The Influencing Factors of China Carbon Price: Analysis Based on GLS Model

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Keywords: Carbon Price, Influencing factors, GLS Model, China.

Abstract: China has officially launched seven carbon trading systems and established a national carbon trading market. Using market mechanism to control and reduce greenhouse gas emissions and promote green and low-carbon development is a major innovation practice. As the core of carbon trading market, carbon trading price plays a vital role in the healthy development of China's carbon market. This paper studies the influencing factors of carbon trading price. This paper selects and analyzes the panel data regression model of each factor, and uses GLS model to extract the data of seven carbon trading pilot projects in China. This paper analyses the factors affecting China's carbon price in terms of carbon price, Daqing crude oil Spot Price, China Coal Price Index, Nymex Natural Gas Futures Price, Exchange rate (with European), Shanghai-Shenzhen 300 index, weather and industrial added value. In general, energy price has the greatest impact on carbon trading price, while Euro exchange rate and Shanghai Stock Exchange Index have little impact on carbon price. Also, the weather in Hubei has a significant impact on carbon trading prices. Finally, this paper gets the conclusion that the carbon trading market should be capitalized instead of being guided by the government.

1. Introduction

In order to promote "green and low-carbon development" and effectively respond to global climate change, the Chinese government has taken measures to control greenhouse gas emissions. The construction of China's carbon market has been launched with seven pilot projects. In October 2011, to implement the requirements of the 12^{th} Five-Year Plan for gradually establishing a domestic carbon emission trading market, the National Development and Reform Commission (NDRC) agreed to pilot carbon emission trading in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong and Shenzhen. On June 18^{th}, 2013, Shenzhen Carbon Emissions Exchange officially opened, becoming the first Carbon Emissions Exchange in China. In the past few years, seven carbon trading pilot projects have completed the whole process of data discovery, rule-making, enterprise education, transaction initiation, performance clearance, offset mechanism use, and tried different policy ideas and distribution methods. The Carbon Trading Market is mainly affected by the following aspects. The first is the supply and demand mechanism of the carbon market. Carbon quota is essentially a kind of credit assets issued according to law and cancelled periodically. As a market supplier, the control and emission enterprises have significant entry barriers. Therefore, the supply and demand mechanism of carbon market and its influencing factors are unique from the ordinary commodity market. Generally, the supply of carbon market quotas is determined by the quantity that emission control enterprises are willing and able to sell at a given price level. The second is the price mechanism of the carbon market. The ideal carbon market price mechanism should reflect the supply-demand relationship by transmitting price information, guide the energy-saving and emission reduction behavior of emission control enterprises and Carbon Asset Management strategies, as well as investors' investment decisions. In theory, carbon price is an equilibrium price formed by the interaction of quota supply and demand. This equilibrium price equals the marginal emission reduction cost of enterprises. The actual transaction price fluctuates around this equilibrium price, and the equilibrium price guides enterprises' medium and long-term investment decision-making and behavior. The third is the competition mechanism of carbon market. Usually a unit quota represents a ton of carbon dioxide emission rights, so the trading target is homogeneous, standardized goods. Fourthly, the construction of carbon market should play the role of market mechanism. This requires us to tighten the allocation of quotas, diversify the needs of investors, and establish an information disclosure management system. Finally, the continuity of the policy is guaranteed. The construction of China's carbon market should ensure the continuity of policies and facilitate the market and enterprises to carry out medium and long-term expectations.

2. Literature Review

China formally launched the national carbon emission trading market construction program in December 2017. China has also shifted its role from tackling climate change to the newly established Ministry of Ecology and Environment. In this case, the study of price factors affecting carbon trading market plays a key role in reasonable short-selling carbon trading market and stabilizing carbon emissions. Chen and Wang(2013)[1] found that energy prices such as crude oil, natural gas and coal are the main factors and coal price is the biggest factor, while other factors such as wind speed should also be put into consideration. Chung at el. (2018)[2] concluded that except the lowest temperature, all variables are positively correlated with EU prices; EU electricity prices have causal relationship with electricity and natural gas prices. When unexpected shocks occur, EU prices have the highest response to past prices, followed by electricity prices and coal prices. Similarly, this paper can infer that the carbon trading price in China is positively correlated with the use of energy. Bredin and Mulckley (2011)[3] reported significant correlations between carbon prices and stock prices and industrial production indices. It seems that the impact of compliance and potential fundamentals make the carbon market more complex than other commodity markets.

Among the factors affecting carbon price that mentioned above, energy price is the most intuitive factor. Chen, et al. (2012)[1] and Jiang, et al. (2018)[5] focused on the impact of energy prices on the carbon trading market and found that coal prices have a strong effect on carbon price. The results in Sun et al. (2011)[6] showed that the steel production effect is the major factor that is responsible for the rise in CO_2 emissions, whereas the energy consumption effect contributes most to the reduction in CO_2 emissions. Wang et al. (2007)[7] and Sun et al. (2012)[8] predicated in the long run, emission reductions will respond more frequently to the restructuring of the steel industry, including the adjustment of production processes and larger-scale modern chemical plants. Cai et al. (2007) [9] evaluated the technical measures of emission reduction in power industry. Measures with low cost and high emission reduction potential have high priority. Long et al. (2015)[10] concluded through unit root, they found that energy consumption, carbon emissions and economic growth are not stable.

However, through cointegration analysis, they have a long-term equilibrium relationship. Through Granger causality analysis, it has been found that GDP has a two-way relationship with carbon dioxide emissions, coal, natural gas and electricity consumption. Through static and dynamic regression, it showed that coal plays a leading role in economic growth and carbon emissions, and oil consumption has a positive impact on carbon emissions. Through the impulse response function, the impact of hydropower and nuclear power has a positive impact on economic growth. Researchers think there is another relationship affect carbon price and that is price mechanism. Chen et al. (2013)[1] suggested simulating the price mechanism of the EU will not only benefit traders, brokers and risk managers in the carbon market, but also enable enterprises to monitor the cost of carbon dioxide emissions in their production process. Jiang et al. (2018)[5] found carbon price is mainly affected by its own historical price. Zhang et al. (2018)[11] found the distribution of emission permits, carbon price fluctuations and trading volumes vary from region to region. The market has not yet fully developed and there is a lack of futures and options trading, which will affect carbon prices and trading volumes of carbon assets. Jiang et al. (2018)[5] stated that auction drives the market price close to the auction transaction price. Carbon prices have a positive sensitivity to regulatory involvement and carbon forwarding. Zhang et al. (2018)[11] suggested Chinese authorities should establish effective regulatory and economic mechanisms to ensure that fluctuations to be controlled. It is said that the stock market influences the carbon price. Zhang and Wei (2010)[12] and Arouri et al. (2012)[13] employed vector autoregressive (VAR) models to investigate the dynamic relationships between the EU Emission Allowances (EUA) spot and futures prices. Bredin and Mulckley (2011)[14] reported significant correlations between carbon prices, stock prices and industrial production indices. Zhang et al. (2018)[11] found carbon price has a significant negative impact on stock value when looking at the complete sample and the impact varies between different markets. Jiang et al. (2018)[5] stated the significant correlation between carbon price and stock price and industrial production index. Jiang et al. (2018)[5] thought stock index have a negative impact on carbon price. With a special economic system in China, Chinese government policies have a big influence on the carbon price. Jiang at el. (2018)[5] and Zhang et al. (2018)[15] claimed that more regulatory attention and economic measures are needed to improve market efficiency, and carbon trading mechanisms should be improved. Zhang et al. (2018)[11] found the impact of carbon price on stock value in China is unstable. Carbon emitters' understanding of emission trading mechanism is mainly influenced by government regulations and policies. China's energy price is not market-driven, not based on supply and demand, but controlled by the government. Carbon trading pilot has a significant positive impact on all stages in the long run, but no significant impact in the short run. Therefore, the carbon price effect of enterprise evaluation is market-specific. Li et al. (2012)[16] suggested in the process of regional pilot projects, the central government should issue general directives to guide regional pilot projects, including market coverage, licensing caps and allocation rules, carbon price management, carbon account registration system, MRV, training courses, etc. Wang et al. (2015)[17] claimed the government should do its utmost to prevent the rapid growth of carbon dioxide emissions in underdeveloped provinces, accelerate regional technology transfer and avoid the transfer of carbon-intensive economic activities from coastal developed areas to underdeveloped provinces. Some new points need to be mentioned. Wang et al. (2015)[17] identified five driving factors: population, emission intensity (carbon dioxide emissions per unit GDP), production structure (reciprocal of Leontief), consumption composition and per capita consumption. Changes in consumption patterns have led to significant increases in carbon footprints in all regions. Wang et al. (2019)[18] thought the air quality index (AQI) is most relevant to the market carbon price of carbon trading.

Some previous studies on the relationship between energy consumption and economic growth discussed Granger causality time series method, unit root test and cointegration test to determine the relationship between economic growth and energy consumption. For example, Zhang and Cheng

(2009)[19] used a multivariate model to predict China's economic growth, energy use, carbon emissions, capital and urban population from 1960 to 2007. Linear and non-linear Granger causality tests were applied to six Asian industrialized countries and the United States by Qiu Wei et al. The relationship between energy consumption and economic growth may be uncertain due to time series data, structural breakthroughs, and policy changes in technological and economic changes. Zhang (2015)[20] used the equilibrium price theory and found that there is a co-integration relationship between carbon price and market fundamentals. Jiang (2018)[5] analyzed the optimal lag sequence analysis, when the lag time is long, the explanation is weak; while in the VAR estimation and stability test, the co-integration relationship between carbon price and coal, oil and coal is analyzed on the basis of unit test and co-integration test. Chung (2018)[21] used Granger causality test and the result shows that there is a unilateral causality between EUA price, electricity price and natural gas price. More specifically speaking, the economic environment is remarkable, but the impact of energy prices is not the same as awaiting further scrutiny, the impact of accidents, carbon prices and even suspension of trading. Some papers have studied the relationship between spot carbon emissions and futures prices. For example, Arouri et al. (2012)[13] used the Vector Autoregression (VAR) model to study the dynamic relationship between spot and futures prices of the European Union Emission Limit (EUA) during the second stage. In order to solve this problem, VAR model with impulse response function and variance decomposition technology are used to understand the impact of carbon prices, study the impact of these factors on carbon prices and provide decision-making basis for national policymakers. In this study, the price mechanism of seven carbon trading pilot projects in China is taken as the research object. This paper once tried the VAR model and found the data is unstable, so this paper plans to use other models. The estimation of regression equation can make the result closer to reality and more persuasive with appropriate estimation method under specific conditions. Under the basic assumptions of classical linear regression model, the coefficients estimated by the ordinary least squares method (OLS) have excellent properties of best linear unbiased estimators (BLUE). If any conditions are not satisfied, such as heteroscedasticity, sequence correlation and so on, it means it is necessary to improve the estimation method. Therefore, the generalized least squares (GLS) method is adopted in this paper. This paper also uses autoregressive conditional heteroscedasticity model (ARCH), because it solves the problem caused by the second hypothesis (constant variance) of time series variables in traditional econometrics.

3. Empirical Research

3.1 Descriptive Analysis

Figure 1 depicts the changes in carbon prices in seven pilot carbon trading projects in China from June 2014 to June 2018. From the chart, it can be found that there are significant differences in carbon prices in seven cities. Hubei is the most stable one out of the seven pilot projects in terms of carbon price. The main types of trading include carbon emission quota and CER. The threshold for enterprises to be included in the scope of emission control in Hubei is much higher than that of the other six pilot projects. Hubei has introduced investment institutions into the trading market, allowing individual investors to participate. This has greatly activated the Hubei carbon trading market, and Hubei has become the largest pilot of carbon trading volume in China. It is advisable to keep all the given values.

Carbon quota prices can be high or low, depending on the following circumstances:

1. having a certain market size and activity, high transaction concentration;
2. trading varieties are mainly local quota spot, with similar financial products;
3. Carbon prices are declining year by year, with significant regional differences;
4. trading subjects and modes are diverse and market participation is limited;

5. quota prices of primary and secondary markets are limited.

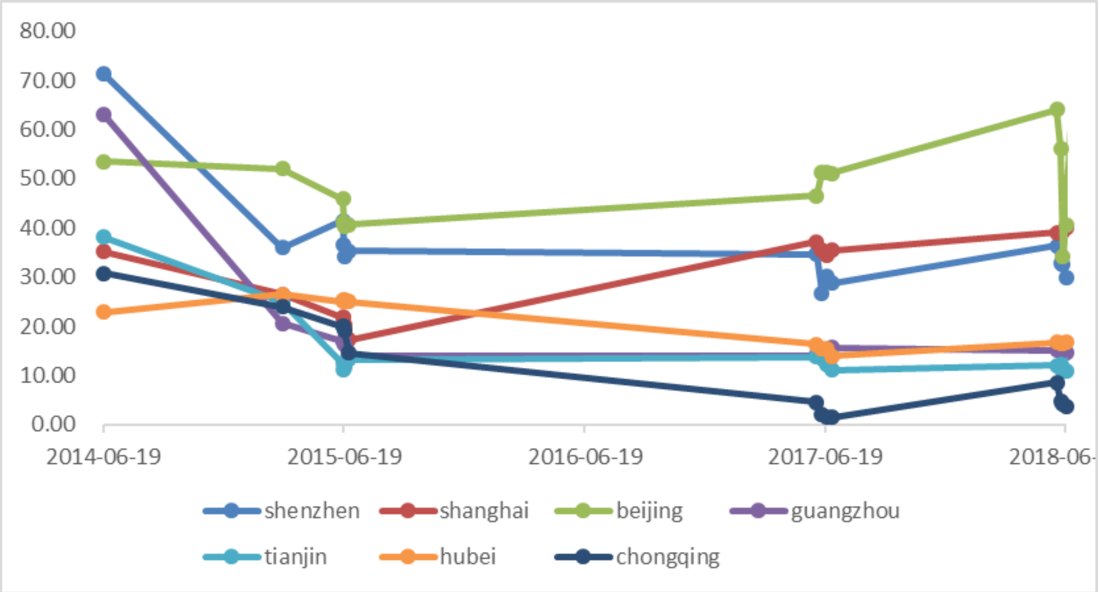

Figure 1. National carbon price trend in seven pilots.

From the pie chart (figure 2), Hubei accounts for the largest proportion of carbon emissions, then followed by Guangdong, Shanghai, Beijing and Shenzhen. The number of enterprises included in Tianjin is the smallest among the seven pilot provinces and cities, and iron and steel enterprises account for nearly half, reflecting the relatively concentrated characteristics of greenhouse gas emissions in Tianjin. The carbon trading amount in Shenzhen is the smallest of the seven pilot projects, which mainly include carbon emission quotas, CCER and other approved trading varieties.

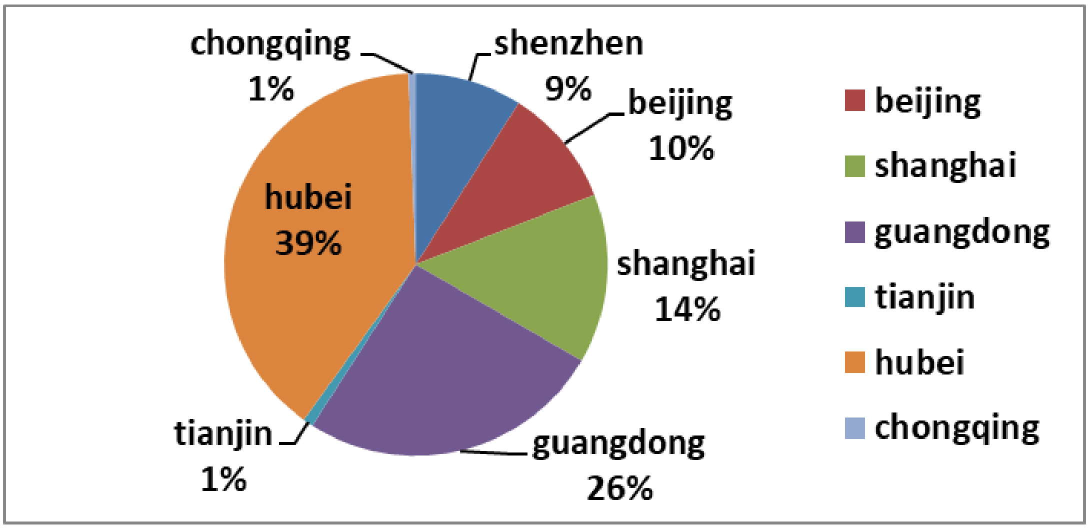

Figure 2. The ratio of national carbon trading volume in seven pilots.

Taking all factors into account, the following eight indicators are selected for empirical analysis, as detailed in Table 1.

Transaction price of carbon emission rights. Carbon price is an explanatory variable of empirical analysis. Seven pilot projects in Beijing, Shanghai, Shenzhen, Guangdong, Hubei, Tianjin and Chongqing were selected for research and analysis. The selected time range is from June 2014 to June 2018 with relatively active trading degree. Data source: the official website of the pilot provinces and municipal carbon exchanges.

Macroeconomics. Macroeconomics has a direct impact on carbon trading prices. When the macroeconomy is in the stage of development, enterprises increase investment and production, increase carbon dioxide emissions, increase demand for carbon emission rights, and increase carbon trading prices, especially from the impact of increased industrial output value. This paper chooses the Shanghai-Shenzhen 300 Index as the index to describe macro-economy. Data source: Wind.

Energy prices. The use of fossil energy emits a large amount of carbon dioxide gas, whose price constitutes the production cost of enterprises, and is the main factor affecting the price of carbon emission rights in China. This paper chooses coal price index to describe energy price, spot price of Daqing crude oil and natural gas futures price of New York Mercantile Exchange.

Weather factors. Carbon dioxide, as one of the main pollutants involved in air quality assessment, has an important impact on the value of air quality index. Air quality index reflects the emission of carbon dioxide on the side, and air quality index is selected as the index to measure the daily weather factors. The data is from the National Weather Service website.

International carbon price. The price of EU emission quota (EUA) is determined by the OTC market, spot market and futures market. The price data in the OTC market are not published. Therefore, EUA futures settlement price (in euros) on the European Climate Exchange market is selected as the international carbon price index. Considering the consistency of monetary units, the Euro is converted into RMB. Exchange rate factors need to be taken into account. The information comes from Wind.

Table 1. Descriptive Statistics.

Variables	Measurement	Mean	S.E.	Min	Max
Carbon Price	Yuan/Tonne	34.75	124.7	1.4	3785
Daqing Crude Oil Spot Price	USD/ Bareel	57.23	28.33	28.7	118.5
China Coal Price Index	-	141.2	15.3	127.4	164.2
Nymex Natural Gas Futures Price	USD/ Million British Themal Units	3.1	0.84	1.7	5.91
Exchange Rate	RMB/ Euro	7.54	0.52	6.27	8.64
Shanghai and Shenzhen 300 Index		3360.98	650.4	2086.97	5353.75
Weather	Celsius	19	9.1	-12.2	38.1
Industrial Added Value	Percent	6.67	0.87	6.02	8.36

3.2 GLS Model

The European Union has now the most perfect carbon price trading system. In addition to China's data, I also have to consider the international impact. Seven market-oriented mechanisms are not enough developed. The mechanism of subjective market regulation has been taken into consideration. Currently, China's carbon price is mainly regulated by the government, which is not in line with the international standards, so it needs the exchange rate factor. This paper uses P for carbon price, oil for Daqing crude oil spot price, coal for China coal price index, gas for Nymex Natural Gas Futures Price, ET for exchange rate, SSI for Shanghai and Shenzhen 300 index, W for weather, IAV for industrial added value and builds the model used in the data of the total data, Beijing data and Hubei data below.

$$P_{it} = \beta_0 + \beta_{1t}oil_t + \beta_{2t}coal_t + \beta_{3t}gas_t + \beta_{4t}ET_t + \beta_{5t}SSI_t + \beta_{6t}w_t + \beta_{7t}IAV_t + \mu_{it}$$

To check the homoskedasticity, P-Value in three data sets are all less than 0.05 in table 2, which means the heteroskedasticity is significant. Therefore, it would be better to choose GLS model rather than OLS model.

Table 2. White Test Results.

White test for H0: homoskedasticity for All data	
Chi(6)	78.3
Prob>chi2	0.000
White test for H0: homoskedasticity for All data for Hubei data	
Chi(6)	57.4
Prob>chi2	0.003
White test for H0: homoskedasticity for All data for Beijing data	
Chi(6)	73.9
Prob>chi2	0.002

After using the GLS regression model. Table 3 shows the gas, carbon price, coal and Industrial Added Value have negative influence to the carbon price and the effect decreases gradually in turn. Yang et al[22]. suggested regional economic pattern and energy structure determine the demand for carbon emission quotas. The correlation of crude oil price is negative, that is because when energy price rises, the energy consumption of high carbon emissions enterprises decreases, thus the total production will decrease, which leads to the decrease of demand of carbon emissions rights. Above all, coal, natural gas and industrial value added have a negative impact on carbon prices. The results are similar to those of the three sets of data in Table 3, and also similar to previous researchers' results. But Zhang et al. (2018)[11] showed an opposite point that In the long run, energy prices will not affect thermal listed companies, mainly because China's energy prices are not market-driven. China's energy price fluctuation is not based on supply and demand, but controlled by the government. The industrial added value is not significant, which is inconsistent with the intuitive perception. However, the A-share index of industrial enterprises is basically good, and the average price is rising, which is intuitively considered to be positively correlated and significant. This may be the annual government carbon quota for businesses. But corporate carbon quotas require more carbon emissions, accompanied by fixed carbon quotas. Yang et al. (2018)[22] once said the rational distribution of carbon is the key to the stability of market price, industrial value added, representing the variables of pilot economy and industrial development, accounts for 20% of carbon price. On the contrary, the negative influence coefficient of natural gas is very large, which indicates that carbon emission is most sensitive to natural gas. China is taking efforts to control air pollution and natural gas consumption is gradually increasing. Government subsidies for natural gas because natural gas consumption produces less carbon, which stimulates the demand of natural gas. China's policy is being strengthened, and the demand of enterprises is greater and the sensitivity is the greatest.

Table 3. GLS regression results.

Variable	Seven Cities	Beijing	Hubei
Oil	-21.6*** (-5.00)	-1.27*** (-0.544)	-3.39*** (-0.59)
Coal	-9.35*** (-4.85)	-1.34*** (-1.15)	-2.15*** (-3.42)
Gas	-158.4*** (-3.91)	-11.33*** (-0.024)	-32.86*** (-1.71)
ET	115.8 (-0.7)	2.54 (0.156)	-2.45 (-0.12)
SSI	0.04 (0.42)	0.209 (1.043)	0.043 (0.021)
W	1.93*** (2.41)	0.062 (0.243)	0.00577** (0.00484)
IAV	-0.3 (1.40)	-1.776 (0.023)	-3.45e-05 (2.59e-06)
Constant	128.2*** (2.17)	14.38** (2.578)	-32.54*** (4.33)
R Square	0.645	0.565	0.532
*** p<0.01, ** p<0.05, * p<0.1			

Exchange Rate, Shanghai and Shenzhen 300 Index and Weather have positive effect on carbon price. But Exchange Rate, Shanghai and Shenzhen 300 Index are not significant. Wang et al. (2018)[18] thought the reason for this phenomenon is the number of holding listed companies. Zhang et al. (2018)[11] tested whether the impact of carbon trading pilot on the value of power companies is market-specific. The results show that carbon price has a significant negative impact on stock value when looking at the complete sample, and the impact is different between different markets. Also, Jiang et al. (2018)[5] showed there is a significant correlation between carbon price, stock price and industrial production index. Yang et al. (2018)[22] thought weather is not the factor on carbon price. However, this paper still find weather has significantly positive impact on carbon price based on total data and the data from Hubei, for the reason that Hubei has a large sample size data, the results of Hubei will affect the overall effect.

The Euro exchange rate shows that China's carbon trading is in line with international standards. China's stock market is irrelevant, and carbon trading pilot projects are independent of each other. China has not yet fully formed the subject matter to enter the market, which is different from other major shopping malls and is not significant in the stock market. At the same time, the subject matter of carbon trading can also be traded in the capital market to improve its own. It has no influence on traditional finance and the market is imperfect. There are many possibilities and diversities in carbon trading and basic capital market connection. In the financial products of the carbon trading market, carbon funds are not connected to the capital market. Extreme climate will affect carbon prices through government response and increased energy consumption. In order to prevent the further deterioration of the environment and protect the common living home of mankind, countries will control carbon dioxide emissions of enterprises more strictly, making carbon emission rights relatively rare and carbon prices rising. In addition, extreme cold and extreme warm will increase carbon dioxide emissions, increase the demand for carbon emission rights, and increase carbon prices.

4. Conclusion and Suggestions

Jiang et al. (2018)[5] claimed carbon price is mainly affected by its own historical price. Coal price and stock index have a negative impact on carbon price, while oil price has a negative impact on carbon price in the first three weeks, and has a positive impact on carbon price. This paper also puts forward some suggestions on related aspects affecting carbon price. Firstly, in energy consumption, coal has the least impact on carbon price, and most pollutants are emitted in energy structure. The energy consumption structure of China is reasonable at present, and this paper hope to deepen the proportion of clean energy consumption on this basis, and continue to reduce the proportion of coal consumption. Secondly, it would be better to learn from the international market such as the European Union carbon trading market, so China's carbon trading can be in line with international standards. At the same time, companies can take climate into account when making carbon emissions. According to the local climate and environment, enterprises take weather forecast information as the main reference basis can choose suitable carbon trading pilot and buy more carbon emissions trading rights. Finally, industrial value-added carbon quotas should be consistent with the macro-market situation, not to blindly limit carbon emissions, but to ensure appropriate carbon quotas in large carbon demand. Wang et al. (2018)[22] put forward that it's time to promote the replacement of capital, labor and energy resources. Although China's energy prices are becoming market-oriented, China's energy prices are still regulated by the government and state-owned enterprises. State-controlled prices inhibit the substitution of input factors and ultimately lead to more energy consumption. Therefore, the implementation of government energy saving and emission reduction policy depends on reducing the rebound effect. To reduce the rebound effect, the promotion of energy saving technology should be combined with reducing energy price control, reducing energy subsidies and promoting the substitution of input factors.

This paper tries to use VAR model. But due to the large number of missing data, the data formed is unstable. This paper adopts GLS model. However, the model is too simple to consider the time series problem. Also, the variables in this paper are imperfect. Some scholars have proposed that air quality index is also an influencing factor. This factor isn't considered in this paper. At the same time, China's market is regulated by the government, while there is no government factor in this article. I will further process the missing data and improve the impact of missing data in many pilot projects. In the future, it's better to consider the nationwide marketization of carbon trading, and further analyze the progress of marketization.

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