Study on the coupling relationship between the efficiency of regional Sci-Tech innovation and Sustainable development

Yusheng Zhang
School of Tianjin University of Technology, Tianjin, China
*Corresponding author e-mail: zys199509@163.com

Abstract. Based on the Slack Based Measure model and the coupling degree model, this paper calculated the efficiency of scientific and technological innovation and sustainable development of 13 cities in Beijing, Tianjin and Hebei from 2008 to 2017, and analyzed the coupling relationship between their efficiency. The results show that: 1) from 2008 to 2017, the scientific and technological innovation efficiency and sustainable development efficiency of the Beijing-Tianjin-Hebei urban agglomeration maintained an overall upward trend, and the overall coupling degree of the urban agglomeration was in a fluctuating growth trend; 2) the change process of coupling type from medium and low level coupling at the beginning to medium and high level coupling later. In addition, the coupling development level between Beijing and Tianjin is good, while Hebei's overall level is low.

1. Introduction
During the “Thirteenth Five-Year Plan” period, the state proposed to gradually transform regional sustainable development into innovation-driven development [1]. As an important economic development center, the urban agglomeration of Beijing-Tianjin-Hebei has a profound impact on the development of national politics, economy and culture. Summing up the domestic and foreign literature research, it is found that foreign scholars have been studying scientific and technological innovation and sustainable development for a long time. Simonies [2] studied the impact of innovation factors on enterprise competitiveness from the perspective of sustainable development. Arico [3] discussed the contribution of scientific and technological innovation to sustainable development based on relevant experience of UNESCO. Andrea Larsson et al. [4] believe that sustainable innovation is scientific and technological innovation related to ecological environment. Relevant domestic scholars mainly focus on theoretical analysis and research, index system construction and other aspects [5-8], and research on the interaction between social, economic and environmental subsystems and scientific and technological innovation in sustainable development system is relatively common. In general, the research of scholars at home and abroad mostly focuses on the micro level of industrial enterprises, lacking systematic and holistic thinking and research on the relationship between them. The research content includes not only the empirical analysis of scientific and technological innovation and sustainable development, but also the theoretical exploration of the concept of sustainable development in scientific and technological innovation. However, from the perspective of efficiency, systematically analysing and coordinating the coupling and coordination between technological innovation efficiency and sustainable development, and taking urban agglomeration as the research
object, is very limited. Therefore, this paper takes the Beijing-Tianjin-Hebei urban agglomeration as the research object, and from the perspective of efficiency, conducts the coupling relationship analysis of the efficiency between scientific and technological innovation and sustainable development of the urban agglomeration.

2. Material and Methods

2.1. Construction of evaluation index system

According to the functional relationship between scientific and technological innovation and sustainable development and based on the principles of scientific, systematic, accessibility and operability, the efficiency evaluation index system of scientific and technological innovation and sustainable development was constructed respectively (see table 1).

| Table 1. Technology innovation and Sustainable development Efficiency Evaluation Index System |
|-----------------------------------------------|
| Technology innovation Efficiency Evaluation Index System | Sustainable development Efficiency Evaluation Index System |
| Level indicators | The secondary indicators | Indicators of characterization | Level indicators | The secondary indicators | Indicators of characterization |
| Input indicators | Invested capital | Proportion of R&D expenditure (%) | Input indicators | Invested capital | Total investment in social fixed assets; |
| | | Proportion of scientific research practitioners (%) | | | Proportion of employees related to economy, society and environment (%) |
| | Staffing | | | Staffing | |
| | Invest resources | Proportion of r&d expenditure in GDP (%) | | | Resource consumption (10,000 tons of standard coal); |
| Output indicators | Social benefits | Per capita turnover of technology market; | Output indicators | Social benefits | Environmental improvement, circular economy (m²/person); |
| | Economic benefits | Annual GDP growth level; | | Economic benefits | Per capita income; |
| | Undesired output | Adverse impact on economy, society and environment | | Undesired output | Discharge amount of three wastes (t/10,000 ¥) |

2.2. Research Method

1) The non-expected output SBM model

The SBM model is as follows:

$$\rho^* = \min \left\{ 1 - \frac{1}{T} \sum_{i=1}^{T} \frac{s_i^l}{x_{ij}} \frac{1}{y_i + N \left( \sum_{a=1}^{A} \frac{z_i^l}{y_{ai}} + \sum_{k=1}^{K} \frac{z_k^l}{u_{ak}} \right)} \right\}$$

$$s_i^l x_{ij} + s_i^r = x_{ij}, i = 1, 2, A, j; \sum_{i=1}^{T} z_i^l y_{ai} + s_i^r = y_{ai}, a = 1, 2, A, y;$$

$$\sum_{i=1}^{T} z_i^l u_{ak} + s_i^r = u_{ak}, a = 1, 2, A, n; \sum_{i=1}^{T} z_i^l = 1; z_i^l \geq 0; s_i^r \geq 0; s_i^r \geq 0; s_i^r \geq 0$$
Type in the $x_i$ represents an input variable for a decision unit, $y_m$ represents the expected output variable, $u_n$ represents an unexpected output variable, $s_i^i$, $s_i^e$, $s_i^u$ symbolic representations of inputs, expected outputs, and non-expected outputs respectively. $\rho^*$ is the efficiency value of scientific and technological innovation or sustainable development, The range of $[0,1]$, when $\rho^* = 1$, completely valid, and vice versa.

2) The coupling measurement model

$$C = 2 \left\{ \frac{(T_1 \cdot S_1)}{[(T_1 + S_1)(T_1 + S_1) \cdot 1/2] \right\}$$  \hspace{1cm} (2)$$

Equation (2), the coupling degree value C is in [0,1]. When C is close to 0, there is almost no coupling degree, indicating that the two systems or internal elements are mutually coerced and constrained. When C approaches 1, it indicates that the two systems are in a highly coupled state of benign resonance, complement and promote each other, and the system develops in an orderly direction.

2.3. Data collection
The data collection mainly involves China statistical yearbook, China environmental statistical bulletin, China regional economic statistical yearbook, China science and technology statistical yearbook, and Beijing, Tianjin and Hebei statistical yearbook of national economic and social development.

3. Results Analysis

3.1. Analysis of evaluation results
Based on SBM model and using MaxDEA6.0 software, the 2008-2017 panel data of 13 cities in the Beijing-Tianjin-Hebei urban agglomeration are calculated year by year, and the results are shown in table 2.

According to the results in table 2, the measurement curves of the efficiency of scientific and technological innovation and sustainable development of the Beijing-Tianjin-Hebei urban agglomeration from 2008 to 2017 (figure 1) are compared and analyzed. The efficiency of scientific and technological innovation and the efficiency of sustainable development have undergone twists and turns, and progress has been made in the efficiency of scientific and technological innovation and the efficiency of sustainable development in the Beijing-Tianjin-Hebei region. Its efficiency value is between 0.30 and 0.93. In the first stage, the efficiency of scientific and technological innovation kept increasing from 2008 to 2011. The efficiency of scientific and technological innovation was at the lowest value of 0.30 in 2008, and then increased continuously at a rate of about 50% every year. By 2011, the efficiency of scientific and technological innovation had been greatly improved. In the second stage, from 2012 to 2014, the efficiency of sustainable development continued to rise, with an annual growth rate of 7%, while the efficiency of scientific and technological innovation increased by 10%. In the third stage, from 2015 to 2017, the efficiency value of the two will basically increase steadily, showing a linear growth trend. By 2017, the efficiency of scientific and technological innovation will reach 0.93 and 0.90, respectively. Compared with 2008, the efficiency of scientific and technological innovation will increase by 310%, and the efficiency of sustainable development will increase by 200%. On the whole, the governments of Beijing, Tianjin and Hebei have paid enough attention to scientific and technological innovation and sustainable development.
Table 2. Sci-Tech innovation efficiency and Sustainable development Efficiency Value in Beijing-Tianjin-Hebei Region, 2008-2017.

| area       | 2008 | 2009 | 2010 | 2011 | 2012 |
|------------|------|------|------|------|------|
| Beijing    | 0.64 | 0.72 | 0.68 | 0.74 | 0.68 |
| Tianjin    | 0.52 | 0.63 | 0.56 | 0.65 | 0.64 |
| Shijiazhuang| 0.46 | 0.54 | 0.48 | 0.56 | 0.53 |
| Tangshan   | 0.45 | 0.53 | 0.46 | 0.55 | 0.51 |
| Qinhuangdao| 0.29 | 0.32 | 0.32 | 0.32 | 0.32 |
| Handan     | 0.26 | 0.31 | 0.28 | 0.30 | 0.29 |
| Xingtai    | 0.23 | 0.29 | 0.25 | 0.30 | 0.25 |
| Baoding    | 0.31 | 0.38 | 0.36 | 0.42 | 0.36 |
| Zhangjiakou| 0.18 | 0.36 | 0.25 | 0.34 | 0.28 |
| Chengde    | 0.19 | 0.32 | 0.23 | 0.35 | 0.29 |
| Changzhou  | 0.16 | 0.28 | 0.38 | 0.32 | 0.40 |
| Langfang   | 0.15 | 0.35 | 0.39 | 0.46 | 0.53 |
| Bengshui   | 0.14 | 0.55 | 0.28 | 0.58 | 0.39 |
| mean value | 0.30 | 0.45 | 0.38 | 0.52 | 0.46 |

| area       | 2013 | 2014 | 2015 | 2016 | 2017 |
|------------|------|------|------|------|------|
| Beijing    | 0.95 | 0.85 | 0.96 | 0.87 | 0.98 |
| Tianjin    | 0.92 | 0.82 | 0.93 | 0.83 | 0.94 |
| Shijiazhuang| 0.83 | 0.78 | 0.86 | 0.76 | 0.88 |
| Tangshan   | 0.81 | 0.76 | 0.84 | 0.78 | 0.86 |
| Qinhuangdao| 0.79 | 0.79 | 0.86 | 0.81 | 0.88 |
| Handan     | 0.73 | 0.75 | 0.83 | 0.78 | 0.84 |
| Xingtai    | 0.72 | 0.76 | 0.78 | 0.79 | 0.82 |
| Baoding    | 0.79 | 0.75 | 0.89 | 0.82 | 0.91 |
| Zhangjiakou| 0.75 | 0.78 | 0.82 | 0.84 | 0.87 |
| Chengde    | 0.78 | 0.65 | 0.81 | 0.72 | 0.83 |
| Changzhou  | 0.82 | 0.63 | 0.89 | 0.76 | 0.91 |
| Langfang   | 0.89 | 0.79 | 0.91 | 0.82 | 0.92 |
| Bengshui   | 0.76 | 0.76 | 0.83 | 0.78 | 0.86 |
| mean value | 0.81 | 0.76 | 0.86 | 0.80 | 0.88 |

Figure 1. The sequence evolution of technological innovation efficiency and sustainable development efficiency in the Beijing-Tianjin-Hebei region from 2008 to 2017.
3.2. The coupling relationship between the efficiency of regional Sci-Tech innovation and Sustainable development

According to the efficiency data results in table 2 and the coupling degree model, the coupling coordination degree values of the two can be calculated, and the calculation results are shown in table 3.

**Table 3.** Coupling Coordination Value of Science and Technology innovation Efficiency and Sustainable development Efficiency of Beijing-Tianjin-Hebei Urban Agglomeration in 2008-2017.

| Area       | 2008 | 2009 | 2010 | 2011 | 2012 |
|------------|------|------|------|------|------|
| Beijing    | 0.81 | 0.87 | 0.78 | 0.84 | 0.79 |
| Tianjin    | 0.78 | 0.76 | 0.77 | 0.83 | 0.78 |
| Shijiazhuang | 0.60 | 0.67 | 0.67 | 0.67 | 0.70 |
| Tangshan   | 0.64 | 0.62 | 0.62 | 0.65 | 0.66 |
| Qinhuangdao | 0.52 | 0.45 | 0.46 | 0.62 | 0.51 |
| Handan     | 0.48 | 0.49 | 0.41 | 0.54 | 0.50 |
| Xingtai    | 0.41 | 0.47 | 0.38 | 0.43 | 0.48 |
| Baoding    | 0.52 | 0.49 | 0.42 | 0.52 | 0.50 |
| Zhangjiakou | 0.54 | 0.48 | 0.39 | 0.45 | 0.53 |
| Chengde    | 0.44 | 0.38 | 0.40 | 0.45 | 0.50 |
| Changzhou  | 0.56 | 0.49 | 0.40 | 0.51 | 0.52 |
| Langfang   | 0.58 | 0.60 | 0.61 | 0.63 | 0.66 |
| Hengshui   | 0.41 | 0.49 | 0.38 | 0.54 | 0.48 |
| mean value | 0.56 | 0.56 | 0.51 | 0.59 | 0.58 |

According to the coupling degree value in table 3, we plotted the trend of the coupling degree of Beijing-Tianjin-Hebei urban agglomeration, and the results are shown in figure 2. which can be seen from the figure 2, the coupling coordination degree value is higher, Beijing and Tianjin Beijing chronically high levels of coupling phase, The coupling degree of Hebei is relatively low, and the development trend is consistent with the trend of regional coupling degree of Beijing-Tianjin-Hebei urban agglomeration. The coupling degree of Beijing-Tianjin-Hebei increased by more than 25% from 0.55 in 2008 to 0.69 in 2017. The coupling degree of the two has been improved and improved over time. In addition to the declining coupling degree value in 2010, the coupling degree of Beijing-Tianjin-Hebei region maintained a basically rising trend in all other years, and the overall coupling trend was good. The gap between the coupling degree of Beijing-Tianjin-Hebei region and that of Beijing-Tianjin region was gradually narrowed, showing a good development trend. It is believed that this trend will continue in the future for a period of time.
Figure 2. Coupling degree of technological innovation efficiency and sustainable development efficiency of Beijing-Tianjin-Hebei urban agglomeration in 2008-2017.

4. Discussion and Conclusions
Overall, from 2008 to 2017, the coupling degree between the sustainable development efficiency and the scientific and technological innovation efficiency of the Beijing-Tianjin-Hebei urban agglomeration are on the rise. The efficiency of scientific and technological innovation is growing faster than that of sustainable development. This means that the efficiency of scientific and technological innovation plays a more and more important role in promoting regional sustainable development, and it is expected that the innovation-driven development strategy implemented by the country will achieve good development results in the future. We should take scientific and technological innovation as the direction to promote all-round social innovation and development, upgrade the industrial level, optimize the industrial structure, and achieve all-round and sustainable development of the economic and social environment.

Acknowledgements
This work was financially supported by National Key Research and Development Program Funding Project (2016YFF0201603).

References
[1] Zhao C S, Ren J L. (2017) Correlation analysis between efficiency of scientific and technological innovation and sustainable development in China -- empirical study based on entropy method and grey correlation model [J]. Ecological economy, 33:58-61+72.
[2] Samonis V. (2014) Sustaining innovation: theory and policies for new Europe [J]. Ekonomika, 10 :68-79.
[3] Aricò S. T (2014) Contribution of the sciences, technology and innovation to sustainable development: The application of sustainability science from the perspective of UNESCO’s experience[J]. Sustainability Science, 8:453-462.
[4] Larson A L. (2010) Sustainable innovation through an entrepreneur-ship lens[J]. Business Strategy and the Environment, 9 :304-317.
[5] Yang W, Yang M. (2016) Measurement of China's economic development and structural optimization driven by the efficiency of scientific and technological innovation [J]. Soft science, 30:1-7+12.
[6] Wang G X, Liu T. (2017) Dynamic coupling relationship between scientific and technological innovation efficiency and ecological environment in resource-oriented cities in central urban agglomeration [J]. China population • resources and environment, 27:80-88.

[7] Ge J T. (2018) On the coordinated development of economy and society based on the efficiency of scientific and technological innovation [J]. Journal of Jinan university (social science edition), 18:80-83+92.

[8] Zhao C S, Ren J L, Chen Y B, Liu K. (2018) Coupling coordination and spatiotemporal differentiation between the efficiency of scientific and technological innovation and sustainable development in China [J]. Geographical science, 38:214-222.