The Impact of International Coal Prices on China's Macroeconomy in The Context of "Double Carbon"

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Abstract. Fossil energy is a bulk commodity that human beings rely on for survival and plays a pivotal role in a country's production, consumption, trade, and economic security.This paper analyzes the theoretical mechanism of international coal price on four aspects: economic growth, price level, consumer and investor expectations, and employment level; then constructs the FAVAR model based on 30 major economic indicators in China from 2001 to 2022 and uses impulse response to measure the direction and degree of response of each variable in the face of the international coal price shock, and finally uses variance Finally, the variance decomposition is used to analyze the contribution and association of the responses among the variables.The main conclusions of this paper include: (1) The rise of international coal prices will cause generalized inflation in China's economy, and compared with the CPI, the response generated by the PPI is more pronounced, but the CPI is more profoundly affected. (2) The international coal price shock will produce a particular blow to investment and consumption expectations, but through economic warming, investment levels and consumption expectations will be restored. (3) The rise in international coal prices will reduce the pre-existing level of unemployment. Although the rise in international coal prices makes the production costs of energy-intensive industries increase, which will reduce the number of jobs in the industry, it also increases the number of jobs in more energy-saving, emission reduction, and energy consulting services, so the overall level of the unemployment rate has decreased. (4) The rise in international coal prices has not reduced the economy's original output level and has had a relatively small impact on economic growth. Accordingly, this paper puts forward relevant suggestions such as stabilizing market expectations and exploring green financial models.

Keywords: international coal price; economic growth; inflation; expectation; FAVAR model

1 Introduction

Coal, as one of the most important sources of economic and social energy, has had a profound impact on the face of human society. With the rapid development of the economy after 1978, China's demand for coal has increased dramatically, and the production and consumption of coal have climbed rapidly. After entering the 13th Five-Year Plan period, China's economy has shifted to high-quality development, and governments at all levels have implemented a series of "carbon reduction and emission reduction" measures; the 14th Five-Year Plan puts forward a "carbon neutral" and "carbon emission reduction" plan. In the " 14th Five-Year Plan",

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"carbon neutral" and "peak carbon" targets were proposed, which put certain restrictions and higher requirements on the coal industry.

According to the "Statistical Bulletin of National Economic and Social Development of the People's Republic of China 2022", China's total energy consumption in 2022 will total 5.41 billion tons of standard coal, of which coal consumption will account for 56.2%; China's total power generation is one-fourth of the world's total power generation, with coal's thermal power generation accounting for more than 70% of that amount. The data on coal in energy consumption and power generation shows that China's demand for coal is vital.

Hence, there is the evident contradiction in use of coal in China : policy China to limit the production of coal energy and clean production requirements, advocating the use of other clean energy. However, in the short term, there is no way to achieve. People's lives, business production need to use a large number of coal. If the import situation is not optimistic, and the proportion of domestic coal use is more than half of the situation, will inevitably choose to increase the use of domestic coal but will face the original problem: the use of coal to rise and with the current "dual-carbon goals" conflict, difficult to reconcile. Therefore, how to harmonize the conflict between the two is a task that needs to be solved urgently in the coming period. In addition to keeping an eye on the international situation and working hard in the field of new energy research, the most direct way is to recognize the impact of imported coal on China's primary economic operations and to face the significant fluctuations in coal prices, which still require macro-control by the government in order to safeguard production and life. To what extent does the volatility of international coal prices affect China's macroeconomy? How can we weaken the negative impact of coal price volatility on policy? Against the background of facing the above significant realities in the long term, this paper studies the macroeconomic impact of international coal price volatility on China, which is still significant.

1.1 Impact of international energy price changes on the economy

What exactly is the impact of international energy price changes on the economy? Many scholars have tried to explain the impact mechanism and results from different paths and models. The content can be divided into four types: economic growth, price level, employment, and related industries, and the models usually use the VAR model, input- output model, CGE, and others.

Regarding the impact of energy price fluctuations on economic growth, most scholars suggest that the higher marginal cost of production brought about by rising energy prices will make the economy slow down; for example, the oil price of petroleum and GDP have a negative relationship [1-2], and the degree of impact is significant [3]; coal price increases initially hurt economic growth, and then turned into a positive effect [4] . However, some studies show that firms will promote energy inputs more before the actual increase in energy prices, which increases employment and brings higher labor income and capital rents and instead promotes GDP growth in the short run [5-7]. In addition to the direction of the effect of energy price fluctuations on economic growth, other scholars have also studied the size of the impact [8-9], such as the famous scholar Lin Boqiang that the effect of coal price increases constrains economic growth is small [10], which may be due to the future growth of real GDP is not only related to the current energy prices, but also with the forecast of the long-run average and the

changes in unanticipated fluctuations [11], but from the perspective of elasticity there is still a clear impact [12] . At the same time, there is an asymmetry in the impact of whether price changes in energy are up or down on economic growth; for example, the impact of rising crude oil prices on economic growth is more significant than that caused by the decline [13] .

Most studies about the impact of energy price fluctuations on price levels have been conducted through the CPI and PPI indices due to the good explanatory power of commodity price shocks on price increases [14] . There is a unidirectional long-run equilibrium relationship between oil prices and CPI and PPI [15], and their fluctuations profoundly affect the PPI and outweigh the impact on the CPI [16] . From the overall inflation perspective, the increase in international oil prices leads to inflation. It reduces domestic output and investment [17- 18] . The effect of commodity price changes on the price level is negative first and then positive [19]. The above studies empirically proved that energy price volatility significantly impacts the price level. Some other scholars compare the degree of impact of the price volatility of different energy sources on the price level; for example, the international oil price fluctuations on China's price index and economic growth rate will be more significant than the impact of price fluctuations of natural gas [20]; international non-ferrous metal prices on China's inter- provincial inflation transmission effect will be asymptotic over time [21] .

Regarding the impact of energy price volatility on employment, the direction of the effect obtained by different scholars' studies varies. Uncertainty about oil prices increases the unemployment rate in the U.S. Positive oil price shocks increase the unemployment rate; adverse oil price shocks decrease the unemployment rate, and the extent to which positive and negative oil price shocks affect the unemployment rate is asymmetric [22]. At the same time, common sense suggests that some jobs in energy-intensive industries are lost. As a result, new jobs are created in sectors that produce and install pollution abatement technologies and provide energy consulting services [23]. Thus, higher energy prices are associated with an increase in overall net employment, illustrating that the impact of energy price volatility on employment cannot be generalized. In domestic studies, the urban and rural registered unemployment rates are affected unilaterally by international oil price fluctuations, with the unemployment rate moving inversely by 0.0383% for every 1% change in the international crude oil price in the short run [24]. It is also suggested that unemployment declines rapidly in the short run and then grows again, with a long-lasting effect in the long run [25].

1.2 FAVAR model

The FAVAR model addresses the shortcomings of VAR, SVAR, and VECM in terms of too few model variables and limited information and uses multivariate and large-scale macroeconomic time series to explore the impact of a variable on the system, which is more in line with the reality of the economic situation, by extracting a small number of common factors from the high-dimensional set of economic information, and then using the common factors and other variables to establish the VAR model [26] to describe the response of all data series to macroeconomic disturbances. Response of all data series to macroeconomic perturbations. From the view of empirical effect, the FAVAR model's empirical effect is better than the VAR model [27-28]; from the view of the application, the use of the FAVAR model is mainly concentrated in the analysis of inflation and monetary policy [29-30] but also can be used to

study the response of prices to macroeconomic shocks and assess the impact of monetary policy on prices in different sectors [31].

Through the organization of the literature, it is found that oil and natural gas are mainly used as energy sources in the study of international energy prices and China's macroeconomy. Most impact objects focus on the price level and economic growth. The domestic and international literature on the macroeconomic impact of international coal prices on China is limited, and the use of models is more limited. To summarize, the existing literature has the following elements to add:

(1) Focus on the national situation and study the impact of international coal price fluctuations. Currently, most scholars take international oil prices as the object of study, but there needs to be more literature on research on international coal prices.

(2) Using different methods of empirical analysis. In this paper, the FAVAR model is selected, mainly used for modeling time series systems that influence each other and to analyze the impact of a particular shock on this system. The existing literature uses the input-output method to explore the correlation effects among different industrial sectors. The CGE model requires employment and monetary policy, etc., to establish a system of linear equations under the closure conditions for solving. However, the choice of closure will cause many problems for model solving. Hence, this paper chooses the FAVAR model.

(3) Using expectations as a new direct perspective.In many scholars' studies, expectations have been analyzed as an important influence on price changes, but in an indirect way. This paper will use expectations as a new direct perspective to explore how people's subjective, uncontrollable, judgments affect international coal prices.

2 Impact mechanism analysis

Coal, as a bulk commodity in the production and life of modern society, is widely involved in thermal power generation, industrial production, commodity production, etc., and substitutes and complements oil, which significantly impacts the economy. On the one hand, the price of coal affects the cost of production, directly affecting people's expectations of investment and consumption as well as factor inputs and outputs. On the other hand, it indirectly affects the price of industrial products transmitted to consumer goods, thus affecting the price level. This paper will explore the theoretical mechanism of the macroeconomic impact of international coal prices from four aspects: economic growth, price level, investor and consumer expectations, and employment level.

2.1 Economic growth

Economic growth, in a narrow sense, is expressed as GDP growth. According to the four sectors of the economy, consumption, investment, government purchases, and net exports constitute total output. In the consumption part, energy, as a factor of production, presents the law that the more inputs there are, the greater the total output under constant returns to scale. When the structure and variety of energy sources cannot be adjusted in the short term, if the original quantity continues to be purchased, the price of energy rises, raising the share of energy consumption expenditures in total consumption expenditures, a change that is not conducive to

economic growth. Higher energy prices increase the consumption burden and negatively affect domestic consumption.

In the investment part, energy-intensive enterprises face a steep rise in production costs; if they are unable to transfer part of the cost to the downstream enterprises in the industrial chain, it will make the enterprise investment willingness decline, reduce production, and some enterprises will face the shutdown of production. Therefore, rising energy prices are not conducive to investment and will reduce economic output, slowing macroeconomic growth.

In the import and export, energy prices will theoretically increase the freight costs of import and export enterprises, so the specific impact of international coal prices on economic growth has to be followed by further empirical evidence.

2.2 Price level

According to New Keynesianism, the common causes of inflation are demand-pull, cost-push, and structural push. The cause of demand-pull inflation is the result of high demand and low unemployment generated by GDP growth; cost-push inflation is the result of a significant increase in prices due to the increase in the cost of raw materials and other costs of production; and structural inflation is due to changes in the structural factors of the economy, which can also result in a sustained increase in the general price level. The causes of inflation in real life are more complex, and it is challenging to state whether it is the supply or demand side of the reason, so this paper chooses to use a mixture of supply and demand to push the type of inflation to analyze. Samuelson and Solow together proposed hybrid inflation. They argued that inflation can begin with excessive demand or cost advances, but sustained inflation requires increased demand.

According to the context of this paper, the price increase of coal, which is used as a raw material for many industrial goods and fuel for electricity and transportation, triggers inflation in the production sector first. This type of hybrid inflation that starts first in the production sector is characterized by two things: firstly, prices spiral upwards. Secondly, this type of inflation occurs when actual production does not fall much or not at all.

2.3 Expectations

Psychological expectations mainly refer to people's optimistic attitude towards economic prospects. In a broad sense, expectation refers to the prediction of economic subjects, including investors and consumers, on the future economic situation or an economic variable that influences the future economic behavior of each subject.

The classical cobweb model can explain the fluctuation of production and price of commodities with long production cycles. However, it ignores the fact that people can revise their expectations through experience, so this paper uses the cobweb model with adaptive expectations, in which economic agents will revise their expectations in each subsequent period according to the degree of the mistakes they have made in the past in making expected decisions. The specific equations are as equation(1)(2) and (3).

$$Q_s = c + dp \tag{1}$$

$$Q_d = a - bp \tag{2}$$

$$P_t^e = P_{t-1}^e + \beta(P_{t-1} - P_{t-1}^e) \quad (3)$$

P_t^e, P_{t-1}^E are the producer's expected product prices in periods t and t- 1, respectively, and β is the adaptation coefficient, which indicates the speed at which expectations are corrected for past errors. Suppose the actual price level in the previous period is higher than expected. In that case, the expected price in the current period will be adjusted upward based on the expected price in the previous period. Under the adaptive expectations condition, price expectations for the current period are a weighted average of several past prices, and the further away they are from the present, the less valuable they are in shaping current expected prices.

In this paper, known changes in energy prices can influence the expectations of investors and consumers. When investment and consumption agents use information about known energy price increases to draw forecasts of future price increases, they adjust their activities, which in the short term accelerate existing economic activity. Many contracts for purchase and sale and arbitrage operations in the market in the short term impact the future energy price, further affecting the spot price. Energy will continue to rise in the next period. When the price of energy deviates from its equilibrium price, instead of converging to the equilibrium price, it oscillates significantly. This process describes a divergence spiderweb model with adaptive expectations. Overall, investor and consumer expectations can significantly influence subsequent price changes by altering supply, demand, and funding, further amplifying the impact of rising energy prices.

2.4 Employment levels

Structural changes in the economy cause structural unemployment. Economic structural changes include changes in industrial structure, product structure, regional structure, etc. When these changes cause the market demand for a specific type of labor in a particular market to be relatively lower than its supply, unemployment will result.When the international price of coal rises, the cost of production rises in industries that use more coal. This will cause some companies to stop production, while others will choose to use cleaner energy, improve technology, and transform their industries to minimize the impact of rising production costs. At this time, the original use of coal industry structure and product structure adjustment, the labor market for the coal industry in terms of labor demand is reduced, and labor resources are relatively abundant, supply elasticity, and short-term labor in the knowledge, skills and regional distribution of challenging to adjust, will lead to structural unemployment.When employment opportunities in coal-related industries are reduced, new employment opportunities are generated in areas such as energy consultancy and new technologies. Therefore, further empirical evidence is needed on the direction and magnitude of the impact of rising international coal prices on employment levels.

3 Empirical analysis

3.1 Model presentation

In this paper, we use the FAVAR (factor-expanded vector autoregressive) model, which works better for modeling large-scale and multivariate data compared to the VAR model, which intuitively appears as a linked form of multiple equations, and estimates the dynamic

relationship by regressing the current periodical variables on their own lagged values. The classical mathematical form of var(p) is shown as equation(4):

$$y_t = A_t y_{t-1} + \ldots + A_p y_{t-p} + \varepsilon_t \quad (4)$$

Bernanke (2005)[26] explains that the shortcoming of VAR is the inability to reflect more economic information when faced with rich economic data, making the modeling itself less effective and failing to identify problems when conducting structural shocks. To address this shortcoming, the FAVAR model is made more effective by extracting a small number of common factors from high-dimensional macroeconomic data and regressing them against observable variables.

In the FAVAR model, Yt is set to be an L × 1 matrix of observed variables with macroeconomic implications. F_t For contains information that cannot be captured for Yt and is a matrix of K × 1. B(L) is a p-order lag polynomial andε_t is the random error term.

$$\begin{pmatrix} F_t \\ Y_t \end{pmatrix} = B(L) \begin{pmatrix} F_{t-1} \\ Y_{t-1} \end{pmatrix} + \varepsilon_t \quad (5)$$

The model focuses on the estimation of Ft. Since Ft is unobservable, equation (5), although resembling a VAR model, cannot be estimated using the common OLS method. Therefore, setting Ft and Yt can be expressed as Xt, in the form of equation (6).

$$X_t = \Lambda^F F_t + \Lambda^Y Y_t + e_t \quad (6)$$

where Xt is an N × 1 matrix of a large number of economic time series, the Λ^F andΛ^y are factor loading matrices, ande_t is white noise.The number of N should be much larger than the number of K+L, which in practice is usually required to be more than 100.

3.2 Data sources and processing

The sample range used in the model is China's monthly time series data from January 2001 to December 2022, containing 33 variables, each containing 8712 observations, which meets the quantity condition of N above.

Macroeconomic indicators are divided into consumption expectations, output and boom situation, investment, foreign exchange, trade, and price categories, totaling six categories and 30 variables, as shown in Table 1. In order to eliminate the problem of the data's magnitude, this paper standardizes the data with Z-score, and the data are obtained from the National Bureau of Statistics (NBS), General Administration of Customs (GAC), the IEA's U.S. Energy Information Administration (EIA), the World Bank, and CEIC databases.

Table 1. Macroeconomic information variables

form	alphanumeric	name
Consumption expectations	CCI	Consumer confidence index
Output and boom situation	GDP	Gross domestic product
Investment grade	DEX_LEA	Macroeconomic sentiment index

	IND	value added by industry
	EN	Electricity generation from industrial production
	FAI	fixed-asset investment
	HS_N	New construction of commercial housingInvestment in real estate development
	HSS	Sales of commercial properties
foreign exchange rate	ER	Exchange rate: PBC: end of period: United States dollars
	FER	Size of the country's foreign exchange reserves: $ billion
	FRI_HEARN	P/E Ratio: Shanghai Stock Exchange: Stocks
	FRI_QUA	Number of transactions: Shanghai Stock Exchange: Tot
	FRI_SPI	Index (Shenzhen Composite Index)
trade group	SALE	Total retail sales of consumer goods: current value
	EX	Total exports FOB
	IM	Total imports CIF
price category	CPI	consumer price index CPI
	PPI	Industrial producers' ex-factory price index
	PPI_P	Industrial producer factory price index: means of production
	PPI_P_ 1	Industrial producer factory price index: extractive industries for means of production
	PPI_P_2	Industrial producer factory price index: production raw materials industry
	PPI_P_3	Industrial producer ex-factory price index: processing industry of means of production
	PPI_V	Industrial producer factory price index: information on living conditions
	PPI_V_ 1	Industrial producers' factory price index: foodstuffs for domestic consumption
	PPI_V_2	Industrial Producer Price Index: Clothing, Means of Living
	PPI_V_3	Industrial producers' ex-factory price index: means of subsistence, general daily use
	PPI_V_4	Industrial Producer Price Index: Durable Consumption of Means of Living
	API	Price index for means of agricultural production Price of electricity use: General industrial electricity
	P_POWER	General industrial electricity
International coal prices	COAL	Baroque Gold Index

unemployment rate	UE	Urban registered unemployment rate
Internationaloil prices	OIL	OPEC crude oil prices

These data types themselves contain many of the factors affecting international coal, such as foreign exchange category in the export FOB, import CIF, can effectively represent the different international trade situation, the overall impact of trade policy. Industrial factory price index is divided into two categories, one related to industrial enterprises, one related to the daily life of residents. Finally, OPEC crude oil prices are also added to explore the impact of the relationship between alternatives, making the data more comprehensive.

3.3 Results of empirical analysis

3.3. 1 Principal factor extraction and estimation of unobservables

In this paper, we use SPSS to carry out the KMO and Bartlett test on the macroeconomic time series Xt (excluding COAL and UE) above. The obtained value is 0.817, which indicates that it is very suitable for factor analysis. Then, we use principal component analysis to obtain five principal factors. The cumulative degree of explanation of their variance reaches 87.83%,

which indicates that the explanatory ability of these five factors is excellent. Finally, The five factors were named according to the rotated variance matrix; see Table 2 for details.

Table 2. Principal factor extraction and naming

factor	christen	Macroeconomic variables represented
FAC_1	Economic output factor	GDP, FER, ER, EX, IM, PPI_V_4, IND, SALE, FRI_SPI, FRI_QUA, DEX_LEA ,FRI_HEARN
FAC_2	Producer price factor	PPI, PPI_P, PPI_P_1, PPI_P_2, PPI_P_3
FAC_3	Price of living factor	PPI_V, PPI_V_1, PPI_V_3, API, CPI
FAC_4	investment factor	HS_N, FAI
FAC_5	Expected Factor	P_POWER, PPI_V_2, CCI

3.3.2 Correlation test

In real life, a large number of macroeconomic time series are stochastic wandering series; if the unit root test is not carried out, it will often make the model appear to be a "pseudo- regression" phenomenon so that there is no causal relationship between the variables can also have a better fit. Therefore, in order to avoid this phenomenon, this paper first determines the unit root test form of each variable and then uses the ADF method to carry out the unit root test on the variables COAL, OIL, FAC_ 1, FAC_2, FAC_3, FAC_4, FAC_5, UE, and their differences, the test results are as follows.

Table 3. Unit root test

variant	ADF_t statistic	5% threshold	steady
COAL	- 1.374	-2.873	NO
DCOAL	-3.071	-2.873	YES
FAC_ 1	-0.520	-2.873	NO
DFAC 1	-3.650	-2.873	YES
FAC_2	-3.284	-2.873	YES
DFAC_2	-5.271	-2.873	YES
FAC_3	-2.951	-3.427	NO
DFAC_3	-4.157	-3.427	YES
FAC_4	- 1.763	-3.995	NO
DFAC_4	-3.605	-3.428	YES
FAC_5	- 1.781	-3.427	NO
DFAC_5	- 19.277	-2.872	YES
UE	-3.604	-2.873	YES
DUE	-6.098	-2.873	YES
OIL	-2.821	-2.872	NO
DOIL	- 10.355	-2.872	YES

According to Table 3, all seven variables exhibit smooth properties after performing first- order differencing, and except for the FAC_2 and UE factors, the original data of the other series are not smooth and have unit roots. Here, it is noted as COAL~I(1), OIL~I(1), FAC_ 1~I(1), FAC_3~I(1), FAC_4~I(1), FAC_5~I(1), and then the regression equations are established. The unit root test is carried out on the generated residual series, which is considered to be smooth. Accordingly, it can be inferred that there is a long-run equilibrium relationship between these sequences and the existence of unstable series. It is able to make the residual series smooth, so it is necessary to do further cointegration relationship tests.

Next, Johansen's cointegration test is performed on COAL, OIL, FAC_ 1, FAC_2, FAC_3, FAC_4, FAC_5, and UE, and the trace test results are obtained. According to the results of the two tests in Table 4, the hypothesis of "up to three cointegration equations" is rejected at the 5% confidence level, indicating that there are at least four cointegration relationships between the variables. In the long run, there is the same trend of change between the variables (COAL, OIL, FAC_ 1, FAC_2, FAC_3, FAC_4, FAC_5, UE). There exists the same trend of change.

Table 4. Johansen cointegration test

Hypothesized No. of CE(s)	Eigenvalue	Trace statistic	0.05 Critical Value	Prob.**
None *	0.463	714.675	159.529	0.000
At most 1*	0.448	552.804	125.615	0.000
At most 2*	0.341	398.067	95.753	0.000
At most 3*	0.292	289.584	69.819	0.000
At most 4*	0.247	199.765	47.856	0.000
At most 5*	0.194	125.783	29.797	0.000
At most 6*	0.150	69.465	15.494	0.000
At most 7*	0.098	27.022	3.841	0.000

According to the previous unit root test, it is known that the original series is not smooth after the first-order difference is smooth, which meets the conditions for establishing the VAR model.

Then, the VAR model is established by using the series after the first-order difference, with Dcoal as the explanatory variable, and the other variables are used as explanatory variables after the first-order difference. After a comprehensive comparison of the results of lagging different periods, the model is considered optimal in lag two based on the AIC and LR values. AndThe AR test is conducted, and it is found that all the points fall within the unit circle, for an example see **Figure 1.**. It is considered that the model is more stable in lag 3.

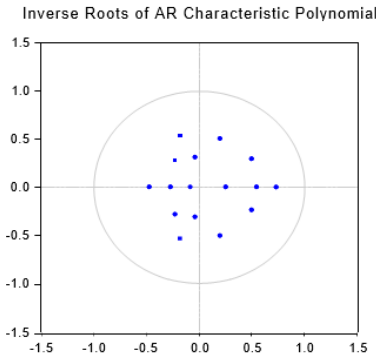

Fig. 1. Unit circle test

3.3.3 Impulse response analysis

In order to reflect the impact of international coal prices on China's macroeconomy, this paper employs an impulse response function to analyze the response of each factor in the face of international coal price shocks. Figure 2 illustrates the impulse response results, which are the shocks of Dcoal to DFAC_ 1, DFAC_2, DFAC_3, DFAC_4, DFAC_5, DUE. In addition, DOIL and DCOAL have also been added to the impulse response to reflect the substitution between coal and oil, meaning the volatility of the growth rates of the eight variables in the following 10 periods when the growth rate of coal price has a positive unit standard deviation. The blue line indicates the impulse response function, and the red dashed line represents the positive and negative two-times standard deviation bands. The following impulse response analysis based on Figure 2 shows that.

The increase in international coal price will increase the price of input factors in industrial production, which will lead to an increase in PPI and CPI, as shown in the figure for the response of FAC_2 and DFAC_3 to the increase in coal price. In the factor naming, FAC_2 is the production price factor and FAC_3 is the living price factor. The production price factor shows the strongest response at period 2, after which the response weakens and disappears around period 6. In contrast, the price of living factor is more volatile around period 3 and disappears in period 5. Both in terms of duration and degree of response, the PPI indicator is more pronounced than the CPI indicator. Because the PPI is more closely linked to coal in real life and is used to a relatively high degree than the LPI, it is more sensitive and reacts earlier to shocks, and because industry is heavily influenced by energy, it will take longer to neutralize the impact of shocks.

In addition, the transmission effect of hybrid inflation will cause a general increase in the price level. Mild inflation is good for the economy, so it can be observed that FAC_ 1 shows a positive

response in period 1, indicating that the economy is showing some prosperity at this time. However, if the price of coal continues to rise, it will result in further inflation. The decline in people's purchasing power calls for an increase in the level of the real wage; the final price-wage cycle formed will spontaneously drive inflation. Excessive inflation will have a reverse effect on the economy, which is shown in the graph as a significant negative response in periods 2 and 3, a situation that needs to be noted.

For investor and consumer expectations, FAC_4 shows a negative response in the face of rising coal prices, which is consistent with the results of impaired investment expectations and declining investment described in the theoretical mechanisms in Chapter 2. FAC_5 reacts positively in the graph, and theoretically, the expectations of the economic agents affected by the shock of international coal prices are impaired, which temporarily reduces economic activities such as consumption. However, due to the weakening of the impacts suffered by the CPI as well as moderate inflation, the weak positive effect shown by the economic output factor will gradually restore the expectations in the market, so FAC_5 shows a positive effect overall.

For the unemployment rate the increase in international coal prices reduces the original level of the unemployment rate. The rise in international coal prices caused generalized inflation in the country. In theory, according to the Phillips curve, in the short term, the unemployment rate and the inflation rate show a short-term directional substitution relationship, so the unemployment rate shows a downward trend. In practice, the rise in international coal prices has reduced employment opportunities in energy-intensive industries. At the same time, it has increased employment opportunities in energy-saving environmental protection and energy consulting, so the unemployment rate has decreased.

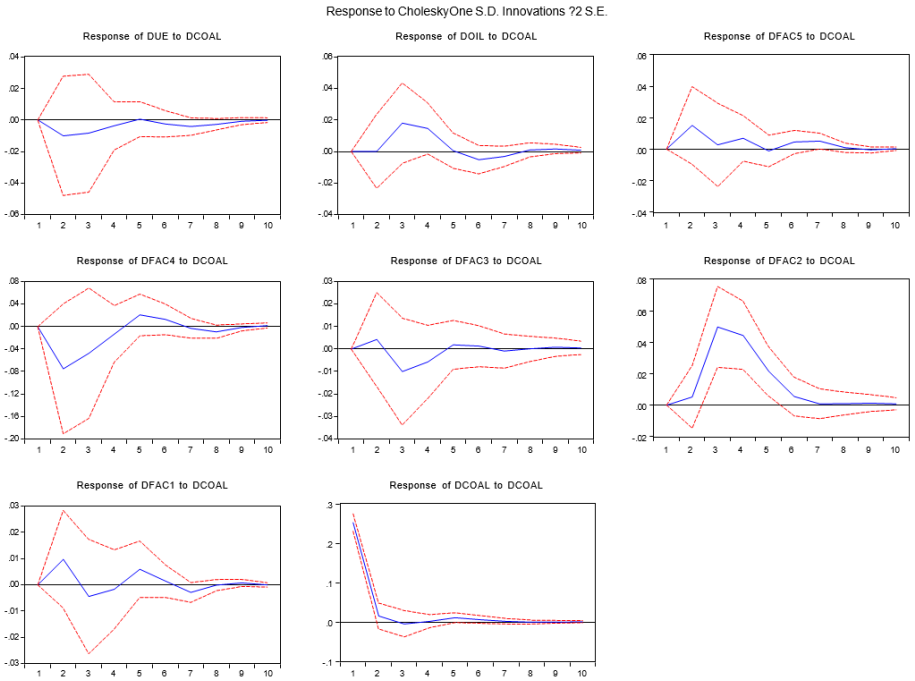

Fig. 2. Impulse response analysis

In addition, the substitutes relationship is clearly reflected in the chart. DOIL and DCOAL show obvious substitution in the time period when facing the international coal price shock:

when Dcoal shows a short and sudden positive feedback in the first two periods, DOIL keeps the original level; in the period of 2-5, the fluctuation of DCOAL is gradually weakened, and at this time, DOIL shows a positive feedback. It can be seen that the relationship between substitutes is obvious, and it also shows that the substitution ability of oil is stronger than that of coal. In real life, the use and price status of oil is higher than that of coal, so when coal appears to have a high price, the price of oil won't fall easily; and when the price of coal is too high, oil will be chosen as a substitute.

Overall, the impact of coal price changes on each factor is the strongest in the 2nd-3rd period, so the subsequent formulation of policies can be effectively adjusted according to the lag period of the impact.

4 Conclusions

In today's context of advocating energy conservation and energy transition, China is committed to accelerating the construction of a clean, low-carbon, safe, and efficient energy system in order to realize the dual-carbon goal as soon as possible, which is manifested in but not limited to, lowering the rate of coal use, reducing the application of thermal power, vigorously promoting the construction of water conservancy, and establishing a multi-energy utilization system of wind, hydro, tidal, solid heat and nuclear energy, etc. However, research on and the application of new energy sources is still in the developmental stage, and it is challenging to replace traditional fossil energy sources in a better way in the short term. Hence, the study of the effects of the international coal price on China's macroeconomic impacts is still of some practical significance.

By explicitly analyzing the degree and duration of the impact of international coal price shocks on the five major indicators of China's economic growth, price level, investment, expectations, and unemployment, it is possible to reduce the use of coal while supporting the corresponding policy measures to attenuate the negative impact on the leading domestic economic indicators.

(1) The rise in international coal prices will cause generalized inflation in China's economy, and compared with the CPI, the reaction generated by the PPI is more evident and far- reaching.

(2) The international coal price shock will deal a blow to both investment and consumption expectations, but through the warming of the economy, both investment levels and consumption expectations will recover.

(3) The rise in international coal prices will reduce the original level of unemployment in China, contrary to our subjective belief that rising energy prices will have a negative impact on employment. Although the rise in international coal prices caused some employees in energy-intensive industries to lose their jobs, it increased more employment opportunities related to pollution reduction and energy consulting services. Moreover, some enterprises may increase their workforce and expand their production ahead of time in anticipation of the rise in coal prices. The overall number of new jobs should be larger than the number of unemployed people so that the original level of the unemployment rate decreases.

(4) The rise in international coal prices did not reduce the level of output in the economy. It is mentioned in the theory of hybrid inflation in Chapter 2 that when this kind of inflation occurs, the actual output of the economy does not fall or fall slightly, and the conclusion is in line with the theoretical results of hybrid inflation.

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References

[1] K. L. Kliesen.: Oil and the U.S. Macroeconomy: An Update and a Simple Forecasting Exercise. Oct. 2018.

[2] G. Oladosu.: Identifying the oil price – macroeconomy relationship: An empirical mode decomposition analysis of US data. Energy Policy, vol. 37, no. 12, pp. 5417 –5426, Dec. 2009.

[3] S. Balashova and A. Serletis, "Oil prices shocks and the Russian economy," The Journal of Economic Asymmetries, vol. 21, p. e00148, Jun. 2020.

[4] W.B.Li, R.Y.Long, Z.H.Ding.: The impact of coal price volatility on China's economic growth under the dual perspectives of linearity and nonlinearity. Resource Science, vol.37, no.10, pp:1973-1982, 2015.

[5] M. T. Punzi.:The impact of energy price uncertainty on macroeconomic variables. Energy Policy, vol. 129, pp. 1306– 1319, Jun. 2019.

[6] D. Zhihu.: Impact of Coal Price Fluctuation on China's Real Economy. Journal of Beijing Institute of Technology,Journal of Beijing Institute of Technology, Jan. 2014.

[7] S.L.Wei.: An Empirical Analysis of the impact of international crude oil price fluctuations on China's macro-economy. Special Economic Zone Economy, no.10, pp:94-96, 2011.

[8] T. Azomahou, NjugunaS. Ndung'u, and M. Ouedraogo.: Coping with a dual shock: The economic effects of COVID- 19 and oil price crises on African economies. Research Papers in Economics,Research Papers in Economics, Jan. 2021.

[9] S. Wang, X. Zhang, and L. Zhao.: Why the Effects of Oil Price Shocks on China's Economy are Changing. The Energy Journal, vol. 41, no. 01, Sep. 2020.

[10] D.G.Mou, B.Q.Lin.: Research on time-varying parameters interinfluencing economic growth, electricity consumption and coal price in China. Financial Research, no.6, pp:42-53, 2012.

[11] J. Isaac Miller, Shawn Ni.: Long-term oil price forecasts:A new perspective on oil and the macroeconomy. Macroeconomic Dynamics, vol.15, pp:396-415, 2011.

[12] X.Y.He.: Empirical study on the impact of coal price fluctuations on regional economic growth--taking Anhui Province as an example. Price Theory and Practice, no.8, pp:52-53, 2013.

[13] X.H.Yang.: Study on the asymmetrical impact of International Crude Oil Price fluctuation on China's economic growth. Price Theory and Practice, no.10, pp:54-55, 2009.

[14] H.Q.Zhang, Y.Q. Zhao, R.H.Xu.: A Study on the Impact of International Commodity Prices on Domestic Inflation. Finance and Economy, no.4, pp:9- 16, 2019.

[15] L.L.Zheng.: Study on the impact of international oil price fluctuations on China's price level--estimation based on n cointegration and state space model.Economic longitude, no.2, pp: 116- 120, 2013.

[16] L.J.Xiao, D.Q. Zhou.: Study on the impact of international oil price fluctuation on China's price level. Journal of Tianjin University (Social Science Edition), vol. 12, no.5:405-409, 2010.

[17] S.S.Wu, B.G.San .: Study on the impact of international oil price fluctuations on macroeconomic shocks. Price Theory and Practice, no.4, pp:51-55+177, 2020.
[18] G.H.Cao, K.Wei, L.Li.: Study on the impact of international commodity price fluctuations on China's CPI--an empirical analysis based on FAVAR model. Price Theory and Practice, no. 12, pp:101-103, 2015.
[19] Z.P.Ren .: The potential and practical impact of energy price fluctuations on China's price level . Economic Research, vol.47, no.8, pp:59-69+92, 2012.
[20] Q.Li, W.Wei.: Study on the impact of international resource price shock on China's macro-economy. Journal of Guangxi University of Finance and Economics, vol.28, no.5, pp:1-8, 2015.
[21] X.H.Zhu, J.Y.Chen, M.R.Zhong.: Research on the temporal and spatial characteristics and influencing factors of the transmission of international non-ferrous metal prices to China's inflation. International Trade Issues, no.7, pp:130- 140, 2016.
[22] O. Kandemir Kocaaslan, "Oil price uncertainty and unemployment," Energy Economics, vol. 81, pp. 577–583, Jun. 2019.
[23] E. Hille and P. Möbius, "Do energy prices affect employment? Decomposed international evidence," Journal of Environmental Economics and Management, vol. 96, pp. 1–21, Jul. 2019.
[24] G.H.Hu, Y.L.Meng.: The impact of international oil price fluctuations on China's employment level. Special Economic Economy, no.4, pp:173- 174, 2013.
[25] W.Z.He, F.C.Lu.: Empirical analysis of the relationship between factor price fluctuations and employment. Price theory and practice, no.3, pp:62-63, 2013.
[26] Ben S. Bernanke, J. Boivin, and P. Eliasz, "Measuring the effects of monetary policy: a factor-augmented vector autoregressive (FAVAR) approach," Quarterly Journal of Economics,Quarterly Journal of Economics, Jan. 2004.
[27] C. Vargas-Silva, "The effect of monetary policy on housing: a factor-augmented vector autoregression (FAVAR) approach," Applied Economics Letters, vol. 15, no. 10, pp. 749–752, Aug. 2008.
[28] R. Gupta, M. Jurgilas, and A. Kabundi, "The effect of monetary policy on real house price growth in South Africa: A factor-augmented vector autoregression (FAVAR) approach," Economic Modelling, vol. 27, no. 1, pp. 315–323, Jan. 2010.
[29] U. Akkoç, A. Akçağlayan, and G. Kargın Akkoç, "The impacts of oil price shocks in Turkey: sectoral evidence from the FAVAR approach," Economic Change and Restructuring, vol. 54, no. 4, pp. 1147– 1171, Nov. 2021.
[30] P. Jithin and B. M. Suresh, "Testing for the Effectiveness of Inflation Targeting in India: A Factor Augmented Vector Autoregression (FAVAR) Approach," Journal of Central Banking Theory and Practice, vol. 9, no. 3, pp. 163– 182, Sep. 2020.
[31] Boivin J,Giannoni M P,Mihov I.: Sticky Prices and Monetary Policy: Evidence from Disaggregated US Data. American Economic Review, vol. 99, no. 1, pp. 350 –84,Feb. 2009.