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# *Research on Industrial Optimization and Expenditure Efficiency of Ecological Development in Beijing*

**Wensen Wu***

*North China University of Technology, Beijing, China*
**Corresponding author*

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***Abstract*:** Under the framework of the coordinated strategy, the research on the efficiency of industrial and ecological expenditures is gradually deepened. This paper uses DEA-Malmquist model to calculate the expenditure and effect of industrial optimization and ecological development policies in 16 districts of Beijing from 2010 to 2020. It focuses on the changes of overall efficiency and decomposition efficiency. Results show that: First, the overall efficiency of expenditure shows a fluctuating trend, the effectiveness of expenditure efficiency level varies greatly in different regions. The efficiency of the upper central city is low, while that of the marginal city is high. Second, technological progress and scale efficiency are the main factors that cause the overall efficiency to decrease. The pure technical efficiency is the key to promote the industrial structure and urban ecological optimization expenditure efficiency. Third, the change of technological progress efficiency is related to the cyclical change of technology. The characteristics of effect have changed from a large change range and a short change time in the early stage to a small change range and a long change time.

## 1. Introduction

China is currently promoting the optimization of industrial structure and urban ecology. Guided by this strategy, governments in various regions are pursuing different policies to achieve this goal. Government policies are often seen as an administrative tool for resource deployment, which is able to concentrate a large amount of resources to achieve a specific purpose. But since resources are limited. This is an important issue in how to make use of the limited resources and how to make use of the policy to play a role in both industry and ecology.

From the perspective of the interaction of urban ecological and economic systems [1], aiming at assessing the environmental and economic performance of a decentralized biowaste management system, using the frameworks of life cycle assessment and net present value analysis. Understanding the public's perceived benefits and concerns can support policy makers and industry in implementing responsible risk governance and can have design and operational implications. Goerlandt [2] explore this topic for a hypothetical autonomous urban ferry in Halifax, Nova Scotia. A survey was conducted to explore a household's environmental awareness and willingness to recycle based on socio-demographics, environmental hazard awareness, and used cell phone usage in Abideable, Indonesia. METHODS: a peer questionnaire was used and organized into five sections: The first section contained the sociodemographic details of the respondents [3]. Background information for the role of cities in climate change and environmental pollution globally will be explained [4]. By using a multiregional input–output model, structural path analysis, and exploratory spatial data analysis [5] present a spatiotemporal analysis of how upstream energy interactions change in the context of rapid urbanization and the Chinese economy. Green technology progress is selected as an important representation of Industry 4.0, and samples of China's A-share resource-based enterprises from 2004 to 2018 are used to examine the relationship between environmental regulation, green technology progress, and total factor productivity to explore the role of social, environmental, and technological factors in manufacturing development [6-7] aim to fill an important research gap by investigating the role of environmental-related technologies on energy demand and energy efficiency in a sample of 28 OECD economies. The objective of Wang [8] is to explore the impact of urbanization on the coupling of economic growth and environmental quality. The primary purpose of Rafique [9] is to explore the role of environmental taxes and economic growth on the growing ecological footprint in 29 OECD economies. Other influential work includes Morello [10].

However, the current research focuses more on the interpretation of urban ecology rather than the relationship between industrial structure, urban ecology and policy implementation. The research lacks a deeper interpretation of the overall expenditure efficiency and decomposed efficiency. Considering the above shortcomings, this paper selects 16 districts in Beijing as the research subjects. It adopts the DEA-Malmquist model to measure the expenditure efficiency of industrial structure optimization and urban ecology in 16 districts. This paper innovatively combines the quantity theory and technology cycle theory in policy. The study analyzes the impact on industrial structure and urban eco-efficiency under government policy expenditure. And it delves into the reasons for the overall efficiency and the efficiency changes after each decomposition, and puts forward effective policy recommendations.

## 2. Design and Index Selection

### 2.1. Model Design

Data Envelopment Analysis (DEA) is a nonparametric production frontier model for measuring the efficiency index when there are multiple input and output indicators. The research unit is called decision-making unit, and the efficiency value of the unit is evaluated according to the distance between the decision-making unit and the frontier.

On this basis, Sten Malmquist put forward Malmquist index in 1953. DEA-Malmquist model can reflect the productivity changes before and after the decision-making units and measure the productivity growth in different periods. Different from the traditional DEA model, Malmquist index can analyze the efficiency changes of decision-making units in different periods. The calculated index can be used as total factor productivity, which can be used to indicate the overall efficiency changes in the two periods before and after.

This paper uses Malmquist index to evaluate the effectiveness of coordinated development between investment and industrial optimization in Beijing, and the productivity growth is divided into technological progress, technical efficiency, scale efficiency and pure technical efficiency. Among them, technical efficiency is the product of scale efficiency and pure technical efficiency. Under the condition of increasing returns to scale, and from the perspective of output maximization, a nonparametric measurement model of total efficiency of medical insurance fund expenditure is established. In this model, 1 is used as the benchmark to judge whether the production efficiency will increase or decrease. If the Malmquist index is greater than 1, the production efficiency will be improved; If the Malmquist index is less than 1, it means that the production efficiency decreases; If the Malmquist index is equal to 1, it means that the production efficiency is unchanged. Taking t period as the base period, the output-oriented Malmquist index measurement model is:

$$M_t(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D_C^t(x^{t+1}, y^{t+1})}{D_C^t(x^t, y^t)} \tag{1}$$

$$M_{t+1}(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D_C^{t+1}(x^{t+1}, y^{t+1})}{D_C^{t+1}(x^t, y^t)} \tag{2}$$

Consider that the Malmquist productivity indices defined based on the t and t+1 reference techniques are symmetric in an economic sense. Based on the idea of ideal indices, their geometric mean can be defined as a composite productivity index.

$$(x^t, y^t, x^{t+1}, y^{t+1}) = (M_t M_{t+1})^{\frac{1}{2}} = [\left(\frac{D_C^t(x^{t+1}, y^{t+1})}{D_C^t(x^t, y^t)}\right) \times \left(\frac{D_C^{t+1}(x^{t+1}, y^{t+1})}{D_C^{t+1}(x^t, y^t)}\right)]^{\frac{1}{2}} \tag{3}$$

The productivity index can be divided into four parts: technical efficiency (EFFCH) and technical progress (TECHCH), scale efficiency (SECH) and pure technical efficiency (PECH), and technical efficiency consists of scale efficiency and pure technical efficiency:

$$M(x^t, y^t, x^{t+1}, y^{t+1}) = EFFCH \times TECHCH = \frac{D_C^{t+1}(x^{t+1}, y^{t+1})}{D_C^t(x^t, y^t)} \left[\left(\frac{D_C^t(x^{t+1}, y^{t+1})}{D_C^t(x^t, y^t)}\right) \times \left(\frac{D_C^{t+1}(x^{t+1}, y^{t+1})}{D_C^{t+1}(x^t, y^t)}\right)\right]^{1/2} \tag{4}$$

$$SECH = \left[\frac{D_{vrs}^{t+1}(x^{t+1}, y^{t+1})/D_{crs}^{t+1}(x^{t+1}, y^{t+1})}{D_{vrs}^{t+1}(x^t, y^t)/D_{crs}^{t+1}(x^t, y^t)} \times \frac{D_{vrs}^t(x^{t+1}, y^{t+1})/D_{crs}^t(x^{t+1}, y^{t+1})}{D_{vrs}^t(x^t, y^t)/D_{crs}^t(x^t, y^t)}\right]^{1/2} \tag{5}$$

$$PECH = \frac{D_{vrs}^{t+1}(x^{t+1}, y^{t+1})}{D_{crs}^t(x^t, y^t)} \tag{6}$$

## 2.2. Variable Selection

Based on Malmquist model, this paper takes Beijing as a sample to calculate the expenditure efficiency of ecological and industrial optimization under the environment and financial expenditure from 2010 to 2020. The data of this paper come from Beijing Regional Statistical Yearbook, China Regional Statistical Yearbook, China County Statistical Yearbook and CEADs (China Carbon Accounting Database), and the missing data of some variables are filled by proportional smoothing.

Based on the feasibility and measurability, this paper selects the optimization of industrial structure (Indup) and the rate of trees (Forest) as the output indicators. General industrial optimization can be divided into two concepts: industrial rationalization and industrial upgrading. In recent years, industrial ecologicalization has also become one of the important orientations of industrial optimization. However, it must be clear that the concept of industrial optimization is different in different regions. Beijing's current industrial policy orientation is mainly high-tech industries, and the concept of industrial optimization is more inclined to industrial upgrading. Combined with the above description, this paper uses Gan Chunhui [11] and other treatment methods for reference, and measures the degree of industrial structure optimization by comparing the output value of the tertiary industry with the added value of the secondary industry. Rate of forest greening is an important variable to describe urban greening ecology, which is used to represent the comprehensive situation of urban ecology in this paper. The input-output indicators of this paper refer to the research of Wang [12] and Ren Yufei [13] respectively, environmental support (Enviro), government intervention (Gov), physical capital (Cap) and carbon emission ($CO_2$) are selected as the main input indicators. Among these indicators, environmental support is the proportion of environmental expenditure in fiscal expenditure, which reflects the government's centralized governance investment in the environmental field; Government intervention is the proportion of fiscal expenditure to GDP, which reflects the government's macro-control of the economic system in a comprehensive field; Physical capital is the proportion of fixed capital to GDP, which reflects the activity of various social productive investments; Carbon emissions can be divided into natural emissions and artificial emissions. Artificial emissions are carbon emissions caused by human activities, mainly including fossil fuel consumption, biomass combustion, etc. In this paper, carbon emissions from industrial industries are mainly used as input indicators. Descriptive statistics of each variable are shown in the Table 1.

Table 1: Indicators and Descriptive Statistics

| | Variable | Variable Explanation | Min | Max | Avg | S.D. |
|---|---|---|---|---|---|---|
| Input Variables | Enviro | Environmental expenditure/Financial expenditure | 0.001 | 0.18 | 0.03 | 0.027 |
| | Gov | Fiscal expenditure /GDP | 0.048 | 0.948 | 0.27 | 0.193 |
| | Cap | Fixed investment /GDP | 0.038 | 2.18 | 0.619 | 0.396 |
| | CO2 | *CO2* emissions (million tons) | 0.564 | 16.413 | 4.445 | 3.387 |
| Output Variables | Forest | *Forest* area *proportion* | 0.107 | 0.850 | 0.470 | 0.207 |
| | Indup | Added value of tertiary industry /Added value of secondary industry | 0.365 | 39.486 | 3.886 | 5.831 |

## 3. Analysis of Empirical Results

### 3.1. Time Dimension

Use DEAP 2.1 software to calculate the efficiency of ecological and industrial optimization in Beijing from 2010 to 2020 based on Malmquist model. Then make a chart according to the data. Figure 1 shows the fluctuation trend of Malmquist index and its components in Beijing from 2010 to 2020, and Table 2 shows the change values of Malmquist index and its components in each year. Since 2010 is the first year, data changes will be counted from 2011.Variable Description. The result is shown in Table 2.

Table 2: Efficiency and Composition Changes of Ecological and Industrial Optimization

| Age | Technical Efficiency | Technical Progress | Pure Technical Efficiency | Scale Efficiency | Total factor productivity |
|---|---|---|---|---|---|
| 2011-2012 | 0.972 | 1.068 | 0.977 | 0.994 | 1.038 |
| 2012-2013 | 0.995 | 3.308 | 1.005 | 0.991 | 3.293 |
| 2013-2014 | 1.019 | 0.291 | 1.000 | 1.019 | 0.296 |
| 2014-2015 | 0.939 | 1.278 | 0.950 | 0.988 | 1.200 |
| 2015-2016 | 1.035 | 0.511 | 1.027 | 1.007 | 0.528 |
| 2016-2017 | 1.037 | 1.559 | 1.038 | 0.998 | 1.616 |
| 2017-2018 | 1.015 | 1.311 | 1.005 | 1.010 | 1.331 |
| 2018-2019 | 0.871 | 1.144 | 0.925 | 0.941 | 0.996 |
| 2019-2020 | 0.964 | 0.536 | 1.071 | 0.900 | 0.517 |
| mean | 0.982 | 0.981 | 0.999 | 0.983 | 0.963 |

This paper analyzes the change values of total factor productivity of ecological and industrial optimization expenditures. The study finds that its overall change characteristics show a sharp upward or downward trend. His fluctuations show the characteristics of growth, decline and then rebound. The main trends of change coincide with the trends of change in technological progress. Analyzed in terms of its value, the overall efficiency of ecological and industrial optimization expenditures rose from 1.038 to a maximum value of 3.293 between 2011 and 2013. it fell sharply to a minimum value of 0.296 in 2014 and recovered to 1.200 the following year. since then, the Malmquist index has fluctuated in the range of 0.5 to 1.5. During this period, the overall spending efficiency for 2016-2018 was greater than 1 and was in the spending efficient period. Overall, the spending efficient period accounts for the time.

From Figure 1, technological progress is the main factor that causes overall efficiency reduction, and pure technical efficiency is the main factor that affects overall efficiency improvement. Observed from its values, the technological progress was mainly less than 1 in 2013-2014, 2015-2016 and 2019-2020, with values of 0.291, 0.511 and 0.536 respectively. In other time ranges, the efficiency of technological progress remained at a high level for a long time; In the whole research period, the pure technical efficiency has been greater than 1 for a long time. The efficiency decreases slightly in the three time periods 2011-2012, 2014-2015 and 2018-2019, but the overall efficiency stays in the range of 0.9-1. The fluctuation of scale efficiency is similar to pure technical efficiency, but its inefficiency lasts longer. It is greater than 1 in 2013-2014, 2015-2016 and 2017-2018, with values of 1.019, 1.007 and 1.01. In this case, technical efficiency is greater than 1 in 2013-2014 and 2015-2018, influenced by scale efficiency. From the perspective of the distribution of changes, the range of fluctuations of scale efficiency and pure technical efficiency is relatively small, and the overall scale efficiency is above the level value of 1. However, the pure technical efficiency, which represents the overall level of resource allocation, and the scale efficiency, which represents the effectiveness of expenditure, change very closely, and their ranges of change are quite stable. Since technical efficiency is the product of pure technical efficiency and scale efficiency. Combining the images, it can be assumed that the main factor of technical efficiency changes comes from the influence of scale efficiency. The range of fluctuations of technical progress is quite large. However, it tends to fluctuate sharply and decline. This makes the fluctuation of the overall scale efficiency, i.e. total factor productivity level, completely influenced by the efficiency of technical progress. At the same time, whenever there is a significant increase in the efficiency of technological progress, there is bound to be a sharp decline followed by a sharp correction. This is quite significant in all three phases: 2012-2013, 2014-2015 and 2016-2017, which becomes the focus of this paper.

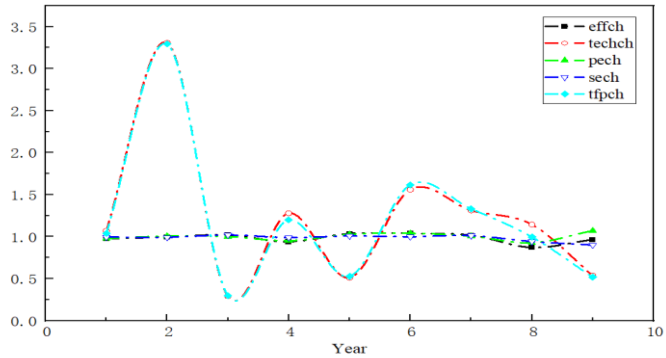


Figure 1: Fluctuation chart of expenditure efficiency index of ecological and industrial optimization from 2010 to 2020

In deeper analysis, excluding the years when the overall efficiency is abnormal due to technological progress, the overall efficiency remains valid most of the time. Even the overall efficiency from 2019 to 2020 is 0.996, which is quite close to 1. This also proves that despite the effect of a small amount of technological regression, the expenditure efficiency is generally high in most years. The impact of technological progress on the optimization of the industrial structure and the coordinated development of the urban ecology is in the effective category in these years. At the level of resource allocation, pure technical efficiency has maintained a high and stable level. This proves that policies have played a clear role in fully mobilizing various resources and optimizing the original allocation structure throughout the coordinated development process. The coordination of policies is good, and the authorities have a high ability to control, transfer and allocate resources. However, its grasp of the scale of expenditure is not accurate enough, and the scale effect has not been effectively brought into play. This leads to the contradiction that the scale of expenditure cannot meet the needs of industrial structure and urban ecological optimization.

This deviation of expenditure scale is not the most important factor, but the most important factor is still technological progress. In fact, the fluctuation of overall efficiency and technological progress can naturally be linked with the technological cycle, and the cyclical change of technology will greatly affect the utilization efficiency of technology. Especially in the transition period of technological change, the new technology is not yet mature and popular, while the old technology is facing elimination, and this change in technical efficiency will be quite drastic. From the "Window of the Capital" in Beijing, with environmental protection technology as the key word, we can find that there are 24 policy documents related to environmental protection technology in 2011, the highest total number of policies between 2010 and 2022, and several times the total number of policies in many years. If the impact of policy delay and technology replacement is taken into account, the impact of this technological progress should reach a peak in 2012, which is the same as the research fact. In 2012, the overall expenditure efficiency reached a peak of 3.293. Since then, the number of corresponding policy documents has been kept between 2 and 6. If the lag effect of one to two years of policies is taken into account, it can be judged that the policy documents of environmental protection technology adjustment will obviously affect the expenditure efficiency of technological progress on industrial and ecological optimization. Moreover, from this sample period, in the past ten years, technology has experienced three consecutive changes, and the characteristics of the change have changed from a large change range and a short change time in the early stage to a small change range and a long change time. This phenomenon is consistent with the rapid technological change in the early stage and the fact that technological breakthroughs have entered the bottleneck area in recent years. It is foreseeable that the change of environmental protection technology will become more and more stable in the future, and the expenditure efficiency for industrial and ecological optimization will also maintain a long-term effective and stable situation.

### 3.2. Spatial Dimension

The Malmquist index and its composition decomposition changes of 16 districts in Beijing are measured from the spatial dimension, as shown in Table 3.

From the overall efficiency analysis, 10 districts have an expenditure efficiency less than 1 and 6 districts have an overall expenditure efficiency greater than 1. The districts with relatively high expenditure efficiency are mainly peripheral cities, including Yanqing District, Shunyi District, Pinggu District, and Tongzhou District. Only Xicheng District and Shijingshan District in the central city have higher overall expenditure efficiency. As a whole, central cities have lower spending efficiency, including Dongcheng District, Chaoyang District, and Haidian District. However, there are also peripheral cities with lower spending efficiency, such as Fangshan District and Huairou District. Thus, it can be seen that the reasons for the efficiency of industrial and urban eco-optimization expenditures in different regions are complex and difficult to be simply generalized to a single cause. The differences in location, economic scale and population of each region can only be partly, but not decisively, responsible for the expenditure efficiency.

From the perspective of overall decomposition efficiency, the average value of technological progress is 0.981, which is the lowest value among all decomposition efficiencies, and the technological progress efficiency of all urban areas with overall expenditure efficiency lower than 1 is in an invalid range. The same situation also appears in the efficiency value analysis of technical efficiency. All the urban areas with overall expenditure efficiency lower than 1 have invalid technical efficiency. However, in terms of technical efficiency, the pure technical efficiency of almost all urban areas maintains an effective range, which is closely related to Beijing's efficient policy management and resource allocation mechanism. It is mainly affected by scale efficiency. It can be said that, with the exception of Changping District, in areas where the overall efficiency is below 1, scale efficiency determines the scope of technical efficiency, and technical efficiency interacts with technological progress. Ultimately this leads to a state of relative ineffectiveness of policy expenditure efficiency on industrial optimization and urban ecology. This is actually consistent with the analysis results of the time dimension and is more in line with the actual situation.Therefore, the problems of ineffective industrial optimization and urban ecological expenditure in most urban areas are similar, such as inaccurate control of technology cycle and inappropriate control of expenditure scale.

Table 3: Malmquist index and its composition decomposition changes in various districts

| Province | Technical Efficiency | Technical Progress | Pure Technical Efficiency | Scale Efficiency | Total factor productivity |
|---|---|---|---|---|---|
| Changping | 1.017 | 0.794 | 1.003 | 1.013 | 0.807 |
| Chaoyang | 0.991 | 0.851 | 0.993 | 0.998 | 0.844 |
| Daxing | 0.993 | 0.871 | 0.998 | 0.995 | 0.865 |
| Dongcheng | 0.998 | 0.901 | 1.000 | 0.998 | 0.899 |
| Fangshan | 0.967 | 0.884 | 1.000 | 0.967 | 0.854 |
| Fengtai | 0.913 | 0.891 | 0.997 | 0.917 | 0.814 |
| Haidian | 0.930 | 0.855 | 1.000 | 0.930 | 0.796 |
| Huairou | 0.929 | 0.902 | 0.993 | 0.936 | 0.838 |
| Mentougou | 0.976 | 0.910 | 1.000 | 0.975 | 0.887 |
| Miyun | 0.996 | 0.931 | 1.000 | 0.996 | 0.927 |
| Pingu | 1.000 | 1.013 | 1.000 | 1.000 | 1.013 |
| Shijingshan | 1.000 | 1.032 | 1.000 | 1.000 | 1.032 |
| Shunyi | 1.000 | 1.099 | 1.000 | 1.000 | 1.099 |
| Tongzhou | 1.000 | 1.296 | 1.000 | 1.000 | 1.296 |
| Xicheng | 1.003 | 1.316 | 1.000 | 1.003 | 1.320 |
| Yanqing | 1.000 | 1.380 | 1.000 | 1.000 | 1.380 |
| mean | 0.982 | 0.981 | 0.999 | 0.983 | 0.963 |

## 4. Conclusions and Recommendations

### 4.1. Conclusions

Based on the DEA-Malmquist model, this paper calculates the expenditure efficiency of industrial and urban eco-optimization in Beijing from 2010 to 2020, and analyzes the overall efficiency and the decomposed efficiency changes. The conclusions are as follows. First, the overall expenditure efficiency shows a trend of big ups and downs. The regions with higher expenditure efficiency levels are mainly peripheral cities, while the central cities generally have lower expenditure efficiency levels, and the causes of expenditure efficiency problems in different regions are complex. Second, technological progress and economies of scale are the main factors causing the overall efficiency decline, while pure technical efficiency is the main factor affecting the overall efficiency improvement. They are also the key to promote the efficiency improvement of industrial structure and urban ecological optimization of expenditure. Thirdly, the changes in the efficiency of technological progress are related to the cyclical changes of technology. And the characteristics of changes have changed from large changes and short changes in the early period to small changes and long changes.

## 4.2. Recommendations

Based on the above research conclusions, this paper puts forward the following policy suggestions:

(1) Pay attention to the different development conditions and environment of each district, and improve the overall efficiency of policy guidance on industrial structure optimization and urban ecological construction. Due to the great differences in location, economic scale and population of each district, the corresponding urban ecological construction process and the different progress of industrial structure adjustment, the guiding work at the policy expenditure level of each district must be adapted to local conditions. For marginal urban areas with relatively high expenditure efficiency, it is necessary to keep the policy stable and make appropriate adjustments; The central city with low expenditure efficiency should grasp the time and cost of environmental protection technology update and change, and stabilize the corresponding expenditure efficiency.

(2) Effectively control the overall scale of expenditure and promote the process of coordinated development of industrial structure optimization and urban ecological development. From the time and space dimensions, it can be clearly found that, whether from the perspective of Beijing as a whole or from the perspective of various districts, the mismatch of expenditure scale leads to the fact that the efficiency of resource expenditure under the guidance of policies can't meet the needs of industrial structure and urban ecological optimization, and the overall level of expenditure efficiency in the central city is low. This reflects that the current scale is likely to exceed the corresponding demand, resulting in a certain distortion of internal resource allocation, which occupies the space for some resources to give full play to their effectiveness. Therefore, it is necessary to control the overall scale of expenditure more effectively.

(3) Grasp the cyclical law of technology, and use technology to promote industrial optimization and coordinated development of urban ecology. In the analysis of various efficiency changes, technological progress has always been one of the most important factors affecting the overall expenditure efficiency. The periodicity of technology indicates that in the transition period of technology, the new technology is not yet mature and popular, while the old technology is facing elimination, so the change of technical efficiency will be quite drastic. Therefore, if we want to ensure that policies can effectively promote the coordinated and stable development of industrial structure and ecology, we must carefully study and control the cyclical development and changes of related technologies.


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