gasoline and diesel market as a representative of the Chinese fuel market, and use the data from 2014 to March 2022 to establish an SVAR model to analyze the dynamic relationship between world oil prices and the Chinese fuel market. This article attempts to quantify the impact of the above two crude oil price fluctuations on China's gasoline and diesel market in order to address (i) The duration and degree of impact of global oil prices on the gasoline and diesel market in China, and (ii) Differential pass-through impact of international oil price on gasoline and diesel market in China. Using SVAR model, we obtain the following results. Although the gasoline and diesel markets are largely controlled by the state, empirical analysis shows that gasoline and diesel markets respond quickly to oil price fluctuations, and the pass-through effects of oil prices on the gasoline and diesel markets are heterogeneous. This heterogeneity is also present in the response of different variables in the gasoline and diesel markets (price, consumption and output) to fluctuations in oil prices. Based on the research of Dallas et al. (2022) [4], this paper adds the variable of fuel output to conduct a comprehensive analysis of the Chinese fuel

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market. The gasoline and diesel price data we used were calculated by weighting data published by the Beijing Development and Reform Commission updated to March 2022, revising and supplementing the database established by Kpodar and Abdallah (2017) [5].

The structure of this paper is arranged as follows: In Section II we discuss the findings of previous research on this topic; In Section III we collect detailed data and conduct a rough trend assessment of the data; In Section IV, we apply the model and list the specific constraints we impose on the model; In the fifth section, we present the specific results of the model estimation, and discuss the estimation results for different markets. The limitations of the research are discussed in Section VI and then summarize the empirical research in Section VII.

2. Literature review

The economic consequences and determinants of fluctuation in global oil prices have been the subject of intense research in the energy economics and policy literature. The current research can be divided into two major streams, the first one focuses on the explanatory factors of oil price fluctuations, and the other stream focuses on the pass-through effect of oil price fluctuations on the fuel markets of various countries.

For studies on explanatory factors of oil price fluctuations, the mainstream view is around the theory of oil price supply and demand [6]. Sufficient research shows that the peak oil price during the economic crisis was created by the high demand of China and other developing countries [7]. China became the world’s largest crude oil importer in 2018 [8], as statistics from the GACC (General Administration of Customs People’s Republic of China) show that China's crude oil imports exceeded 400 million tons in 2018 and 500 million tons in 2022. According to Jie et al. (2020) [9], China crude oil futures market was launched on March 26th, 2018, becoming the third largest crude oil futures market in the world. Given the role played by China in crude oil importing, more and more scholars began to explore the role played by China in global oil price pricing, but the conclusions are mixed. To be specific, some literatures found that the global market is highly integrated but has one-way influence[10], which means that China has no significant impact on world oil price [11]. Meanwhile, some literatures have attributed the continuous rise in oil prices to the "China factor"[12], which believe that due to the rapid growth of China's INE crude oil futures trading volume, coupled with the expansion of China's own oil and gas market volume, China's crude oil market has been an important source of international and Asian crude oil pricing.

The second type of research focuses on the pass-through effect of oil price fluctuation on fuel markets. Starting from Bacon (1991) [13], scholars have studied the pass-through mechanism of oil price fluctuations, but the conclusions are mixed. Coady and Clements (2013) [3] find that the subsidy policy set to stabilize the fuel price makes the fluctuation of world oil price have poor pass-through effects on fuel markets timely in many countries (such as Niger, Nigeria, and oil-importing countries). Benjamin et al. (2017) [14]examines that the pass-through effect of crude oil prices on U.S. gasoline prices is significant, but failed to account for the effect of market structure on the pass-through effect. Under the background of high oil price and oil price volatile, Aidan Meyler (2009) [15]analyzes the pass through effect of oil price on liquid fuel price (gasoline, diesel oil and household heating fuel oil) in the euro zone, finds that oil price pass through occurs quickly, with 90% occurring within three to five weeks. However, considering the substitutability between the fuels and the interconnectedness between variables in the fuel market, it is meaningful to explore the impact of oil price fluctuations on the fuel markets (i.e., gasoline and diesel in this study).

3. Data Description

Following Kpodar and Abdallah (2017) [5] and Dallas et al. (2022) [4], we use high-frequency monthly data of oil price, consumption and output from January 2014 to March 2022. In this paper, we choose the crude oil price of West Texas Intermediate (WTI) as the international benchmark oil price, and the world oil price comes from the website of Energy Information Administration (https://www.eia.gov/). Retail fuel prices for Beijing are taken as a proxy of national average, and calculate the monthly gasoline and diesel prices in China by weighted average of real-time data. The real-time gasoline and diesel prices in Beijing can be found on the website of Beijing Development and Reform Commission (http://fgw.beijing.gov.cn). We obtained the monthly gasoline and diesel consumption and output data of China from JODI database (http://www.jodidb.org/ReportFolders/reportFolders.aspx).

Therefore, we set the following seven variables. We divide the target market into two parts according

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to different fuel types, and use the converted data to establish SVAR models.

Table 1: The variables and expression.

Variables	Global Oil Price	Gasoline Price	Gasoline Consumption	Gasoline Output	Diesel Price	Diesel Consumption	Diesel Output
Expression	Price	GP	GC	GO	DP	DC	DO

4. Methodology.

Kilian(2009) [6]creatively used the variable recursive structure SVAR model to analyze the explanatory power of oil supply shocks, oil-specific demand shocks, and aggregate demand shocks to oil price fluctuations, and this method is widely used in the study of the relationship between oil prices and economic variables [16] [17].

In order to estimate the dynamic response of China gasoline and diesel market to the impact of world crude oil price, we estimate two SVAR models, aimed at gasoline and diesel markets respectively. The SVAR models use a form of iterated forecasting on the relationship across time sequenced variables. Next, we use the estimated SVAR models to estimate the IRF and variance decomposition results for the two markets. Lastly, we estimate the comparison results of the two markets.

4.1 SVAR model with short-term constraints

Following Kilian(2009) [6] , we use SVAR model to estimate the endogenous relationship between vectors, and the structural representation of the model in Eq. (1). According to the AIC standard, we determine the length of the lag period as 2, that is, establish the SVAR (2) model and impose short-term constraints in the form of the AB matrix on the SVAR models.

$$\boldsymbol{z}_t=\boldsymbol{\alpha}_0+\sum_{i=1}^{p} A_i Z_{t-i}+\boldsymbol{\varepsilon}_t \tag{1}$$

where: $\boldsymbol{z}_t$ is a vector of endogenous variables containing world oil prices, China's domestic fuel prices (i.e., gasoline and diesel), fuel consumption, and fuel production. p is the lag period, it is set to 2 in the model.$\boldsymbol{A}_0$ is a contemporaneous matrix for identifying structural relationships among variables. $\boldsymbol{A}_i$ represents autoregressive coefficient matrix. $\boldsymbol{\varepsilon}_t$ is the vector of uncorrelated structural disturbances. $\boldsymbol{A}_0$, $\boldsymbol{\alpha}_0$, $\boldsymbol{A}_i$ and $\boldsymbol{\varepsilon}_t$ are unknown to be estimated.

The reduced form of the VAR is represented in Eq. (2)

$$\boldsymbol{z}_t=\boldsymbol{c}_0+\sum_{i=1}^{p} B_i Z_{t-i}+e_t \tag{2}$$

where, $\boldsymbol{c}_0=\boldsymbol{A}^{-1}{}_0\boldsymbol{\alpha}_0$, $\boldsymbol{B}_i=\boldsymbol{A}^{-1}{}_0\boldsymbol{A}_i$, $\boldsymbol{e}_t=\boldsymbol{A}^{-1}{}_0\boldsymbol{\varepsilon}_t$, noting that $\boldsymbol{e}_t=\boldsymbol{A}^{-1}{}_0\boldsymbol{\varepsilon}_t$ is the vector of the estimated residuals in the reduced VAR. The relationship is as follows:

$$\begin{pmatrix} e_t^{oil\ price\ shock} \\ e_t^{fuel\ price\ shock} \\ e_t^{fuel\ output\ shock} \\ e_t^{fuel\ consumption\ shock} \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix} \begin{pmatrix} u_t^{oil\ price\ shock} \\ u_t^{fuel\ price\ shock} \\ u_t^{fuel\ output\ shock} \\ u_t^{fuel\ consumption\ shock} \end{pmatrix}$$

Based on our knowledge of the fuel market, we imposed constraints on the A_0 matrix. To be specific, we assume a hierarchical relationship in fuel markets, with shocks "upstream" in the international fuel market (such as a global oil price shock) flowing "downstream" in the domestic fuel market.

We can simplify this relationship, by assuming: (i) Global oil prices can simultaneously affect all variables, including itself. (ii) Gasoline and diesel price can simultaneously affect gasoline and diesel prices and consumption, including itself. Considering the cost of adjusting fuel production, we assume that the price is determined in advance, and there is a lag in the reaction to the market. That is, we assume that the fuel price in the domestic market is completely determined by state-owned enterprises and the government. (iii) Gasoline and diesel output can affect consumption at the same time, including itself. (iv) Gasoline and diesel consumption can only affect itself in the same period.

Therefore, we assume that $a_{12}=a_{13}=a_{14}=a_{23}=a_{24}=a_{34}=0$. Estimating SVAR using the following recursive form of the short-term constraint limit, commonly referred to as Cholesky identification, has become a common practice in the literature[4]. In order to avoid the interaction between the new items,

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we set the B matrix as the identity matrix.

After estimating the SVAR model, we use the estimated results to analyze the impulse response (IRF) of China gasoline and diesel market to oil price fluctuations and the variance decomposition results of various variables in the market. IRF reflects the dynamic change path of endogenous variables in the system after being impacted by a certain structure. The variance decomposition reflects the degree to which each structural shock in the SVAR model explains the forecast error of endogenous variables.

4.2 Model robustness

Traditionally, the premise of estimating a SVAR model is that all variables we used must be stationary. However, when examining the stationary properties using unit root test, many variables in the model violate the stationary premise. The data of price and gasoline output are non-stationary, while the data of other variables are stable. Since the purpose of using SVAR model is not to estimate coefficients, Sims (1980) [18] and other scholars' literature suggests that it is still desirable to estimate the SVAR model without first-differencing the variables [19]. The purpose of this is to ensure that the data information is not lost in the first difference process. In the robustness test of the model, AR root test shows that the characteristic roots of variables are all in the unit circle, so the two SVAR (2) models we established are stable. The result summarized in Figure 1.

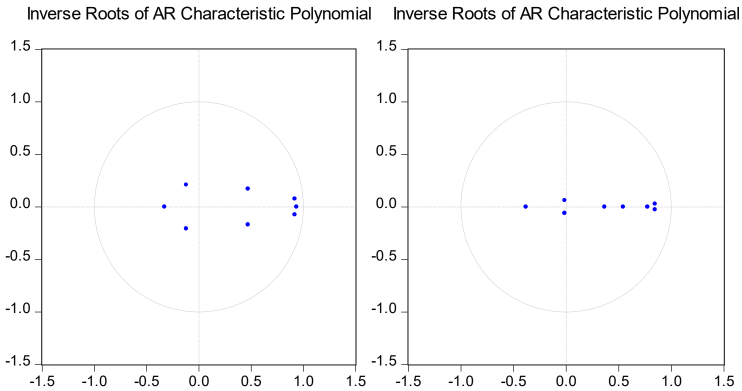

Figure 1: Unit circle test results of gasoline and diesel market model stability (gasoline market on the left and diesel market on the right)

5. Results and discussion

According to the different fuel characteristics, pricing system and consumption structure, we study and compare gasoline and diesel respectively, and find that the response of gasoline market to oil price fluctuation is slightly greater than that of diesel market, and the impact of oil price on gasoline market lasts longer; The oil price has a stronger explanation for the diesel market. The results of IRF estimation are shown in Figure 2 and Figure 4, and the results of variance decomposition are shown in Figure 3 and Figure 5.

5.1 Gasoline market IRF and variance decomposition results

It can be seen from Figure 2 that the short-term positive impact of oil prices has a significant positive impact on the gasoline market, and gasoline prices react quickly within one month after changes in world oil prices. This effect peaked within 3 months of the oil price volatility, then faded and persisted for about 45 months. The effect of oil price on the variables in the gasoline market tends to be similar. It is worth noting that fluctuations in crude oil prices have a greater impact on gasoline production than on gasoline consumption. The range of impact on gasoline production is -8.7 to 11.5, and the range of impact on gasoline consumption is -6.9 to 6.1.Oil price shocks have a temporary positive impact on gasoline consumption and production, lasting about six months, and then begin to have a negative impact, with the negative impact lasting longer. The positive impact peaked within two months of the oil price fluctuation, while the negative impact peaked around 16 months after the oil price fluctuation.

In general, the impact of crude oil price fluctuations on the gasoline market is volatile and persistent. The short-term positive relationship and long-term negative relationship between crude oil price fluctuation and gasoline consumption and production may be caused by the fact that China is a net

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exporter of gasoline, while China's oil and gas market is dominated by the government. The increase of crude oil price will increase government revenue and increase production in the short term. In the long run, however, uncertainty over oil prices may cause companies to delay investment, leading to a decline in market production and consumption.

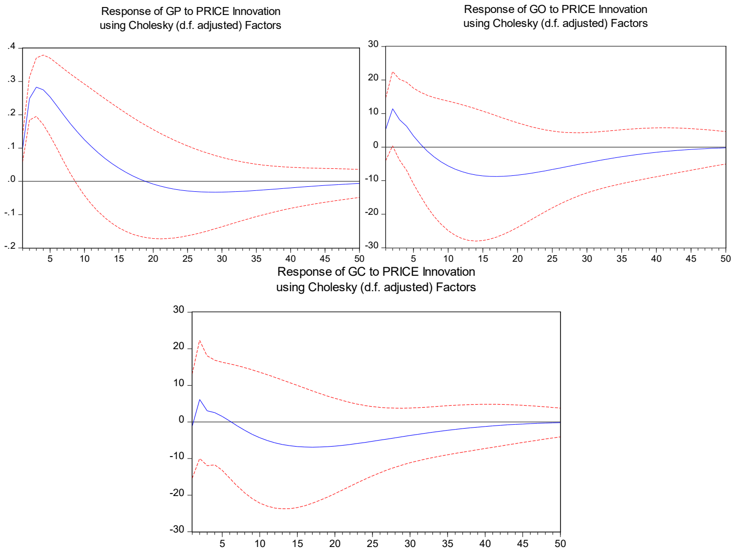

Figure 2: IRF estimation results in gasoline market

Figure 3 shows the variance decomposition results of variables in the gasoline market. Since the impact of crude oil price fluctuations on the gasoline market lasts for a long time, we set the observation period as 30 months to discuss the degree of explanation among variables. As one can see from Figure, oil price shocks are the main factor driving gasoline price volatility. For gasoline prices, crude oil prices and gasoline production are the two largest shock sources, contributing 42% and 37% to gasoline price fluctuations. For gasoline output, crude oil price is the greatest source of shock outside themselves, contributing 11% to gasoline production volatility. Surprisingly, in the empirical results, both the crude oil price and the gasoline price contribute very little to the consumption change, with crude oil price contributing about 6% and gasoline price only contributing about 2%. In general, in the empirical analysis results, the fluctuation of crude oil price and gasoline price is statistically significant, and the fluctuation of gasoline output and consumption are less affected by the change of oil price. This confirms our conjecture that the decision on gasoline output is largely independent of market factors and depends heavily on government decisions.

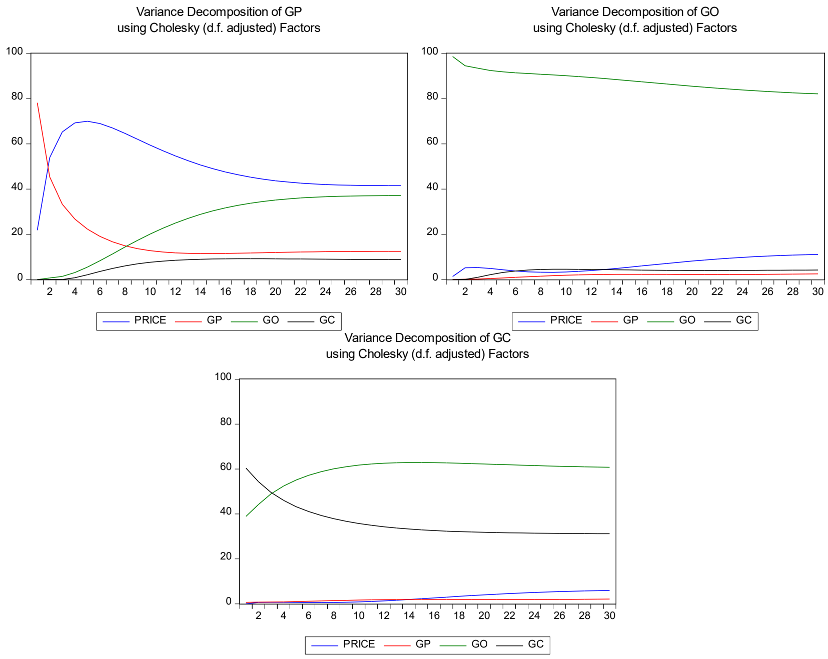

Figure 3: Variance decomposition estimation results of SVAR model in gasoline market

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5.2 Diesel market IRF and variance decomposition results

As can be seen from Figure 4, there is an obvious positive correlation between crude oil price and diesel oil price. The impact of crude oil price fluctuation on diesel price peaked 2 months after the fluctuations occurred, remained at the peak for about 2 months, and then began to weaken and disappear about 24 months after the fluctuations occurred. According to the research of Dallas et al. (2022) [4], the peak of this effect occurs 6 months after the crude oil price fluctuates, and the duration is no more than 9 months, which is quite different from our empirical results. Surprisingly, the response of diesel output to the fluctuation of crude oil price is similar to the trend of diesel price. The diesel output reaches its peak after 2 months of shock, and then began to weaken until it disappeared 25 months later. According to the Figure 6, the impact of crude oil price fluctuation on diesel consumption ranges from -7.4 to 10.9. The range of diesel output is 0 to 9.8.

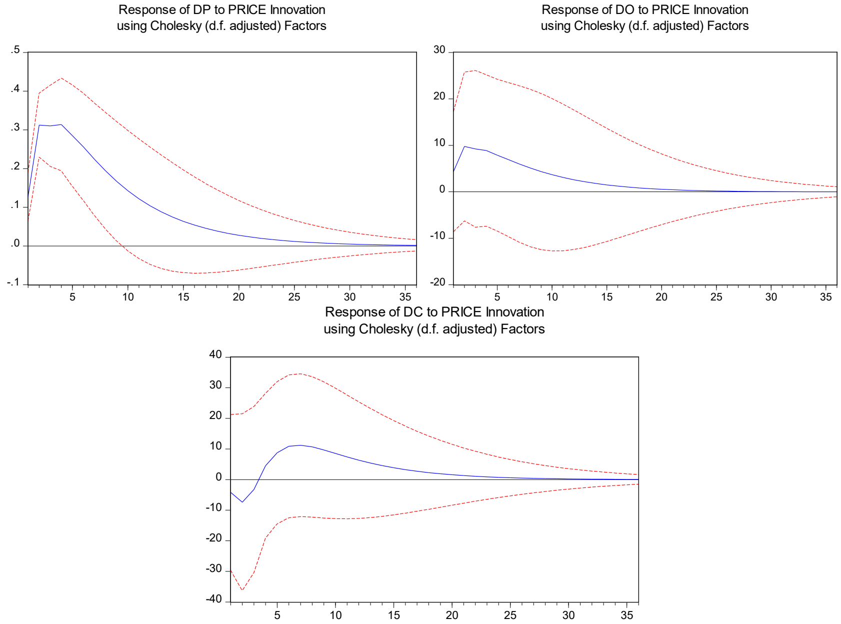

Figure 4: Trend chart of IRF estimation results in diesel oil market

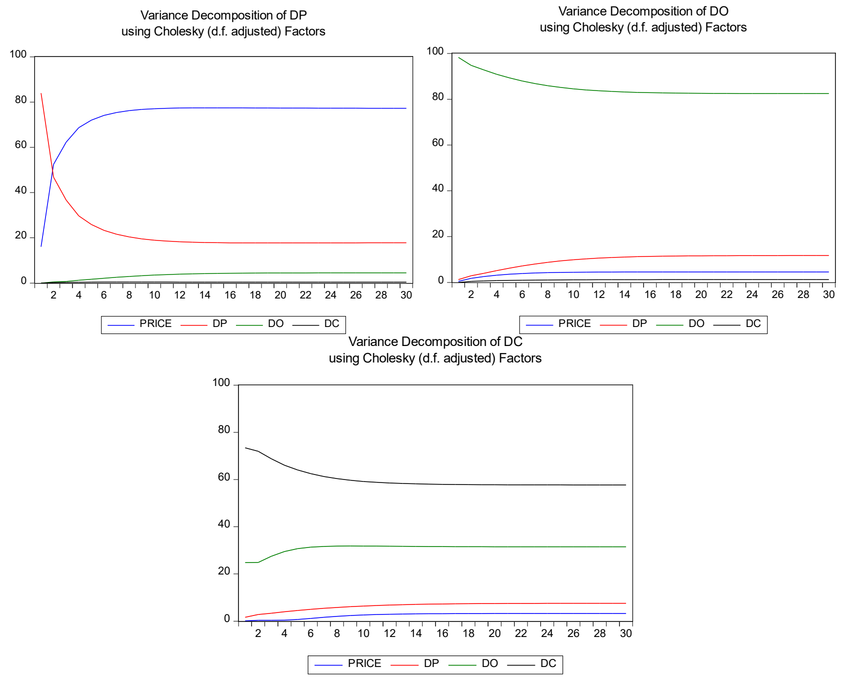

Figure 5: Trend chart of estimation results of variance decomposition of SVAR model in diesel market

Figure 5 shows that the fluctuation of crude oil price has the highest contribution rate to the change of diesel price, which is stable at 77% for a long time, while the contribution rate to the change of diesel production and consumption is lower, 5% and 3% respectively. According to the empirical results, we found that the contribution rate of oil price (including crude oil price and diesel price) to the fluctuation of diesel production and consumption is low, and the contribution rate of diesel price is even lower, about 7% and 5% respectively. It is worth noting that the contribution rate of diesel consumption to itself is significantly higher than other variables, about 58%, followed by output, which contributes about 38% to consumption fluctuations. Given that oil prices contribute less to production fluctuations, we think this may be due to the fact that most diesel production is determined first by the government and state-owned enterprises. As for the result of diesel consumption, we believe that it is determined by the use of diesel. A large part of diesel is used in industry and manufacturing, which is determined by exogenous variables.

5.3 Comparison the Gasoline and Diesel Market

It can be seen from the estimation results of IRF that: (i) The impact of crude oil price fluctuation on gasoline market lasts longer than that of diesel market. (ii) When the price of crude oil changes, the reaction of gasoline market is slightly larger than that of diesel market. Meanwhile, according to the results of the analysis of variance, we find that the contribution rate of crude oil price fluctuation on the structural impact of diesel price is statistically significantly greater than that of gasoline price. That means the oil price has a stronger pass-through effect on the diesel market as a whole than the gasoline market. (ii) The contribution rate of diesel price fluctuation to the structural impact of various variables in the market is slightly greater than that of gasoline price. We think this shows that the diesel market is less affected by government regulation.

From the perspective of consumption structure, diesel consumption mainly flows to industry, manufacturing and transportation, accounting for 90.36% of the total consumption for diesel oil. When the crude oil price change, the downstream industry cannot significantly adjust the output and demand in the short term. Different from diesel, the largest proportion of gasoline consumption is civil consumption, which is mainly used for residents' travel. Due to the diversification of travel modes, the demand for civilian gasoline is more sensitive to prices, which determines that the gasoline market is more responsive to the fluctuation of crude oil prices.

From the perspective of supply, because of the higher requirements for the brand and quality of oil products, China’s gasoline resources rely more on the sale of gasoline stations. As diesel is mainly used in downstream industries such as transportation and industry, and its use environment is relatively broad and rough, the diesel produced by local oil refining can directly meet the needs of most end users. Moreover, the sales of diesel sales mode is mainly wholesale, which makes the production and sales of diesel more diversified. Therefore, the diesel market can adjust itself faster when it is impacted by crude oil prices, and the impact of crude oil price fluctuations on the diesel market lasts for a shorter time.

For the analysis of the above results, we believe that it is basically consistent with our expectations and the conclusions of IRF analysis. That is, whether in the gasoline or diesel market, the output is controlled by the state, the price fluctuation is determined by the cost fluctuation caused by the change of crude oil price, and the consumption fluctuation is mainly determined by the output and consumption itself. However, there are differences between the two markets. Due to the diversification of diesel supply channels and uses, the diesel market is more flexible than the gasoline market.

6. Conclusion

This paper empirically tests the dynamic pass-through effect of world oil price changes on China's gasoline and diesel market. We measure pass-through effects using a SVAR model with short-run constraints. Our research shows that crude oil price fluctuations have a statistically significant pass-through effect on China's gasoline and diesel markets. When crude oil prices fluctuate, economic variables in both markets change to a greater extent. After analyzing and comparing the two markets, we found from the impulse response function that the impulse response of each variable in the gasoline and diesel market reached a statistical peak within two or three months, and the impact of crude oil price fluctuations on the market will last longer. And the duration of the impact on the diesel market is significantly shorter than that on the gasoline market.

In the past two years, the demand of gasoline market has been reduced due to the reduction of residents' travel caused by COVID-19 epidemic prevention and control and the rapid expansion of new energy vehicle market. The difference between production and demand in 2020 and 2021 is close to 15

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million tons. The rising cost of gasoline under the original high oil price has caused a huge impact on the civilian gasoline market, which mainly consumes 95# and 92# gasoline. Coupled with the economic downturn, residents are more sensitive to the change of gasoline prices. It will take a long time for the economy to recover and the epidemic to be completely controlled, which will have a long-term impact on the gasoline market in China.

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