Correlation of Energy Transition and Coordinated Development in the Beijing-Tianjin-Hebei (BTH) Region

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Abstract. Due to the serious air pollution problem since 2012 in the Beijing-Tianjin-Hebei (BTH) region, the Chinese government launched the national strategy of the BTH Coordinated Development (the BTHCD). Meanwhile, energy transition is also a national strategy in the region. What is the relationship between these two strategies, and in particular how can energy transition serve BTHCD strategy? Firstly, the paper identifies the three main areas of the BTHCD strategy, namely, transportation integration, industrial upgrading and transfer, and ecological and environmental protection, and finds that the ultimate goals of the strategy are to promote economic growth and environment protection in the region. Then, an empirical study is conducted by using the BVAR model, which further shows the that energy transition and BTHCD are closely related. Finally, policy recommendations are made for enabling an energy transition that supports the BTHCD.

1. Introduction
Since 2012, the serious haze problem in the Beijing, Tianjin and Hebei province, the so-called Beijing-Tianjin-Hebei (BTH) region, has attracted great attention from the central government on the big city disease. In response, in February 2014 the Outline of Beijing-Tianjin-Hebei Coordinated Development (BTHCD) Plan was issued by the Chinese government. The main elements of the strategy are transportation integration, industrial upgrading and transfer, and ecological and environmental protection across the region.

On the other hand, as in many other countries, the energy transition is progressing in China. To date, however, there is no uniform definition for the energy transition. That said, two research questions deserve in-depth study: What is the correlation between the energy transition and the BTHCD strategy and how can energy transition support the implementation of the BTHCD strategy? Although there are a number of studies of energy transition and the BTHCD, none of them has looked into the relationship between the two comprehensively. To fill these gaps, this research examines the correlation between the energy transition and the BTHCD through both qualitative and quantitative studies, to provide insights for the role of energy transition in the BTHCD and to support the effective implementation of the BTHCD strategy.
2. Literature review

Studies of the BTHCD have focused on the objectives of the BTHCD and the pathways of the three key elements of the BTHCD — transportation integration, industry upgrading and transfer, and ecological and environmental protection.

With regard to transportation integration, Sun (2016) points out that its core is to construct the intercity transportation network, and the current main problems of transportation integration lie in the poor interconnectivity of the transportation infrastructure, the relative backward nature of urban mass transit (UMT), and the underdevelopment of a comprehensive transportation network[1]. To solve these problems, Li (2017) and Sun (2020) recommend the improvement of top-level design for transportation, a new approach to financing approach, and the establishment of a BTH Planning and Construction Commission, among others[2-3].

With regard to industry upgrading and transfer, Zhang (2014) find that the aim of industrial upgrading is to accelerate the transformation of scientific research results, improve and extend the industrial supply chain, build industrial clusters to improve production efficiency and optimize the industrial structure in undertaking the industrial transfer[4].

With regard to ecological and environmental protection, studies have focused on the ecological protection afforded by the energy transition. Xiao (2014) finds that the environmental problems in the BTH region are becoming increasingly severe, and had become a significant obstacle to the BTHCD[5]. Li (2020) further points out that there is a strong correlation between carbon emissions, energy consumption and economic growth in the BTH region[6]. O’Mahony (2013), González (2014) point out that energy intensity and energy structure are the main factors affecting the carbon emissions in the BTH region[7-8].

The study of the energy transition has been focused on the theoretical analysis and the pathway of energy transition. Tong (2018) argues that energy transition is the comprehensive optimization of energy production mode, energy consumption mode, and energy system structure[9]. Schürmann et al. (2019) holds that the main objectives of energy transition are to decarbonize the energy supply and consumption by switching from fossil fuels to renewable energies, and to reduce energy demand by enhancing energy efficiency[10].

As regards energy transition’s pathway, Luo et al. (2019) finds that the energy transition is primarily driven by the deteriorating environment because of energy activities are the largest source of greenhouse gas emissions[11]. Shu (2018) argue that China’s low-carbon energy transition needs to start from these three sectors, by promoting renewable energy penetration, electrification rate and improving energy efficiency[12].

Hermwille (2020) and Burandt (2019) further classify the above three sectors into energy production side and energy consumption side[13-14]. On energy production side, Wang (2020) point out that the power sector needs to phase out fossil energy for electricity generation, and to use more renewable energy such as wind and PV energy[15]. On energy consumption side, the construction sector needs to accelerate the electric power substitution in the field of residential heating, to reduce the use of fossil energy, and to guide users to use heat pumps, electric cold storage, and other alternative technologies. In addition, Mansour et al. (2018) argue that the transportation sector should vigorously enhance electrification by using more new energy vehicles, which can provide substantial savings of 38.7% for hybrids and 88.6% for plug-in hybrids than traditional fuel vehicles[16].

To summarize, extensive studies have been carried out on both the BTHCD and energy transition, which are helpful for our qualitative analysis in the next section. However, these analyses focused on the BTHCD and the energy transition separately. None of them has looked into the correlation between them.

3. Qualitative analysis

As noted above, the three key elements of the BTHCD strategy are transportation integration, industry upgrading and transfer, and ecological and environmental protection. According to the theory of regional economics, regional transportation integration can lead to the reduction of transportation cost, enabling
the acceleration of the industry from clustering to scattering. Consequently, industry upgrading and transfer is enhanced. The logic is as follows: industry upgrading and transfer promote the optimization of regional resource allocation, thus enhancing economic growth, and bringing about population migration from Beijing to Hebei and environmental optimization. This suggests that the ultimate goal of the BTHCD is to promote economic growth, environmental optimization, and population migration.

As shown in Fig. 1, the energy transition and the three key elements of the BTHCD are interrelated and influence each other. Whilst the BTHCD propels the energy transition, the energy transition supports the BTHCD. Transportation integration and industry upgrading and transfer would result in the increase of electricity consumption in total final energy consumption via the increase of transportation electrification rate and the optimization of energy consumption structure respectively. As the cleanest and most efficient secondary energy source, electricity has much higher economic benefits than that of fossil energy in China, which are 3.2 and 17.27 times that of petroleum, and coal. The substitution of electricity for fossil energy reduces energy intensity and supports economic growth. And in terms of environmental protection, the BTHCD has higher requirements than before for energy structure and energy efficiency in various sectors. Thus, energy transition is propelled.

4. Empirical analysis

4.1. Index selection

Based on the above qualitative analysis, this section uses the Bayesian VAR model to further empirically analyze the correlation between the energy transition and the BTHCD. Given that the final policy effect of the BTHCD is mainly reflected in economic growth and environmental optimization, and as evidenced in the above analysis, the energy transition can promote economic growth and environmental optimization, to simplify calculation, we select GDP and total industrial carbon emission as the evaluation indices for the BTHCD. The proportion of renewable energy installation, total power consumption, and energy intensity are selected as evaluation indices for the energy transition, which represents respectively clean energy production, electrification of energy consumption, and high
efficiency of energy consumption. The evaluation indices and variables are shown in Table 1. In order to reduce the multicollinearity and eliminate the influence of dimension, the logarithm of each variable is taken and standardized. The formula is as follows:

\[ x_i = \frac{(x_i - \bar{x})}{s} \]

Where \( x \) is the relevant variable and \( s \) is the standard deviation.

| Symbol | Evaluation index | Variable |
|--------|------------------|----------|
| C      | Total industrial carbon emissions | BTHCD     |
| A      | GDP              |          |
| I      | Energy intensity |          |
| S      | Proportion of renewable energy installation | Energy transition |
| B      | Total electricity consumption |          |

The data used in this paper are from 1991 to 2018, and the data sources are the Beijing-Tianjin-Hebei Statistical Yearbook, China Energy Statistical Yearbook, and China Electric Power Statistical Yearbook. The total industrial carbon emissions data in the BTH region is obtained by multiplying the IPCC carbon emission coefficient and the fossil energy consumption in the industry. All data have been standardized.

4.2. Model building

Vector autoregressive (VAR) was originally proposed by Sims\(^{[17]}\). The VAR model can estimate the dynamic relationship between variables without pre-setting constraints. The prediction result of the VAR model is, in general, more accurate than that of the simultaneous equation model, which makes it widely used to explore the potential dynamic relationship between different macroscopic variables.

But there are considerable requirements for the amount of sample data. If the length of the data sample is not enough, the effectiveness of the traditional VAR model tends to be low. To solve the problem resulted from too small sample, Building on the Bayesian Vector Autoregressions model, Litterman (1986) proposed BVAR (Bayesian Vector Autoregressions) model which assumes that the coefficients in the VAR model obey a certain prior distribution\(^{[18]}\).

The BVAR model can estimate the influence degree of each variable on the whole economic system. This helps to avoid the loss of freedom under the traditional VAR model with unconstrained conditions, and thus the prediction accuracy can be improved. The BVAR model can be written as follows:

\[
Y_i(t) = d(t) + \sum_{j=1}^{m} b_{ij}Y_j(t-j) + \sum_{j=1}^{m} b_{ij}Y_j(t-m) + b_{ij}Y_j(t-1) + \cdots + b_{ij}Y_j(t-m) + \cdots + \varepsilon_i(t)
\]

(1)

Where \( Y \) is the explained variable in the time interval \( t,T \) is the sample size. \( D(t) \) is the deterministic component of \( Y(t) \), a linear function of an \( n \times d \) matrix of parameters. In addition, \( D(t) \) includes a constant term for each component of \( Y \). The scalar form of the \( t \)th equation is as follows:

\[
Y_t = D(t) + \sum_{j=1}^{m} B_j Y(t-j) + \varepsilon(t) \quad t = 1, \ldots, T
\]

\[
E[\varepsilon(t)\varepsilon(s)'] = \sum \text{ if } s = t ; 0 \text{ otherwise}
\]

(2)

Equation (1) can be rewritten as equation (3). Notably, in equation (3), we adopt the somewhat misleading notation that \( X \) includes \( Y \)'s lagging term.

\[ Y = X\beta + \varepsilon \]

(3)

Using this notation, the estimator suggested here is as follows:
\[ \beta^k = (X'X + kR'R)^{-1}(X'Y + kR'r) \]  \hspace{1cm} (4)

This estimator combines the data generated by the model in (3), assuming, with the prior information contained in specification where. This estimator combines the data generated by the model in (3), assuming \( \varepsilon \sim N(0, \sigma^2 I) \), with the prior information contained in specification where \( k = \sigma^2 / \lambda^2 \).

\[ R\beta = r + v \sim N(0, \lambda^2 I) \]  \hspace{1cm} (5)

In the selection of prior type, this paper draws on Litterman (1986), that is, adopts Litterman-Minnesota prior distribution. All equations in the system are given the same form of prior distribution. For the \( i \)th equation this distribution is centered around the specification.

\[ Y_i(t) = Y_i(t-1) + d_i(t) + \varepsilon_i(t) \]  \hspace{1cm} (6)

As the main topic of this paper is a macro one, the relevant data are annual data and are short. If we use the traditional VAR model, there exists the problems of identification and estimation of the model. Therefore, based on the theory noted above, we establish a BVAR model based on Minnesota conjugate prior distribution to study the correlation between the energy transition and the BTHCD strategy.

4.3. Model testing

Since the direct modeling of non-stationary time series data will produce pseudo-regression, it is necessary to test the stationarity of variable data. If the data is stable, the next analysis can be carried out. Otherwise, cointegration test is needed. After unit root tests on each variable are conducted, the output results are shown in Table 2.

### Table 2 Result of ADF unit-root test

|       | Level        | 1st Difference |
|-------|--------------|----------------|
|       | Constant    | Constant+trend | None   | Constant | Constant+trend | None   |
| lnA   | -2.379      | -2.278         | -0.97  | -1.564   | -3.6**         | -1.123 |
| lnB   | -0.775      | -1.502         | -0.532 | -2.645*  | -2.664         | -1.168 |
| lnC   | -1.547      | -0.446         | -1.092 | -2.475   | -2.881         | -1.952**|
| lnI   | -1.03       | -5.176***      | -0.904 | -5.343***| -5.076***      | -1.538 |
| lnS   | -0.096      | -1.917         | -0.179 | -5.797***| -5.691***      | -1.516 |

Note: *and ** and ***denote significance at 10%, 5% and 1% level.

Since the original data is not stable, after further using the Johansen cointegration equation for cointegration test, it is found that at a significance level of 0.05, the Trace test and Maximum Eigenvalue yield a total of 4 cointegration relationships, which can determine the long-term relationship of time series data. The output results are shown in Table 3.

### Table 3 Result of Johansen cointegration test

#### Unrestricted Cointegration Rank Test (Trace)

| No. of CE(s) | Eigenvalue | Statistic | Critical Value | Prob.** |
|--------------|------------|-----------|----------------|---------|
| None *       | 0.929368   | 154.7065  | 76.97277       | 0       |
| At most 1 *  | 0.777701   | 88.44955  | 54.07904       | 0       |
| At most 2 *  | 0.611767   | 50.8563   | 35.19275       | 0.0005  |
| At most 3 *  | 0.480702   | 27.20256  | 20.26184       | 0.0047  |
| At most 4 *  | 0.351325   | 10.8206   | 9.164546       | 0.0241  |

#### Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

| No. of CE(s) | Eigenvalue | Statistic | Critical Value | Prob.** |
|--------------|------------|-----------|----------------|---------|
| None *       | 0.929368   | 66.25696  | 34.80587       | 0       |
| At most 1 *  | 0.777701   | 37.59325  | 28.58808       | 0.0027  |
| At most 2 *  | 0.611767   | 23.65374  | 22.29962       | 0.0322  |
After confirming the long-term co-integration relationship between the data selected by the model, the EVIEWS software is used to select the optimal number of lag periods. There are three optimal lag periods. Therefore, this paper establishes the BVAR (3) model. The stability is further tested after the model is established. Fig. 2 shows that all points fall within the unit circle, which means that the modulus of the reciprocal of all characteristic roots is less than 1, and the BVAR model has good stability. The impulse response analysis can be further carried out next.

4.4. Results analysis

Fig. 3 shows the impulse response results of main variables from 0 to 10 periods when each endogenous variable is subject to an exogenous impact with a positive standard deviation. The first and second columns are the responses of the BTH GDP and total industrial carbon emissions where power consumption, energy intensity, and the proportion of renewable energy installation are positively impacted. The third and fourth columns are the responses of electricity consumption, energy intensity, and the proportion of renewable energy installation where GDP and carbon emissions are positively impacted. As shown in Fig. 3, all impulse response functions finally converge, suggesting that the established model is relatively stable.

Fig. 2 Output of Bayesian VAR model stability test

![Inverse Roots of AR Characteristic Polynomial](image)

Fig. 3 Impulse response results of main variables
In terms of economy, GDP has a strong positive response to electricity consumption, and a certain degree of negative response to the proportion of renewable energy installation and energy intensity. As shown in the first column of Figure 3, the maximum response values of GDP to the three variables are 0.45%, -0.33% and -0.10%, respectively, and the electricity consumption has the greatest impact on GDP followed by energy intensity.

In terms of ecological environment, Fig. 3 shows that power consumption, the proportion of renewable energy installation, and energy intensity have a strong positive impact on carbon emissions and gradually increase when they are subject to a positive impact. As shown in the second column of Fig. 3, the maximum response values of carbon emissions to the three variables are 1.46%, 0.33% and 0.12%, respectively, of which the impact of electricity consumption on carbon emissions is the greatest, followed by energy intensity and the proportion of renewable energy installation. It is worth noting that carbon emissions are positively impacted by the proportion of renewable energy installation, the response is positive in the first two periods, and then turns negative, to almost zero in the sixth period.

Based on the above analysis, we can further get the following results: (1) Electricity consumption is the main driving force for economic growth and carbon emissions; that is, it generates a lot of carbon emissions while promoting economic growth. (2) Energy efficiency has more advantages in terms of both economic growth and the reduction of carbon emissions than renewable energy. The main reasons are as follows: The improvement of energy efficiency is mostly manifested in technological progress or optimization of energy consumption patterns, directly promoting economic growth and low-carbon emissions reduction. However, renewable energy is a commodity that needs to go through the process of production and circulation. Its economic and environmental effects are indirect. In production and circulation, it will face a series of obstacles such as the market pressure, system defect, curtailment and so on.

The first row in Fig.3 shows that GDP and carbon emissions both have a significant positive response to the increase in electricity consumption, and electricity consumption also has a significant positive response to the increase in GDP and carbon emissions. Whilst in the former situation, the growth of electricity consumption is reflected in the increase in fossil energy consumption for power generation on the production side, and in the active economic activities on the consumption side, which in turn leads to an increase in carbon emissions and GDP, in the latter case, the growth of carbon emissions and GDP, in turn, promotes the electrification of secondary energy, which in turn promotes the growth of electricity consumption. This result suggests that under the current energy system dominated by coal-fired power in the BTH region, the goals of economic growth and environmental protection cannot be achieved simultaneously. In other words, the existing power production structure needs to be transitioned to one that is dominated by clean power and the share of renewable power should be increased.

The second row in Fig.3 shows that the increase in energy intensity has led to environmental degradation and economic recession. In other words, when energy intensity is negatively impacted (i.e. energy intensity is reduced), GDP has a strong positive response (i.e. GDP increases) whilst carbon emissions have a significant negative response (i.e. carbon emissions are reduced). When GDP and carbon emissions are positively impacted (i.e. when GDP and carbon emissions increase), energy intensity has a positive response (i.e., energy intensity is reduced or energy efficiency is improved). The reason is as follows: the growth of carbon emissions in the BTH region will force the government to introduce related policies to limit enterprises' energy consumption, thereby promoting enterprises to carry out technological innovations to improve energy efficiency. On the one hand, the improvement of energy efficiency will reduce enterprises' costs and promote regional income growth. On the other hand, it will restrain the use of fossil energy and reduce carbon emissions. At the same time, the increase in income will give enterprises more R&D investment to further promote energy efficiency.

The third row in Fig.3 shows that the increase in the proportion of renewable energy installation has produced neither economic nor environmental benefits. And, GDP and carbon emissions have shown firstly a positive and then negative trend in promoting the proportion of renewable energy installation. The likely reason for this is that the increase in installed capacity at the early development stage of
renewable energy has stimulated the development of upper (for instance, the extraction of silicon sand in solar PV power industry) and middle stream (for instance, the manufacturing industry of solar PV products), in the process of which a large amount of carbon emissions are generated.

5. Conclusions and recommendations
The three key elements of the BTHCD are transportation integration, industrial upgrading and transfer, and ecological environmental protection. The energy transition in this paper is defined as the clean energy production, efficient energy utilization, and the electrification of energy consumption. Qualitative research shows that the energy transition and the BTHCD are interrelated and influence each other. The BTHCD propels the energy transition, and the energy transition supports the BTHCD. Further quantitative analysis using the BVAR model provides the following main conclusions:

(1) In the context of the current power structure dominated by coal-fired power in the BTH region, the BTHCD strategy’s goals of economic growth and environmental protection cannot be achieved simultaneously. (2) Improving energy efficiency is the most effective way to realize both the energy transition and the BTHCD simultaneously. (3) At the current stage, the economic and environmental benefits resulting from renewable energy have not reached the expected level.

To support the BTHCD, policy recommendations for accelerating the energy transition in the BTH region are as follows:

(1) The evaluation indexes of energy transition should be taken into consideration in the BTHCD strategy, such as electrification rate, carbon emission amount, clean energy installation ratio, energy utilization efficiency, among others.

(2) Attention should be attached to energy efficiency in addition to renewable energy at the current development stage of the BTHCD strategy. In this respect, it is recommended that potential efficiency should be explored and improved according to local conditions given that regional energy efficiency has spatial-temporal heterogeneity. To carry out the regional coordinated development strategy, and the rational allocation of energy resources, it is necessary to grasp the impacts of technological progress and industrial structure on energy efficiency, and adjust measures to local conditions to explore the path of energy efficiency.

(3) Stop the construction of coal-fired power plants and formulate plans for the replacement of coal-fired power by natural gas and renewable energy. It is reported that the BTH region is still building new coal-fired power plants whilst increasing renewable energy installations. This has increased the environmental pressure in the BTH region, squeezed the market for renewable energy consumption, hindering the full realization of the economic and environmental benefits of renewable energy. When the current installed capacity is sufficient to meet the power demand in the BTH region, not only the increase in coal-fired installed capacity should be controlled, the stock of coal-fired installation should be reduced as well.

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References
[1] Sun J. Comparison of economic and social systems, 03: 5-9 (2016)
[2] Li X. Northeast University of Finance and economics (2017)
[3] Sun J., Zhang A., Zhou Z,China soft science, 06: 96-111 (2020)
[4] Zhang G., Wang S., Liu S., Jia S,Economics and Management, 28 (04): 14-20 (2014)
[5] Xiao J., Environmental Protection, 42 (17): 21-25 (2014)
[6] Li J, China University of mining and technology,(2020)
[7] O’Mahony T, Energy Policy, 59:573-581 (2013)
[8] González P., Landajo M., Presno M, Energy, 73, 741-750 (2014)
[9] Tong G., Smart Power, 46(10): 1-3+25 (2018)
[10] Karin Schürmann, Anna Ernst, Diana Schumann, Energy Procedia, 158, 3534-3540 (2019)
[11] Luo F., Guo Y., Yao M., et al, Journal of Cleaner Production, 268:121925 (2020)
[12] Shu Y., State Grid, 04: 38-39 (2018)
[13] Hermwille L., Earth System Governance, 8:10054 (2020)
[14] Burandt T., Xiong B., Lffler K., et al., EconStor Open Access Articles (2019)
[15] Wang Y., Wang S., Song F., et al., Energy Policy, 144: 111686 (2020)
[16] Mansour C., Haddad M., Zgheib E, Transportation Research Part D: Transport and Environment, 63:498-513 (2018)
[17] Sims, C., Macroeconomics and reality. Econometrica, 48: 1–48 (1980)
[18] Litterman, R. B., Journal of Business and Economic Statistics, 4, 25-38 (1986)