Modelling the Interaction of Sustainable Variables in Yellow River Basin: A PVAR Approach

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Abstract
Economic development, environmental quality and residents' health are significant topics in sustainability. The relationship between them can, to some extent, determine the potential for sustainable development in the region. The Yellow River basin (YRB) in China has an important strategic position of water conservation, ecological protection, and stability and unity of ethnic minorities for the whole China. Therefore, it is of great significance to study the relationship there. Using balanced panel data from 2014 to 2019, this paper selected carbon emissions intensity, gross domestic products per capita, and proportion of private health expenditure to consumption of nine provinces in the YRB as research variables, constructed a PVAR model, and analyzed and studied the interaction among them. The research shown that the three variables have close impulse and response relationship. The improvement in economic development and public health would stimulate carbon emissions. However, the intensity of carbon emissions increment will basically not affect the physical health of local residents, but might hinder economic development. In order to ensure the high-quality development of the YRB in China, the harmonious and coordinated development of the relationship among these sectors is essential.
Keywords: Environmental Quality, PVAR, Pulse Response Function, Yellow River Basin

Introduction
In the case of increasingly prominent global environmental issues, most of countries in the world have put forward carbon neutral development goals. It is a new international standard that affects the value chain, innovation chain and industrial chain, and induce a systemic change in the current world economy. Carbon emission reduction is not only a climate and environmental issue, but also highly related to development, involving economy, society, population, energy, environment and etc. It makes energy security, economic growth, social livelihood, input cost balances becoming necessary. From the perspective of carbon emission reduction, Yellow River Basin (YRB) is renowned as "energy basin", highly depends on

resources, and has long been at the low end of mining and rough processing with huge carbon emissions, in which it is difficult to control carbon emissions. Meanwhile, YRB is also an important food production base in China, with a complete industrial chain and an important strategic position for economic and ecological protection. For government, the people live and work in peace and contentment, enjoy good health, and enhance people's happiness are also important issues. The smaller the proportion of private health expenditure in personal consumption, the healthier of residents can be measured to a certain extent, in which, the public health is closely related to the environment and the pattern of economic growth. Thus, it can be seen that it is of great significance to study the relationship and achieve the harmonious development of health, environmental quality and wealth. Moreover, only a small number of studies have examined how all of these variables interact at once identified in the Web of Science database in the last seven years(Vyas et al., 2023; Li et al., 2022; Nasreen, 2021; Anwar et al., 2021; Usman et al., 2019; Yazdi and Khanalizadeh, 2017). The research employed the heterogeneous panel causality test, Lagrange Multiplier bootstrap, and auto regressive distributed lag methods. In contrast to previous research, the Panel VAR approach is used in this study because of the significant endogeneity between variables and the long panel data set characteristic. Furthermore, this study utilized the proportion of private public healthcare expenditure to consumption to represent public health since the possibility of bias when considering healthcare spending directly as a proxy for health status in the context of YRB.

Study Area
In recent years, Inner Mongolia, Shaanxi, Shanxi, Henan, Shandong and other provinces in the middle and lower reaches of the Yellow River have all become carbon deficit regions, that is, carbon payment regions, and the carbon deficit of Shanxi and Shandong is significantly higher than that of other provinces[1], mainly because Shaanxi, Shandong, Shanxi and Henan are all major coal producing provinces in China. And green low-carbon development, as well as economic growth, health expenditure and environmental quality are closely related. Long-term linear extensive economic growth has led to a surge in carbon emissions, prominent features of energy and resource extraction industries, and great pressure to reduce emissions.
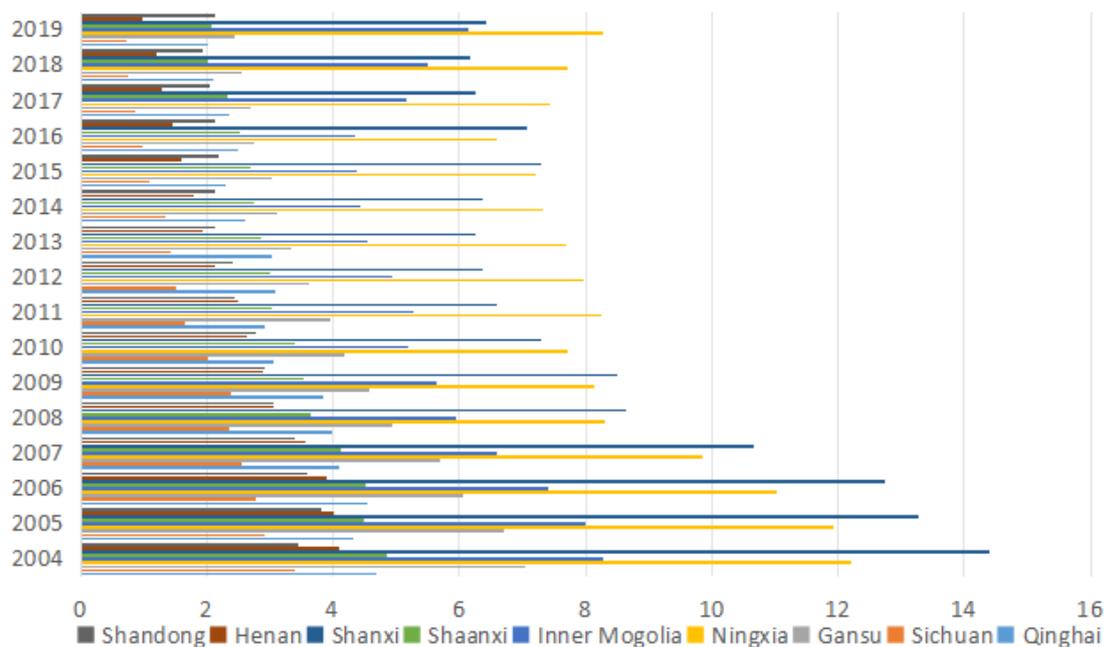
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[1] Source: China environmental Yearbook, 2022

Figure 1: Carbon dioxide emission intensity in YRB in 2004-2019
Data source: China Statistics Bureau, 2004-2019

Figure 1 show the change of Carbon dioxide emission intensity of nine provinces in YRB in 2004-2019. It can be seen from the figure that the intensity of carbon dioxide emissions in each province in the YRB has been mainly kept decreasing year by year generally. As an important energy base in China, the YRB has actively promoted energy structure optimization in recent years, vigorously developed clean energy, reduced its reliance on traditional energy sources such as coal, thereby reducing the intensity of carbon dioxide emissions. The government has also taken measures to effectively control carbon dioxide emissions by restricting the development of high-energy-consuming and high-emitting projects, strengthening supervision and punishment of enterprises, etc. In addition, with the continuous progress of technology, enterprises in the YRB have continuously carried out technological transformation and upgrading, adopted more advanced energy-saving technologies and equipment, improved energy utilization efficiency, and reduced carbon dioxide emissions in the production process.
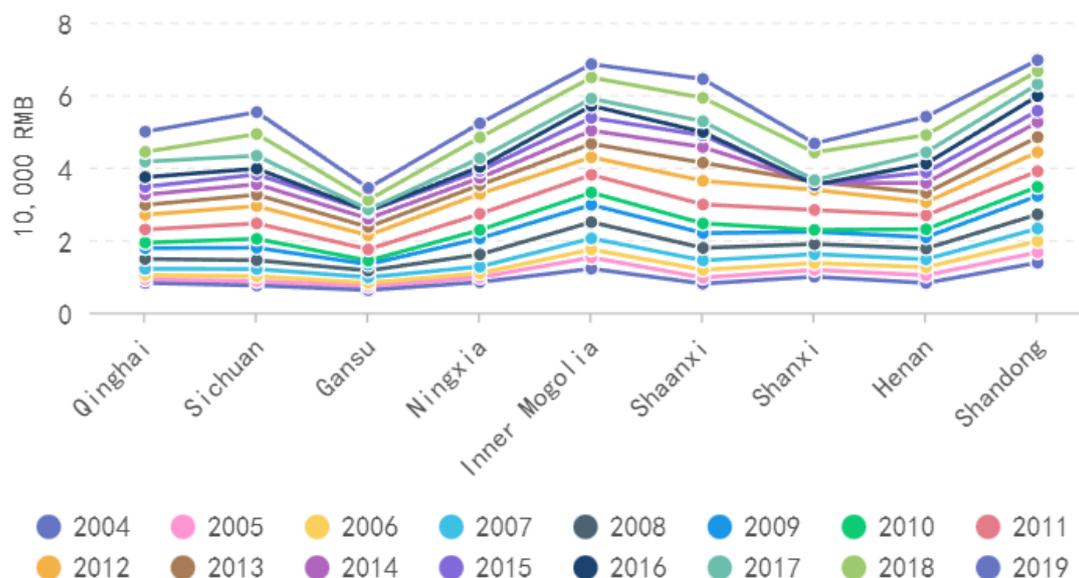
Figure 2 The per capita GDP of the nine provinces in the YRB in 2004-2019
Data source: China Statistics Bureau, 2004-2019

From figure 2, we can see that among the nine provinces along the Yellow River, the GDP of all the provinces has kept an upward trend from 2004 to 2019, with a relatively obvious growth. By calculating the average per capita GDP of the nine provinces, the per capita GDP of the YRB has increased from 9.08 thousand RMB to 54.9 thousand RMB with a rise of 6 times[2]. Among them, Shandong province and Inner Mongolia autonomous region have the largest per capita GDP, while Gansu province has the least. That might because, Shandong has a comprehensive industrial structure with balanced development, relying on rich natural and mineral resources as well as technological innovation, both traditional and emerging industries have achieved significant development, making the economy well developed. While Inner Mongolia not only has rich natural resources such as minerals and grassland, but also has new clean energy like wind energy. The development and utilization of these resources have provided a strong support for local economic development. In addition, Inner Mongolia is an vast region with large land area and relatively small population, which makes the per capita GDP relatively high.

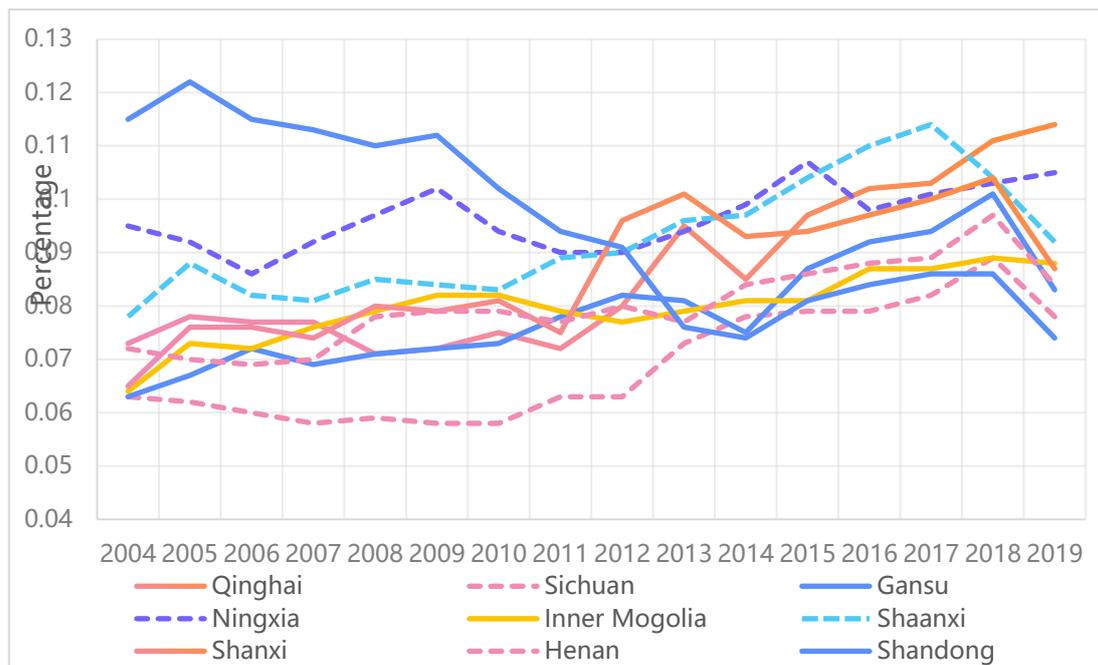[2] Figure source: China Statistics Bureau, 2004-2019

Figure 3 The proportion of private healthcare expenditure in nine provinces of YRB.
Data source: China Statistics Bureau, 2004-2019

It can be seen from Figure 3 that in recent years, with the progress of social development, the accumulation of residents' wealth, and the improvement of modern technology, people's demand for health is constantly increasing, which is reflected in the increasing proportion of personal health expenditure in consumption expect Shandong province. However, compared with carbon emissions and economic growth, the growth trend of health expenditure is relatively small. The continuous improvement and expansion of the medical security system coverage in Shandong, and the continuous improvement of its level of protection enable people to better resist medical risks and reduce the burden of medical expenses, thereby Shandong reducing the proportion of private healthcare expenditure.

Literature Review
The empirical discussion of the relationship among environmental quality, economic growth, and health expenditures could be broadly divided into three categories. The first one concerned the relationship between the environment and economic development. The second aspect related to relationship between economic growth and health spending, while focusing on the direction of its resilience and causality. Some scholars investigated the relationship between environmental quality and health expenditure in different countries and economic regions of the world. In some cases, however, the findings were spotty and contradictory. In addition to the uncertainty of the empirical evidence provided, these studies confirmed that greenhouse gas emissions cause environmental pollution that deplets environmental quality. In the literature on environmental economics, the relationship between environmental degradation and economic growth is frequently referred to as the EKC. The curve assumes a U-shaped relationship between economic development and the environment pollution, that is, in the initial stage of economic growth, environmental quality will be worse, but when a country's per capita income is close to 8000 US dollars, the environmental quality will be improved (Grossman and Krueger, 1995). On the contrary, Liu et al (2007) emphasize that consumptive pollutants do not support EKC, but productive

pollutants can; for low-income developed countries, EKC will not form an inverted U-shape. Hao et al. (2021) studied the relationship between environmental degradation and green growth. It was discovered that green development had both linear and non-linear effects on CO_2 emissions, and that the combination of renewable energy, environmental taxation, and human activities improved the environmental quality of the G7 countries. To find out whether the related theory can truly enhance environmental quality, more research is necessary, nonetheless, as green development policy has received a lot of theoretical and political attention.

Regarding the relationship between environmental quality and health spending, Assadzadeh et al (2014) conducted a panel data analysis of eight oil-exporting countries from 2000 to 2010. Their results indicated that carbon dioxide emissions and production have a significant positive impact on health spending, and the increase in life expectancy reduces health spending in these countries. In China, Yang and Zhang (2018) used the Urban Household Survey database and found that household health spending increases with increasing air pollution, and the elderly are more sensitive to the impact of air pollution (Pm2.5). Abdullah et al. (2016) focused on a middle-income country and used carbon dioxide, sulfur dioxide, and nitrogen dioxide as proxies for environmental quality to study the relationship between health spending and environmental quality in Malaysia. The results from the Autoregressive Distributed Lag method indicate that there was a cointegration relationship between the three indicators of environmental quality and health spending, suggesting that environmental quality affects health spending in both the long and short term.

In terms of the connection of wealth and health, Elmi and Sadeghi (2012) used panel cointegration and VECM frameworks for causal relationship analysis. Their study of panel data from 1990 to 2009 found that there is a short-term causal relationship between GDP and health spending, and a long-term relationship between health spending and economic growth. Ye and Zhang (2018) used linear and nonlinear tests to examine the causal relationship between health spending and economic growth in 15 OECD countries, and found unidirectional linear and nonlinear causal relationships between these variables in South Korea, Ireland, Portugal, and India.

When considering the three variables simultaneously, Chaabouni and Saidi (2017) examined the causal relationships between health spending, carbon dioxide emissions, and GDP growth in 51 countries. Using the Generalized Method of Moments approach, they found that there is a bidirectional causal relationship between per capita GDP and carbon dioxide emissions, as well as between health spending and economic growth in these countries. A similar study by Usman et al. (2019) found that carbon dioxide emissions have a significant positive impact on public health expenditure in emerging economies, but have a negative impact on private health expenditure. They also observed that economic growth significantly affects health expenditure in both the short and long term. However, carbon dioxide emissions have a negative impact on economic growth in the short term, but a positive impact in the long term.

Methodology
HoltzEakin et al. propose the Panel Vector Autoregression (PVAR) model. This model has developed from the Vector Autoregression (VAR) model put forward by Sims in 1980, following the advantages of it. That is, it is no need to define the causal relationship between

variables, but instead, which are treated as endogenous variables to analyze the impact of each variable and time-lagged variables on other variables in the model. And the PVAR model also fully considers individual effects and time effects, and uses panel data to effectively solve the problem of individual heterogeneity. In view of the individual differences of PVAR model, its characteristics could be captured, and the policy implications of regional economic are included by describing individual time performance.

In the present section, data from nine provinces from 2004 to 2019 were analyzed using PVAR to investigate the relationship between the environment quality, citizen health, and economic development via per capita CO_2 emission, the proportion of per capita private health care expenditure to consumption and the logarithm of per capita GDP as proxy (see Table 1). Using 2003 as the base year, all healthcare spending, GDP, and personal consumption value statistics were handled at a constant price.

Table 1
Statistics Description

Variable	Meaning	Calculation	Source	Mean	Std. Dev.	Min	Max
CO_2	CO2 intensity	CO2 emission/GDP	Chinese Environmental Yearbooks, 2005-2020	4.472	2.7809	.718	14.40
HCP	Proportion of average private HCE to consumption per capita	(Total private HCE/population) / (consumption/population)	Provincial Yearbooks, 2004-2019	.084	.013	.058	.122
LNGDPP	The logarithm of GDP per capita	Ln(GDP/population)	Statistics Bureau of China, 2004-2019	.9399	.61029	-.4873	1.939

According to the data, the CO_2 intensity of the nine provinces have gradually decreased from 2004 to 2019, while the logarithm of per capita GDP of the region have upward trend, the proportion of per capita private healthcare expenditure to consumption also increased.

Table 2
Eigenvalue Stability Condition

Eigenvalue		Modulus
Real	**Imaginary**	
.9340401	0	.9340401
.5629639	-.2624286	.6211257
.5629639	.2624286	.6211257

In order to prevent spurious regression, the PVAR model's foundation depends on reliable data. It is necessary to check panel data utilized in the study whether stationary before

constructing it for research analysis. The panel data's eigenvalues, which show the PVAR model's stability, were computed for this study. If the modulus of each eigenvalue is less than one, the panel data met the stability criteria, as Table 2 demonstrates, meaning that the PVAR model could be developed.

Table 3
Selection Order Criteria for Panel SVAR

lag	AIC	BIC	HQIC
1	-8.033*	-7.223*	-7.704*
2	-4.154	-3.091	-3.722
3	-4.774	-3.433	-4.230

* p<0.1, ** p<0.05, *** p<0.01

The lagged results of PVAR model can be determined by Akaike information criterion, Bayes information criterion and HQ information criterion. It can be seen from the table that the values of Akike information criteria, Bayes information criteria and HQ information criteria all obtain the minimum value at lag 1, so the optimal lag order of the proposed model is lag1.

Findings and Results
The impulse-response interaction of the CO_2, HCP, and LNGDPP was estimated by the PSVAR model, as demonstrated in Figure 4. The horizontal axis depicts the lag duration of the impact, while the vertical axis signifies the response of a variable to the exogenous impact of other variables, with the solid line showing the impulse-response function. With the help of control variable method, impulse response chart can intuitively reflect the future interaction between variables, showing the short-term and purely unilateral impact of one variable on another variable after the impact of unit standard deviation.
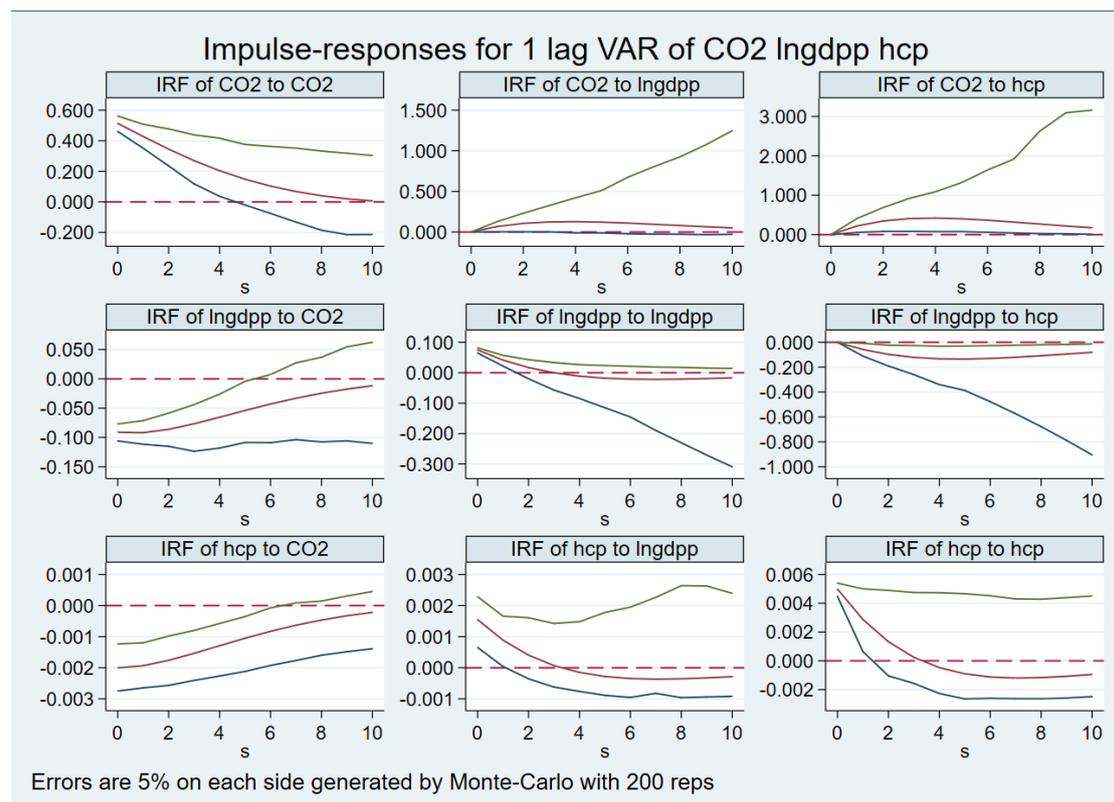
Figure 4. Impulse responses for 1 lag of CO_2, lngdpp and hcp in PVAR

As can be seen from Figure 4 that when HCP and GDP produced a unit of positive impact, carbon intensity will also slightly increase, and the growth rate will decrease with the step increase, reaching a peak at the fourth order, then slowly decreasing, and then after ten periods, it still maintains a positive response and nearly returns to the initial value, indicating that in a certain period of time, the improvement of GDP and HCP will always lead to the increase of carbon dioxide in a certain period of time. From a practical perspective, in the similar technical level or a certain case, the larger the economic aggregation, the higher the GDP, and the more energy is consumed, resulting in the increase of carbon emissions.

Meanwhile, the increase of health expenditure will also slightly simulate carbon dioxide emissions. The reason for this relationship can be attributed to the fact that the health care facilities generally provides pension services, purchasing products, services and technologies from carbon-intensive supply chains, and emits greenhouse gases directly or indirectly. The medical industry emits greenhouse gases through energy consumption, transportation, product manufacturing, use, and scrapping. The direct emissions of private vehicles of healthcare industry account for 17% of the global emissions of this industry. Indirect emissions generated by energy purchases such as electricity, steam, cooling, and heating account for 12% of global industrial emissions. 71% of emissions mainly come from the healthcare supply chain, through the production, transportation, and processing of goods and services, including drugs and other chemicals, food and agricultural products, medical equipment, hospital equipment, instruments, etc (Karliner et al., 2019). Three-quarters of medical emissions, including their supply chains, are generated domestically, which means that about one-quarter of medical emissions are generated outside the countries where medical care products are finally consumed. Fossil fuel consumption is the core of health care

industry emissions, and energy (mainly the combustion of fossil fuels) accounts for more than half of the medical care footprint (Lopreite and Zhu, 2020).

The response of GDP to carbon emissions is negative, with the largest response in the first period, and the reaction weakens afterward, but it remain negatively correlated. Therefore, in the short term, an increase in carbon emissions will lead to a slight decrease in GDP. In which, there is also a certain theoretical support in reality. With increased emission of CO_2, the greater the difficulty of the transition to clean electricity, the higher the macroeconomic costs in terms of lost output and increased inflation, and the greater the need for an equivalent legislation or rise in the greenhouse gas tax to motivate the change. If there is a drastic decrease in the economic growth rate, the financial support in green investment in the short term may not be able to offset the scale of investment in high-carbon industries. Moreover, green consumption may not necessarily rise in the short term, and consumption may be affected (Carton and Natal, 2022).

At the same time, the response of GDP to HCP is also negatively related. The maximum response appears in the first period, and then the response weakens, but it still maintains a negative correlation. HCP can reflect the public health situation to some extent. Therefore, in the short term, an increase in health expenditure may lead to a slight decrease in GDP. Insufficient occupational protection could promote economic growth at the expense of local worker health because the YRB is a crucial basis for China's coal chemical and energy industries. With regard to GDP impulsive reaction to the HCP shock, rapid economic expansion has a detrimental effect on public health, which may impede long-term economic progress. An rise in HCP would cause the relationship show a negative connection. Key industries like agriculture and the service sector will suffer from the decline in employee health. Thus, while pursuing economic progress, it is imperative to prioritize human health for policy maker (Yan et al., 2023).

The estimated value of the impulse response function of health expenditure to carbon emissions reaches the maximum response in the first period with the significantly small value -0.002. After that, the response weakens continuously. The estimated value is located in the middle of the confidence interval, meaning that this response may be relatively weak or less significant compared with other variables. In other word, the carbon dioxide emission could not influence the local residents' health as much since the local carbon dioxide emissions problem has been somewhat contained and is not severe enough to affect public health.

Comparatively, a unit change in GDP will have a positive impact on HCP at the first period, but the response of HCP will gradually decline. After the third period, the impact will continue and receive a negative response. With economic growth, both government and personal income will increase, providing a source of funding for the growth of health expenditure. Secondly, economic growth improves people's living standards and medical technology through providing more financial support provides more financial support for scientific research, leading to an increase in their demand for health, which drives the growth of the proportion of personal health expenditure in consumption.

Conclusion and Suggestions

The article utilized the PVAR research method to analyze the relationship between environmental quality, economic development, and public health in the Yellow River Basin. Based on the impulse response function, regardless of the magnitude of the response, the increment in economic development and proportion of personal healthcare expenditure to consumption would have a positive impact on carbon emissions, meaning that economic development and increased health spending would stimulate carbon emissions. However, the intensity of carbon emissions increment might basically not as seriously as affect the physical health of local residents, but obviously have a negative impact on the economy, in other word, increased carbon emissions may hinder economic development adversely. Meanwhile, there is also a negative correlation between GDP and private healthcare expenditure proportion in consumption. Rapid economic growth might has a negative impact on public health, which could in turn obstruct long-term economic advancement. Through the analysis of the relationship among the three variables, it can be found that the economic growth pattern is particularly important and occupies a central position in this relationship since it has comparatively significant impact both on public health and environmental quality .

The larger the economic aggregate and the higher the GDP, the more energy will be consumed and carbon emissions will increase, but it is unwise to trade the economic aggregate growth at the cost of environment. Therefore, it is necessary to actively attempt industrial structure transformation, and make joint efforts to build a new situation of comprehensive and coordinated development. As an important means of promoting green and low-carbon development, energy conservation and emission reduction is becoming a self-conscious action of the whole society, which effectively promotes the improvement of environment quality, the transformation of growth mode, the rise of modern service industry and emerging industries, and broadens the path of sustainable and high-quality development. Meanwhile,the health problems caused by environmental pollution cannot be ignored, and actively responding to the national overall security strategy and upholding the people-oriented development concept since safety and health issues are closely related to each of us. The negative impact of environmental degradation ultimately falls on us humans, so it is recommended that policy makers vigorously promote energy conservation and emission reduction, as well as green and low-carbon modes of transportation, and strengthen people's personal sense of responsibility for protecting the environment. Furthermore, the government could change its development and governance philosophy and give full play to the policy orientation. The government can implement fiscal policies to increase expenditure on environmental protection and public health, formulate relevant policies reasonably according to the interaction between economic development, environmental quality and citizen's health, improve the economic development environment, abandon the economic growth pattern at the cost of sacrificing the environment and residents' welfare, and adopt a green, sustainable and high-quality development.

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