Interaction of Beijing-Tianjin-Hebei ’s energy consumption on environment

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Abstract. Optimization and upgrade of energy consumption and friendly-developing eco-environment play a core part in Beijing-Tianjin-Hebei’s coordinated development strategy. Energy consumption structure interacts with environment. This paper selects coal, oil and gas consumption in Beijing-Tianjin-Hebei as energy structure variable waste gas, gas and solids discharge as environment variable to establish a Vector Auto-Regression (VAR) model, which is used to study their Johansen Cointegration test, and their interaction via impulse response function and variance decomposition. The result shows an outstanding cointegration between the both, with a lagging effect on three wastes discharge, and coal, oil and gas consumption contributing variably to three wastes discharge. A balanced development between Beijing-Tianjin-Hebei’s energy consumption and environment may be achieved by making full use of such lagging effect and contribution extent and real-time evaluation & adjustment of exterior conditions.

Keywords: Beijing-Tianjin-Hebei; energy consumption structure; three wastes; interaction.

1. Introduction
It is a major decision to promote the coordinated development of the Beijing-Tianjin-Hebei region and deployment made by the country under the new historical conditions. It is of great practical significance for coordinating and advancing the "four comprehensives" strategic layout. When implementing the outline of Beijing-Tianjin-Hebei coordinated development plan, it puts forward the requirement of taking resource and environment carrying capacity as a rigid constraint. The development of regional economy needs the support of energy resources, and energy consumption (especially fossil energy) will affect the environment and public health [1]. With the development of economy, the energy carrying capacity of Beijing-Tianjin-Hebei region based on the ecological environment presents different characteristics. Beijing's energy carrying capacity is on the rise, Tianjin's energy system is always in a state of high load, while Hebei's energy carrying capacity drops sharply [2]. Energy resources and ecological environment are inextricably linked, and the optimization and upgrading of energy consumption structure has been mentioned as an increasingly important strategic position. Therefore, it is necessary to study the impact of the change of energy consumption structure on ecological environment in Beijing-Tianjin-Hebei region.
The adjustment of energy consumption structure plays an important role in environmental improvement, and there is a long-term equilibrium relationship between energy consumption and environmental quality [3-4]. The "three wastes" discharged in the process of energy consumption affect the environmental quality, and the total energy consumption has a significant impact on the "three wastes" emission [5]. Huiyu Liu et al. [6] found that coal consumption has a significant impact on the discharge of industrial waste water and waste residue, among which coking coal consumption has a greater impact on the discharge of industrial waste gas. Xi Zhou et al. pointed out that the consumption of energy resources is closely related to the emission of waste gas and solid waste throughout the country: 90% of sulfur dioxide emissions, 70% of carbon emissions and 67% of nitrogen oxide emissions come from coal [7]. In recent years, haze pollution in China is very serious. Researchers have found that haze pollution level is closely related to energy structure, and changing energy consumption structure has become the key to control haze [8]. In particular, Beijing-Tianjin-Hebei region is deeply affected by haze pollution, and energy source structure adjustment has become one of the important countermeasures to control haze in Beijing-Tianjin-Hebei region. Through research, Boqiang Lin et al. found that the energy structure transformation oriented by environmental governance could significantly inhibit carbon emissions, and would not significantly inhibit economic development.

According to the existing literature review, scholars studied different regions and found that the energy consumption structure had a significant correlation with the regional "three wastes" emission. For the Beijing-Tianjin-Hebei region, the outline of the Beijing-Tianjin-Hebei coordinated development plan puts forward higher requirements for balanced development between energy resources and the environment. In this background, this article is based on econometric and constructing vector autoregressive model (VAR), based on the analysis of energy consumption structure and the relationship of the "three wastes" emissions in the environment, through the impulse response function to delve into the energy consumption structure dynamic effects of the "three wastes" emissions, and by using variance decomposition method to measure the external impact of "three wastes" emissions (endogenous variable) contribution degree of fluctuation change.

2. Study variables and data

In order to study the Beijing-Tianjin-Hebei region energy consumption structure impact on the environment of the "three wastes" emissions, this article selects the Beijing, Tianjin and Hebei three districts in each coal, crude oil, natural gas consumption and energy consumption, and waste water, industrial waste gas emissions and general industrial solid waste production amount for a total of 21 time series variable as the research sample. The sample length is a total of 15 years' data from 2000 to 2014 (data from China energy statistics yearbook from 2001 to 2015).

Firstly, the energy consumption structure of Beijing-Tianjin-Hebei region was calculated through data preprocessing. Since different energy consumption units are different, this paper is based on the "reference coefficient of standard coal for various energy sources" provided in the energy statistical yearbook of China (table 1). Secondly, after converting coal, crude oil and natural gas in the Beijing-Tianjin-Hebei region into standard coal, the energy consumption of the same type is summed up as the corresponding energy consumption of the whole Beijing-Tianjin-Hebei region. Since the total energy consumption of Beijing, Tianjin and Hebei also includes other types of energy consumption, and this paper only takes coal, crude oil and natural gas as the research objects, the calculated coal, crude oil and natural gas consumption is divided by the total energy consumption of Beijing-Tianjin-Hebei region to obtain the energy consumption structure of coal (X1), crude oil (X2) and natural gas (X3), which is also the explanatory variable of this study (table 2).
Table 1. The energy consumptions in Beijing-Tianjin-Hebei

| Years | Beijing Coal | Tianjin | Hebei | Beijing Oil | Tianjin | Hebei | Beijing Gas | Tianjin | Hebei |
|-------|--------------|---------|-------|------------|---------|-------|-------------|---------|-------|
| 2000  | 1 942.74     | 1 766.26 | 8 653.80 | 1 078.18   | 1 013.96 | 1 067.69 | 144.97     | 71.82   | 102.68 |
| 2001  | 1 910.75     | 1 882.18 | 9 029.47 | 1 000.73   | 1 070.52 | 957.95  | 222.64     | 104.94  | 92.70  |
| 2002  | 1 807.89     | 2 092.18 | 9 813.77 | 1 068.59   | 965.13   | 996.58  | 279.30     | 86.18   | 102.94 |
| 2003  | 1 910.05     | 2 289.57 | 10 608.36 | 1 038.14   | 1 072.81 | 1 193.15 | 281.83     | 96.56   | 110.12 |
| 2004  | 2 099.62     | 2 506.17 | 12 195.93 | 1 068.59   | 1 068.59 | 1 193.15 | 281.83     | 113.72  | 129.41 |
| 2005  | 2 192.17     | 2 715.38 | 14 673.43 | 1 142.31   | 1 233.08 | 1 324.01 | 359.37     | 120.23  | 121.56 |
| 2006  | 2 182.67     | 2 720.99 | 15 257.32 | 1 137.34   | 1 246.58 | 1 433.30 | 359.37     | 149.23  | 146.43 |
| 2007  | 2 131.95     | 2 804.84 | 17 629.64 | 1 358.47   | 1 357.37 | 1 606.85 | 620.31     | 189.79  | 160.27 |
| 2008  | 1 962.70     | 2 837.75 | 17 442.22 | 1 595.40   | 1 299.07 | 1 939.51 | 806.65     | 223.97  | 228.36 |
| 2009  | 1 903.39     | 2 942.67 | 18 940.24 | 1 661.36   | 1 206.65 | 1 970.21 | 923.04     | 241.00  | 307.37 |
| 2010  | 1 881.91     | 3 433.49 | 19 618.05 | 1 594.73   | 2 238.32 | 1 995.25 | 994.64     | 307.23  | 395.54 |
| 2011  | 1 689.70     | 3 758.65 | 21 994.55 | 1 578.72   | 2 505.79 | 2 235.30 | 978.36     | 346.04  | 466.70 |
| 2012  | 1 621.46     | 3 784.36 | 22 399.73 | 1 536.84   | 2 206.64 | 2 210.92 | 1 224.49   | 433.34  | 600.26 |
| 2013  | 1 442.34     | 3 770.55 | 22 617.07 | 1 244.20   | 2 513.12 | 1 979.88 | 1 314.17   | 502.61  | 663.14 |
| 2014  | 1 240.41     | 3 590.99 | 21 168.67 | 1 478.06   | 2 290.29 | 1 938.05 | 1 512.21   | 605.02  | 745.86 |

It can be found that the total consumption of coal, crude oil and natural gas in the Beijing-Tianjin-Hebei region fluctuates, which largely avoids the multicollinearity problem (the total energy consumption also includes various other forms of energy consumption, so the total consumption of coal, crude oil and natural gas does not add up to 1). The proportion of coal and crude oil consumption in the Beijing-Tianjin-Hebei region fluctuated and declined, while the proportion of clean energy consumption of natural gas increased year by year. But coal still accounts for nearly 60 per cent of consumption, and there is still plenty of room for natural gas. The total share of coal, crude oil and natural gas is about 80%, and shows a trend of fluctuation and decrease, which is similar to the fluctuation trend of the share of coal consumption. Therefore, the total share of the three types of energy is largely affected by coal consumption. In addition, it is also affected by the rising consumption of other kinds of energy. For example, new energy, as an emerging energy, will play an increasingly important role in the whole energy system.

Then, the environmental variables of Beijing, Tianjin and Hebei are calculated. In this paper, the waste water, industrial waste gas emissions and general industrial waste production in Beijing, Tianjin and Hebei were calculated separately as the "three wastes" emissions in the Beijing-Tianjin-Hebei region (Y1, Y2 and Y3, respectively), which were also the explained variables studied in this paper (table 3). The total amount of waste water discharged in the Beijing-Tianjin-Hebei region increased year by year, and the total amount of industrial waste gas discharged fluctuated and increased, while the total amount of general industrial solid waste production peaked in 2012 and declined slightly in the past two years. However, the emissions of "three wastes" in the Beijing-Tianjin-Hebei region are on the rise in general. Compared with 2000, the emissions of "three wastes" in 2014 increased by 98%, 474% and 417% respectively, which also caused a great impact on the environmental carrying capacity of the Beijing-Tianjin-Hebei region.
3. Analysis on the energy consumption structure and the dynamic effect of "three wastes" emission in Beijing-Tianjin-Hebei region

3.1. Impulse response of Beijing-Tianjin-Hebei energy consumption structure to total wastewater discharge.

In the energy consumption structure, when the consumption proportions of coal (lnX1), crude oil (lnX2) and natural gas (lnX3) are taken as impulse variables, the response of total wastewater discharge (lnY1) in the Beijing-Tianjin-Hebei region after being impacted by external conditions is shown in figure 2. When the proportion of coal consumption is impacted by some external conditions, the total amount of waste water discharged in the Beijing-Tianjin-Hebei region is always negative, and reaches the lowest value in the second lag period, and this effect will last for a long time. When the proportion of crude oil consumption was impacted by some external conditions, the total wastewater discharge in the Beijing-Tianjin-Hebei region was negative in the first lag period, then positive from the second period, and was in a trend of slow growth for a long time. When the proportion of natural gas consumption was impacted by some external conditions, the total wastewater discharge in the Beijing-Tianjin-Hebei region declined in the second lag period, but then showed a slow growth trend.

Table 2. The structure of energy consumptions of coal crude oil and natural gas in Beijing-Tianjin-Hebei%

|       | Coal  | Crude oil | Natural gas | Total |
|-------|-------|-----------|-------------|-------|
| 2000  | 68.18 | 17.43     | 1.76        | 87.36 |
| 2001  | 72.76 | 17.19     | 2.38        | 92.34 |
| 2002  | 65.73 | 14.52     | 2.25        | 82.50 |
| 2003  | 63.93 | 14.27     | 2.11        | 80.31 |
| 2004  | 64.17 | 13.83     | 2.30        | 80.30 |
| 2005  | 66.51 | 12.94     | 2.27        | 81.71 |
| 2006  | 62.61 | 12.17     | 2.60        | 77.38 |
| 2007  | 64.82 | 12.42     | 2.79        | 80.03 |
| 2008  | 61.76 | 12.95     | 3.50        | 78.21 |
| 2009  | 62.82 | 12.78     | 3.89        | 79.49 |
| 2010  | 60.37 | 14.11     | 4.11        | 78.59 |
| 2011  | 62.24 | 14.33     | 4.06        | 80.64 |
| 2012  | 60.93 | 13.05     | 4.95        | 78.92 |
| 2013  | 62.86 | 12.96     | 5.60        | 81.43 |
| 2014  | 58.70 | 12.88     | 6.46        | 78.04 |

Table 3. The emissions of “three wastes” in Beijing-Tianjin-Hebei

|       | Wastewater | Industrial waste gas | Solid waste |
|-------|------------|----------------------|-------------|
| 2000  | 27.82      | 14834.00             | 8637.00     |
| 2001  | 30.40      | 14834.00             | 10558.00    |
| 2002  | 31.80      | 14834.00             | 10199.00    |
| 2003  | 32.10      | 14834.00             | 10805.00    |
| 2004  | 35.40      | 27952.00             | 18821.00    |
| 2005  | 37.00      | 34652.00             | 18640.00    |
| 2006  | 38.60      | 50407.00             | 16877.00    |
| 2007  | 38.80      | 58688.00             | 21362.00    |
| 2008  | 40.90      | 47880.00             | 22405.00    |
| 2009  | 44.60      | 61170.00             | 24734.00    |
| 2010  | 46.70      | 68760.00             | 34819.00    |
| 2011  | 49.12      | 91000.70             | 48007.00    |
| 2012  | 52.89      | 79943.00             | 48500.00    |
| 2013  | 53.97      | 90893.00             | 45925.00    |
| 2014  | 54.99      | 85101.00             | 44684.00    |
3.2. Impulse response of Beijing-Tianjin-Hebei energy consumption structure to total industrial exhaust emission.
When the proportion of consumption of coal (lnX1), raw oil (lnX2) and natural gas (lnX3) is impacted by external conditions, the response of total industrial emission (lnY2) in the Beijing-Tianjin-Hebei region is shown in figure 3. When the proportion of coal consumption was impacted by some external conditions, the total industrial emission in the Beijing-Tianjin-Hebei region was always negative, and reached the lowest value in the second lag period, and then fell to a relatively low level. This shows that external shocks to the share of coal consumption (such as policy incentives) can achieve control of industrial emissions in the short term, but sustained external shocks are necessary to achieve sustained impact. When the proportion of crude oil consumption is impacted by some external conditions, the total industrial exhaust emission in the Beijing-Tianjin-Hebei region is negative for a long time and reaches the lowest value in the third lag period. When the proportion of natural gas consumption is impacted by some external conditions, the total industrial exhaust emission in the Beijing-Tianjin-Hebei region is negative within the lag period of 2 years, and then becomes positive. Due to the small proportion of natural gas consumption at present, the response degree of industrial exhaust emissions in Beijing-Tianjin-Hebei region to external shocks to natural gas consumption is relatively small based on the current situation. However, when the proportion of natural gas consumption gradually increases, the response degree of total industrial exhaust emissions can be enlarged.

3.3. Impulse response of Beijing-Tianjin-Hebei energy consumption structure to general industrial solid waste production.
When the consumption proportion of coal (lnX1), raw oil (lnX2) and natural gas (lnX3) is impacted by external conditions, the response of general industrial solid waste production (lnY3) in the Beijing-Tianjin-Hebei region is shown in figure 4. When the proportion of coal consumption is impacted by some external conditions, the response value of general industrial solid waste production in the Beijing-Tianjin-Hebei region is negative for a long period, and the minimum value is in the second lag period, and then the response degree gradually approaches 0. It reflects the external impact on the proportion of coal consumption, which can effectively and quickly reduce the amount of general industrial waste. When the proportion of crude oil consumption is affected by some external conditions, the response value of general industrial solid waste production in the Beijing-Tianjin-Hebei region is almost stable. When the proportion of natural gas consumption was impacted by some external conditions, the response value of the general industrial solid waste production in the Beijing-Tianjin-Hebei region remained basically unchanged in the second lag period, but from the third lag period, the response value of the general industrial solid waste production rapidly increased and remained at a relatively stable level. It shows that the output of industrial solid waste has a lag effect on the response of natural gas consumption to external shocks.

4. Conclusion
The coordinated development of the Beijing-Tianjin-Hebei region is one of the major national strategies. Therefore, through the accounting of coal, crude oil and natural gas in the Beijing-Tianjin-Hebei region, this paper determined the consumption proportion of three types of fossil energy and took them as explanatory variables. The total amount of waste water, industrial waste gas and general industrial solid waste was selected as the explained variable. The VAR (1) model was constructed, and on this basis, Johansen co-integration test, impulse response and variance decomposition analysis were conducted respectively for energy consumption structure and total emission of "three wastes". The main conclusions are as follows.

1) There is a significant co-integration relationship between the energy consumption structure in Beijing-Tianjin-Hebei region and the total emission of "three wastes" in the environment. Among them, the proportion of coal consumption is negatively correlated with the total emission of "three wastes". The proportion of crude oil consumption is positively correlated with the total discharge of waste water and general industrial solid waste, but negatively correlated with the total discharge of industrial waste.
gas. The proportion of natural gas consumption is negatively correlated with the total amount of waste water, and positively correlated with the total amount of industrial waste gas and general industrial solid waste. It shows that the energy consumption structure in the Beijing-Tianjin-Hebei region is closely related to the total emission of "three wastes" in the environment.

2) The energy consumption structure in the Beijing-Tianjin-Hebei region has a hysteresis effect on the total emission of "three wastes" in the environment, and different hysteresis stages have different influence degrees. The total amount of wastewater discharged from Beijing, Tianjin and Hebei province responded quickly to the impact of external conditions, but the response duration was relatively short, while the response duration for the proportion of crude oil and natural gas consumption was relatively long. The response degree of total industrial exhaust emission to the proportion of coal consumption lagged behind the second stage due to the impact of external conditions, but the response degree declined rapidly in the later stage. The response duration to the proportion of crude oil consumption affected by external conditions was relatively long, and the maximum lag period was the third period. When natural gas consumption is impacted by external conditions, the response of total industrial exhaust emission changes from negative to positive. Due to the small proportion of natural gas consumption, the response degree is relatively small. However, as the proportion of natural gas consumption increases, the response degree of total industrial exhaust emission will also increase. General industrial solid waste production amount of coal and natural gas consumption accounted for by the external condition of shock response degree is bigger, have negative response and positive response, respectively, by the proportion of coal consumption response speed faster, but also reduce the response faster, and degree of response to natural gas consumption accounted for more than one mutation process, and has a longer duration, but there is a lag effect.

3) The contribution of energy consumption structure to the total emission of "three wastes" in the environment is different in Beijing-Tianjin-Hebei region. The total contribution rate of "three wastes" emissions was higher in the early stage-lag period when the coal consumption accounted for a larger proportion, and was later exceeded by the consumption of crude oil and natural gas, but the time difference was different. The proportion of crude oil consumption in total wastewater and industrial exhaust emissions was lagging behind. The proportion of natural gas consumption in total industrial exhaust gas and the proportion of total industrial solid emissions in total industrial solid emissions in the 9th and 4th lagged behind, respectively, and became the main contribution variable.

Through the above analysis results and conclusions, we can have a deep understanding of the relationship between the energy consumption structure and the environment in the Beijing-Tianjin-Hebei region and the dynamic effect of the energy consumption structure on the environment. With the decrease of coal consumption and the increase of natural gas consumption, the energy consumption structure has a significant impact on the emission of "three wastes" in the environment. In the implementation of the Beijing-Tianjin-Hebei coordinated development strategy, we also need to make full use of the lagged effect of energy consumption structure on the environment and the contribution rate of various energy sources to the environment to evaluate the impact of external conditions (such as policy formulation or system implementation) according to the dynamic effect of energy consumption structure on the environment. Pay attention to the relationship between energy consumption structure and environment in the impact process of external conditions, and analyze the dynamic effect of energy consumption structure on environment in real time, so that energy resources and environment in Beijing, Tianjin and Hebei tend to develop in a dynamic balance.

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