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The policy efficiency evaluation of the Beijing–Tianjin–Hebei regional government guidance fund based on the entropy method

Jing Cui¹, Qiaoqiao Liang¹, Xianan Yin^{1†}, Jun Zhang², Hongyan Yan¹¹Management College, Beijing Union University, Beijing 100101, China²Business School, Beijing Wuzi University, Beijing 101149, China

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Abstract

With China's strong support for innovation and development, the policies of government guidance funds are an important driving force for leading innovation and economic transformation, and the effect of its related policies is of great significance. This paper selects 518 policies related to government guidance funds in the Beijing–Tianjin–Hebei region from 2005 to 2018 as the research object and constructs a policy efficiency evaluation indicator system from three dimensions of policy intensity, policy objectives and measures. The analytic hierarchy process (AHP) and entropy method are used to weight the output level of policy innovation performance and economic performance of government guidance funds, and grey relational analysis (GRA) is used to measure the relationship between policies of government guidance funds and innovation performance and economic performance, and corresponding policy recommendations based on the research results. The results of the research show that the policy efficiency of the government guidance funds in Tianjin and Hebei is relatively high, and the policy efficiency of the Beijing government guidance funds needs to be improved. In general, the policy efficiency of the government guidance funds needs to be further improved.

Keywords: policies of government guidance funds, analytic hierarchy process, entropy method, grey relational analysis.**AMS 2010 codes:** 16W60, 16W80

1 Introduction

As the 19th National Congress of the Communist Party of China proposed to implement the innovation-driven development strategy and accelerate the construction of an innovation-originated nation, the demand for innovation and development is also increasing. As one of the main means to promote innovative development and economic construction, government guidance funds can fill up the gap in the equity capital of innovative enterprises by cultivating and promoting the development of private equity markets [1]. It is an important force

[†]Corresponding author.Email address: 190824314@qq.com

to promote regional innovation development and industrial upgrading and can help promote the coordinated development of Beijing–Tianjin–Hebei. Beijing–Tianjin–Hebei, as the first region in China to launch government guidance funds, is in a leading position in the establishment and management of government guidance funds. The number of government guidance funds in the region has grown rapidly, the areas have been continuously expanded, and the operation model has become more and more perfect. Therefore, it is essential to give full play to the policy effect of the policies of government guidance funds for promoting the coordinated development of the Beijing–Tianjin–Hebei region and achieving the goal of ‘mass entrepreneurship and innovation’.

Since 2002, China’s policies of government guidance funds have gone through several important stages of initial exploration, progressive development, massive upsurge and steady development. As of October 26, 2020, the number of government guidance funds established in various places has exceeded 2000, and the amount of funds in place has reached nearly 4.3 trillion yuan. The development of government guidance funds is inseparable from the support of relevant policies. Governments at all levels have introduced many policies and measures related to promoting the development of government guidance funds, standardising the management of government guidance funds and strengthening the performance evaluation of government guidance funds. Driven by policies, all localities actively set up government guidance funds, but the lack of necessary investment management and performance evaluation after the establishment of government guidance funds makes the role of government guidance funds not been effectively realised.

As the capital’s economic circle, Beijing–Tianjin–Hebei’s unique economic development model contributes to the regional commercial economy and technological innovation and is an important part of promoting the innovation and development of Beijing–Tianjin–Hebei. The Beijing–Tianjin–Hebei region has always attached importance to the development of government guidance funds and has issued >500 related policies, hoping to give play to the guiding role of government guidance funds, attract more social capital and promote industrial upgrading and innovative development. Based on this, this paper selects the policies of government guidance funds in Beijing, Tianjin and Hebei as the research object and analyses in-depth whether the policies of government guidance funds have fully played their due role to promote the innovation and development of the region. Has the Beijing–Tianjin–Hebei achieved coordinated economic development brought about by the economic circle? At the same time, to understand the operating efficiency of the policies of government guidance funds in Beijing, Tianjin and Hebei, this paper combines the analytic hierarchy process (AHP) and entropy method to effectively quantify the content of the policies of government guidance funds and uses grey relational analysis (GRA) to measure the policy efficiency of the government guidance funds in the Beijing–Tianjin–Hebei region, the specific policy efficiency of the government guide funds in Beijing–Tianjin–Hebei in terms of policy intensity, goals and measures, as well as comprehensive policy output was obtained. Based on researching and learning from the theory and performance evaluation of foreign government guidance funds to promote innovation and development, it provides some theoretical references for improving the policy efficiency of government guidance funds.

2 Literature Review

Scholars at home and abroad have a relatively unified understanding of the issue that government guidance funds promote enterprise innovation and development. By studying the researches on government guidance funds, Yang Dakai and Li Dandan (2012) found that government guidance funds could solve the problem of market failure caused by information asymmetry to a certain extent, thereby promoting enterprise innovation and economic development [2]. Huang Song, Ni Xuanming et al. (2020) analysed the investment situation of technology-based start-ups through venture capital funds and verified the role of government guidance funds in promoting the level of technological innovation of enterprises [3]. Wang Han, Liu Huixia et al. (2018) also confirmed the positive impact of government guidance funds on corporate innovation [4]. The guidance effects of different provinces’ guidance funds are different. Yang Minli et al. (2014) empirically tested the guidance effects of government guidance funds through inter-provincial big data samples and found that the guidance

effects of government guidance funds are different among provinces with different innovation maturity levels [5]. The guiding role of government guidance funds also has certain limitations. Shi Guoping (2016) concludes that the guiding role of policies of government guidance funds is limited to some venture capital institutions with a difference-in-differences model [6]. Some scholars have also paid attention to the industry differences in the promotion of government guidance funds. Terttu Luukkonen et al. (2013) compared the performance of European government funds in the post-investment development and value-added activities of global and independent venture capital firms and found that the government guidance funds played a less important role in promoting important industries than other industries [7].

To show the implementation effect of fund policies more intuitively, scholars have constructed a fund performance evaluation system from different perspectives, which have promoted the development of performance evaluation for fund policy. However, Jiang Wei (2009) took the weighted internal rate of return as the dependent variable to construct a regression model to evaluate the performance of policies and verify the hypothesis of the relationship between government venture capital and related factors [8]. Li Hongjiang and Bao Xiaoyan (2011) theoretically constructed a performance evaluation system from the perspective of policy effects and provided a new perspective for the research of subsequent performance evaluation [9]. Zhu Jie and Chen Langnan (2013) evaluated the average system risk level of the funds according to the system risk of each period by constructing an SSM model that reflects the changes of dynamic indicators [10]. Gu Jing et al. (2015) investigated the performance of government guidance funds based on the intuitionistic fuzzy analytic hierarchy process (IFAHP) based on comprehensively inspecting the three effects of government guidance funds [11]. Zhou Bowen and Zhang Zaisheng (2017) constructed a policy evaluation system for mass entrepreneurship from both comprehensive efficiency and scale returns by using data envelopment analysis (DEA) [12].

In summary, scholars have done a lot of research on the promotion and guidance role of government guidance funds and performance evaluation, but there are still a few researches on the policy efficiency of government guidance funds. Based on this, this paper collects the relevant policies of government guidance funds in the Beijing–Tianjin–Hebei region from 2005 to 2018 and quantifies them from the three aspects of policy intensity, objectives and measures so as to fully display the content of their policies by means of data. After the research and analysis of the efficiency of its input and output, suggestions and countermeasures for improvement are put forward based on the research results.

3 Quantitative analysis on the policies of government guidance funds in Beijing–Tianjin–Hebei

3.1 Retrieval of policy text

In this paper, we mainly searched the keyword of ‘government guidance funds’ on the China Laws & Regulations Database and pkulaw.cn and collected policies related to government guidance funds issued by various government departments in Beijing, Tianjin and Hebei Province from 2005 to 2018. After excluding irrelevant policies, 518 policies of government guidance funds were finally included in the sample, including 137 policies in Beijing, 56 in Tianjin and 325 in Hebei Province.

3.2 Quantitative analysis of the policy text of the government guidance funds in Beijing–Tianjin–Hebei

This paper uses ‘Government Guidance Funds’ as the search term for the full text of laws and regulations, and collects and sorts out the policies of government guidance funds issued by multiple government agencies in the Beijing–Tianjin–Hebei region from 2005 to 2018 in the Chinese Law Search System (pkulaw.cn). After necessary screening and elimination, 518 policies of government guidance funds were finally included in the research sample, including 137 in Beijing, 56 in Tianjin and 325 in Hebei Province.

The quantitative results of the policies of government guidance funds in the three regions of Beijing, Tianjin and Hebei from 2005 to 2018 are shown in Table 1. From its data, it can be seen that the quantitative values of the policies of government guidance funds in the three regions of Beijing, Tianjin and Hebei are showing an overall

upward trend, indicating that the effectiveness of policies is gradually strengthened over time. According to the results of policy quantification among the three regions, the policy level of Hebei Province is higher, followed by Beijing City and Tianjin City.

Table 1 Quantitative results of the policies of government guidance funds

Region	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Beijing	0	14	26	26	88	33	132	184	42	40	167	260	205	1372
Tianjin	0	13	0	91	47	41	37	46	31	0	84	81	278	102
Hebei	12	12	16	33	179	121	167	149	128	99	702	1221	981	774
	12	39	42	150	314	195	336	379	201	139	953	1562	1464	1031

Fig. 1 The quantitative results of the policies of government guidance funds

4 Quantitative method for evaluation of policies of government guidance funds in Beijing–Tianjin–Hebei

4.1 Standards for quantitative evaluation of policy text of government guidance funds

As the main manifestation of government guidance funds, policies are generally displayed in verbal form. However, since words cannot be directly substituted into formulas and models for calculation, we need to process the policies as data. The specific methods for the quantification of policies of government guidance funds mainly refer to a set of policy quantification standards formulated by Peng Jisheng et al. (2008) in the process of quantifying and quantitatively analysing the national technology innovation policies in the past 30 years [13]. This paper draws on the manual to numerically process the policies of government guidance funds in Beijing, Tianjin and Hebei. Besides, to make the policy content can be fully displayed by the data, this article scores each policy in terms of policy intensity, policy objectives and measures. Among them, according to the characteristics of the policy content of the government guidance funds, this paper has formulated 12 secondary indicators in three aspects: intensity, objectives and measures to score the policy in an all-round way. The detailed policy scoring standards are shown in Table 2.

Table 2: Quantitative Standard Table of Policies

First-level indicator	Second-level indicator	Score	Evaluation criteria
Policy intensity		5	Rules, bylaws, regulations
	Policy intensity	4	Reconsideration, approval, measures, interim regulations

		3	Notices, resolutions, notifications, announcements
		2	Rules, guidelines, plans, measures, opinions
		1	Plans, outlines
Policy objectives	Industrial development and transformation	5	'Must', 'Forbidden', 'Strictly Follow', 'Strictly Enforce' and other strongest and most detailed descriptions
		4	'No less than/exceeding', 'strict use' and other strong words
		3	Strong words such as 'full use', 'fully mobilise' and 'maximum use', etc.
		2	'Under the premise of...', it is also possible', 'perfect', 'sound', 'support' and other general descriptions
		1	General descriptions such as 'may be based on', 'enhance' and 'increase'
	Transformation of scientific and technological achievements	5	'Must', 'Forbidden', 'Strictly Follow', 'Strictly Enforce' and other strongest and most detailed descriptions
		4	'No less than/exceeding', 'strict use' and other strong words
		3	Strong words such as 'full use', 'fully mobilise' and 'maximum use', etc.
		2	'Under the premise of...', it is also possible', 'perfect', 'sound', 'support' and other general descriptions
		1	General descriptions such as 'may be based on', 'enhanced' and 'increase'
	Technological innovation	5	'Must', 'Forbidden', 'Strictly Follow', 'Strictly Enforce' and other strongest and most detailed descriptions
		4	'No less than/exceeding', 'strict use' and other strong words
		3	Strong words such as 'full use', 'fully mobilise' and 'maximum use', etc.
		2	'Under the premise of...', it is also possible', 'perfect', 'sound', 'support' and other general descriptions
		1	General descriptions such as 'may be based on', 'enhanced' and 'increase'
	Financial Innovation	5	'Must', 'Forbidden', 'Strictly Follow', 'Strictly Enforce' and other strongest and most detailed descriptions
		4	'No less than/exceeding', 'strict use' and other strong words
		3	Strong words such as 'full use', 'fully mobilise' and 'maximum use', etc.
		2	'Under the premise of...', it is also possible', 'perfect', 'sound', 'support' and other general descriptions
		1	General descriptions such as 'may be based on', 'enhanced' and 'increase'

National economic and social development	5	'Must', 'Forbidden', 'Strictly Follow', 'Strictly Enforce' and other strongest and most detailed descriptions
	4	'No less than/exceeding', 'strict use' and other strong words
	3	Strong words such as 'full use', 'fully mobilise' and 'maximum use', etc.
	2	'Under the premise of...', it is also possible', 'perfect', 'sound', 'support' and other general descriptions
	1	General descriptions such as 'may be based on', 'enhanced' and 'increase'
Real economy development	5	'Must', 'Forbidden', 'Strictly Follow', 'Strictly Enforce' and other strongest and most detailed descriptions
	4	'No less than/exceeding', 'strict use' and other strong words
	3	Strong words such as 'full use', 'fully mobilise' and 'maximum use', etc.
	2	'Under the premise of...', it is also possible', 'perfect', 'sound', 'support' and other general descriptions
	1	General descriptions such as 'may be based on', 'enhanced' and 'increase'
Administrative measures	5	List specific measures, implement strict implementation and control standards for each item and give specific and detailed explanations
	4	List specific measures, write strict implementation standards for each item and give instructions
	3	List more specific measures and briefly explain
	2	List basic measures without explanation
	1	Only talk about relevant content from a macro perspective, without specific measures
Policy measures	5	List specific measures, implement strict implementation and control standards for each item and give specific and detailed explanations
	4	List specific measures, write strict implementation standards for each item and give instructions
	3	List more specific measures and briefly explain
	2	List basic measures without explanation
	1	Only talk about relevant content from a macro perspective, without specific measures
Fiscal and taxation measures	5	List specific measures, implement strict implementation and control standards for each item and give specific and detailed explanations
	4	List specific measures, write strict implementation standards for each item and give instructions
	3	List more specific measures and briefly explain
	2	List basic measures without explanation
	1	Only talk about relevant content from a macro perspective, without specific measures

Personnel measures	5	List specific measures, implement strict implementation and control standards for each item and give specific and detailed explanations
	4	List specific measures, write strict implementation standards for each item and give instructions
	3	List more specific measures and briefly explain
	2	List basic measures without explanation
	1	Only talk about relevant content from a macro perspective, without specific measures
Financial service measures	5	List specific measures, implement strict implementation and control standards for each item and give specific and detailed explanations
	4	List specific measures, write strict implementation standards for each item and give instructions
	3	List more specific measures and briefly explain
	2	List basic measures without explanation
	1	Only talk about relevant content from a macro perspective, without specific measures

The scoring standards established in Table 2 mainly quantify policies in a comprehensive manner from the three aspects of policy intensity, objectives and measures. The intensity is mainly based on the effectiveness of the level of documentation; the scoring standard for objectives is mainly based on the level of detail of the goal description in the policy and the degree of the tone; the measures are mainly scored from 0 to 5 based on the detailed level of the measures mentioned in the policy so as to determine the final score of a single policy. Finally, the final score of a single-year policy is added to the final quantitative value of all policies in the corresponding year, and the specific calculation is as follows:

$$EAM_{pt} = \sum_{i=1}^n (m_i + a_i) e_i$$

In the formula, p is the province where the scoring policy was published; t refers to the published time of the scoring policy, i refers to the i -th policy promulgated in the p -th province in year t ; stands for the total score of the i -th policy measure (measure) and the policy objective (aim); refers to the score of the policy intensity of the i -th policy; and refers to the overall status of the policy contents, objectives and measures of the government Guidance funds for the year t in the P province.

4.2 Comprehensive evaluation and analysis of the policy output of government guidance funds

This paper establishes an output indicator system in terms of innovation performance and economic performance. First, the first-level indicators are weighted by the AHP method, and then the second-level indicators are weighted by the entropy method. Finally, the policy output of government guidance funds in the Beijing–Tianjin–Hebei region was evaluated comprehensively.

4.2.1 Policy output evaluation indicator system of government guidance funds

Innovation output refers to the input and output results of policies of government guidance funds, which are mainly manifested in two aspects: one is the enhancement of enterprise innovation; the other is the hoisting of economic development. The enhancement of enterprise innovation is mainly manifested in the number of applications for invention technology, the number of authorisations and the turnover of the technology market; and the economic performance is mainly reflected in the promotion of social and economic development.

Among them, the number of applications for regional invention patents and the turnover of the technology market are selected as secondary indicators of innovation performance; the GDP and GDP per capita are selected as economic performance indicators to carry out an evaluation on innovation and economic performance of policies of government guidance funds.

Table 3 Comprehensive Evaluation Index System of Policy Output of Government Guidance Funds

Indicators	First-level indicators	Second-level indicators
Output efficiency	Innovation performance	Number of domestic invention patent applications
		Turnover of the technology market
	Economic performance	GDP GDP per capita

4.2.2 Evaluation indicator weighting

In the indicator weighting, to avoid incomplete results caused by strong subjectivity or objectivity, this paper draws on relevant research methods to fully balance the subjective and objective weighting when constructing the evaluation indicator system.

The specific steps of the combination weighting method to determine the indicator weight are as follows:

(1) Perform AHP subjective weighting for each indicator of the first level and get the weight of the first-level indicator.

(2) Use entropy method to weight the secondary indicators:

Since the measurement units of the various indicators are not uniform, before using them to obtain a comprehensive evaluation, the data needs to be dimensionless first, and then the indicators are weighted. To obtain a more objective weight, the objective weight of the indicator is calculated by the entropy method. The calculation principle of the entropy method is as follows:

1) Since the measurement unit of each indicator is not uniform, it is impossible to directly compare and calculate; so before calculating the weight of each indicator, each data needs to be standardised. According to the needs of the research content, this paper constructs a positive secondary indicator, and the larger the value, the better the factor reflected by this indicator. The standardised formula is:

$$x'_{ij} = \frac{x_{ij} - \min\{x_{1j}, \dots, x_{nj}\}}{\max\{x_{1j}, \dots, x_{nj}\} - \min\{x_{1j}, \dots, x_{nj}\}}$$

2) After some indicator values are standardised, there may be small or negative values. To eliminate the influence of negative values and zeros, this paper performs translation processing on the standardised data:

$$x''_{ij} = H + x'_{ij}$$

Among them, H refers to the magnitude of the indicator shift, generally taken as 1.

3) This paper uses the proportion method to process the data and obtain the ratio of the i -th data in the j -th indicator to the total of this indicator:

$$P_{ij} = \frac{x''_{ij}}{\sum_{i=1}^n x_{ij}}$$

Table 4 Policy Output Indicator System and Weight of Government Guidance Funds

Target level	First-level indicator	Weight	Second-level indicator	Weight	Director
Policy output	Innovation performance	0.667	Turnover of technology market	0.788	+
			Number of domestic invention patent applications	0.212	+
	Economic performance	0.333	GDP	0.539	+
			GDP per capita	0.461	+

4) Calculate the entropy value of the j -th indicator:

$$e_j = -\frac{1}{\ln(n)} \sum_{i=1}^n P_{ij} \ln(P_{ij})$$

5) Calculate the information redundancy of information entropy:

$$g_j = 1 - e_j$$

6) Finally, we get the weight of each secondary indicator:

$$\beta_j = \frac{g_j}{\sum_{j=1}^n g_j}$$

wherein $j = 1, 2, \dots$ and $s, j = 1, 2, \dots, s$

The final weight results are shown in Table 4 with the entropy method.

5 Evaluation and analysis of the efficiency of the policies of government guidance funds in Beijing–Tianjin–Hebei

5.1 Principles of policy input and output analysis of government guidance funds based on GRA

This paper adopts the GRA to analyse the relationship between the input and output of the policies of government guidance funds, chooses the final quantitative value of the policies in Beijing, Tianjin and Hebei Province as the reference sequence and the secondary indicator data of the policy output as the comparative sequence. Suppose the reference sequence is X_0 , $X_0 = \{x_0(1), x_0(2), \dots, x_0(n)\}$ and the comparative sequence is X_i , $X_i = \{X_i(1), X_i(2), \dots, X_i(n)\}$, $i = 1, 2, \dots, m$.

To avoid the inability to make comparisons due to the inconsistent units and quantity levels of the indicators in the system, it is necessary to preprocess the data of the secondary indicators so that the indicators can be directly compared. Therefore, data standardisation is processed for all indicators in this paper:

$$\gamma(k) = \frac{Y_i(k)}{\bar{Y}_i}$$

where $k=1,2,3,\dots,n$; $i = 1,2,\dots,m$

This paper uses the standardised data of the reference sequence and the comparative sequence to solve the correlation coefficient. The formula is:

$$\xi_{x_0(k), x_i(k)} = \frac{\min_i \min_k |x_0(k) - x_i(k)| + \rho \times \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \rho \times \max_i \max_k |x_0(k) - x_i(k)|}$$

Here, $\Delta_i(k) = |x'_0(k) - x'_i(k)|$; the following formula can be obtained:

$$\xi_{x_0(k), x_i(k)} = \frac{\min_i \min_k \Delta_i(k) + \rho \times \max_i \max_k \Delta_i(k)}{\Delta_i(k) + \rho \times \max_i \max_k \Delta_i(k)}$$

wherein $\min_i \min_k \Delta_i(k)$ is the two-level minimum difference of the data, $\max_i \max_k \Delta_i(k)$ is the two-level maximum difference of the data, $\xi_{x_0(k), x_i(k)}$ is the correlation coefficient between the k -th indicator of the comparative sequence x_i and the k -th indicator of the reference sequence X_0 and ρ is the resolution ratio. The smaller the value of ρ , the larger the resolution. Generally, the value range of ρ is in the range of 0 to 1 and ρ is usually taken as $\rho = 0.5$.

Finally, the GRA is solved according to the previous data, and the formula is:

$$\partial(x_0, x_i) = \frac{\sum_{k=1}^n (x_0(k), x_i(k))}{n}.$$

According to previous studies, when $\rho = 0.5$, $\partial(x_0, x_i) > 0.7$, the effect is ideal, indicating that the correlation between the two factors is relatively strong and the greater the GRA, the stronger the correlation.

5.2 Comprehensive evaluation of the policy output of the government guidance funds in Beijing–Tianjin–Hebei

The units and quantity levels of the four secondary output indicators of the policies of government guidance funds are not uniform, which will affect the results of data analysis, so they cannot be directly compared by weighted sum. First, this paper standardises the output indicators of government guidance funds. Since the four output indicators in this paper are all positive indicators, we standardise indicator data so that the result value is between 0 and 1. The formula is as follows:

$$T_{ab} = \frac{t_{ab} - t_{min}}{t_{max} - t_{min}}$$

T_{ab} in the formula is the result of normalisation of the data, and T_{ab} refers to the original value of each indicator; t_{min} and t_{max} are the minimum and maximum values of various indicators, respectively.

The results of the normalisation of the policy output indicator data of the Beijing–Tianjin–Hebei region are shown in Table 5. From Table 5, it can be seen that the technology market has the largest transaction volume in Beijing (2018) and the smallest transaction volume in Hebei Province (2005); Beijing City (2018) has the largest number of domestic invention patent applications, and Hebei Province (2005) has the smallest number; Hebei Province has the largest regional GDP (2017), and Tianjin has the smallest GDP (2005); Beijing has the largest regional GDP per capita (2018), and Hebei Province has the smallest GDP per capita (2005). From the above, we can find that the maximum values of innovation performance output indicators all appear in Beijing, and all the minimum values appear in Hebei Province and all are distributed in 2005; while the maximum values of economic output indicators are in Beijing and Hebei, the minimum values are in Tianjin and Hebei.

According to the above-standardised data and the combination weights obtained by AHP and entropy method, the weighted sum is conducted to obtain the standardised policy output values. The results are shown in Table 6. It can be seen from Table 6 that the policy output of Beijing, Tianjin and Hebei is showing an overall upward trend; among them, Beijing has the highest policy output book reviews. The policy output level of Beijing in 2018 was >8 times that of 2005, reflecting the remarkable achievements of Beijing's policy output. The policy output level of Tianjin was slightly higher than that of Hebei Province, ranking in the middle of the three cities, showing a steady upward trend on the whole. Hebei's policy output level lags far behind Beijing with the growth rate lower than that of Beijing and Tianjin.

Table 5 Results of normalisation of the policy output indicator data of the Beijing–Tianjin–Hebei region

Year	Transaction volume in the technology market			Domestic invention patent applications			Regional GDP			Regional GDP per capita		
	Beijing	Tianjin	Hebei	Beijing	Tianjin	Hebei	Beijing	Tianjin	Hebei	Beijing	Tianjin	Hebei
2005	0.076	0.006	0	0.02	0.006	0	0.055	0	0.109	0.102	0.07	0
2006	0.109	0.008	0.001	0.024	0.007	0.001	0.075	0.01	0.135	0.116	0.087	0.007
2007	0.139	0.01	0.001	0.032	0.007	0.001	0.106	0.024	0.174	0.151	0.111	0.016
2008	0.162	0.012	0.001	0.049	0.009	0.002	0.129	0.05	0.217	0.166	0.146	0.027
2009	0.195	0.015	0.001	0.051	0.009	0.003	0.148	0.065	0.239	0.174	0.159	0.033
2010	0.25	0.017	0.001	0.059	0.011	0.004	0.183	0.095	0.295	0.197	0.194	0.046
2011	0.299	0.025	0.003	0.08	0.017	0.006	0.221	0.132	0.369	0.223	0.235	0.064
2012	0.39	0.035	0.004	0.094	0.022	0.009	0.25	0.161	0.406	0.242	0.261	0.073
2013	0.453	0.042	0.003	0.121	0.038	0.011	0.285	0.189	0.439	0.266	0.284	0.08
2014	0.498	0.06	0.003	0.14	0.04	0.013	0.312	0.212	0.457	0.284	0.301	0.084
2015	0.548	0.079	0.005	0.16	0.05	0.018	0.342	0.226	0.464	0.306	0.311	0.085
2016	0.626	0.086	0.008	0.188	0.067	0.023	0.39	0.25	0.504	0.345	0.334	0.094
2017	0.713	0.086	0.013	0.178	0.044	0.023	0.432	0.262	0.539	0.381	0.347	0.102
2018	0.788	0.108	0.042	0.212	0.046	0.032	0.523	0.169	0.512	0.461	0.237	0.094

Table 6 Standardised policy output values of the Beijing–Tianjin–Hebei region

Year	Beijing	Tianjin	Hebei
2005	0.116	0.031	0.036
2006	0.152	0.042	0.048
2007	0.200	0.056	0.065
2008	0.239	0.080	0.083
2009	0.271	0.091	0.093
2010	0.332	0.115	0.117
2011	0.401	0.151	0.150
2012	0.487	0.179	0.168
2013	0.566	0.211	0.183
2014	0.624	0.238	0.191
2015	0.688	0.264	0.198
2016	0.788	0.297	0.220
2017	0.865	0.290	0.237
2018	0.995	0.238	0.252

5.3 A comparative analysis of the policy efficiency of the government guidance funds in Beijing–Tianjin–Hebei

This paper uses the GRA method to measure the policies of government guide funds and the second-level indicators of policy output. The results are shown in Table 7. From Table 7, we can see that the GRA range of government guide fund policies and policy output in Beijing, Tianjin and Hebei is 0.614, 0.814, indicating that there was a strong correlation between policy and policy output indicators during the period from 2005 to 2018, which showed that the government guide fund policies of the three areas were effective on the whole.

Table 7 Government Guidance Fund Policy and Policy Output Secondary Indicators by GRA

Region	Turnover of the technology market	Number of domestic invention patent applications	GDP	GDP per capita
Beijing	0.680	0.687	0.629	0.614
Tianjin	0.765	0.762	0.762	0.760
Hebei	0.781	0.812	0.705	0.698

GRA, grey relational analysis.

Table 8 Policy efficiency of government guide fund

Beijing	Tianjin	Hebei
0.725	0.806	0.808

Table 9 GRA analysis result of government guidance fund policy and policy output

Region	Intensity	Objectives	Measures
Beijing	0.633	0.678	0.649
Tianjin	0.772	0.775	0.749
Hebei	0.733	0.689	0.722

GRA, grey relational analysis.

Taking the GRA value of 0.7 as the criterion, there are seven combinations with significant influence and five combinations with insignificant influence, and all insignificant combinations appear in Beijing. This shows that the policies of the Beijing municipal government guidance funds tend to be less effective than the other two places. The policies of government guidance funds have the strongest impact on the turnover of the technology market in Hebei Province, while the impact on the per capita GDP of Beijing is the weakest.

According to the GRA ranking of the policies of government guidance funds of Beijing, Tianjin, Hebei and the various policy output indicators, the first two value indicators of each region ranked from largest to smallest are taken, respectively: Beijing (domestic invention patent application > turnover of technology market), Tianjin (turnover of technology market > domestic invention patent applications and regional GDP) and Hebei Province (domestic invention patent applications > domestic invention patent applications > turnover of technology market). It can be seen from the above that the policy output effects of Beijing and Hebei are relatively similar, and the government guidance funds in the Beijing–Tianjin–Hebei region are more effective in promoting innovation performance output. It also proves that government guidance funds have a positive impact on corporate innovation and entrepreneurship.

After analysing the policy efficiency of the government guidance funds on the four secondary indicators of policy output, the result is not intuitive enough. Therefore, in this paper, the four indicators were weighted and averaged by the overall weight to synthesise a comprehensive output index, which was analysed by GRA with the quantitative value of the policy, and the result was taken as the policy efficiency of government guide fund. The results of the study are shown in Table 8.

From the perspective of the policy efficiency of government guidance funds in Table 8, with the grey correlation value >0.7 as the criterion, the government guidance funds of the Beijing–Tianjin–Hebei region and the policy output show a strong correlation, while the policy efficiency of government guidance funds in the Tianjin and Hebei is similar, reaching a relatively ideal level. Although the policy efficiency of the government guidance funds in Beijing has exceeded the judgement standard, there is still a big gap compared with the other two places. Therefore, although Beijing has the lowest policy efficiency, its innovation output is the highest among the three places. Therefore, it can be seen that Beijing's policies of government guidance funds are not the main factor for its innovation output. For Tianjin and Hebei, although the policy efficiency is relatively large, there is still a big gap from fully exerting the policy effect, and there is still more room for improvement in the policy efficiency of government guidance funds.

The GRA analysis of government guidance fund policy and policy output is carried out in three aspects: intensity, objectives and measures. The results are shown in Table 9.

Taking the GRA value >0.7 as the criterion for judging the ideal effect of policies, it can be seen that Tianjin, as the city with the most ideal output effect among the three places, is in a leading state in terms of policy intensity, objectives and measures. Although Hebei Province has achieved a relatively ideal state in terms of policy intensity and measures, there is still a lot of room for improvement in terms of policy objectives. However, Beijing has failed to achieve the desired results in terms of policy intensity, objectives and measures.

Combined with its innovation indicator data, the main reason for the low-efficiency results may be the result of Beijing's relatively large number of resources in innovation and the influence of other policies.

6 Conclusions and suggestions

This paper takes 518 policies of government guidance funds in Beijing, Tianjin and Hebei from 2005 to 2018 as the research object and studies the relationship between economic output, innovation output and policy input and tries to seek countermeasures to improve the policy efficiency of the government guidance funds.

The research findings show that from the perspective of policy efficiency, the efficiency of the policies of government guidance funds in Beijing–Tianjin–Hebei has reached a relatively ideal level. From the perspective of policy input and output efficiency, the policy efficiency of Beijing, Tianjin and Hebei is reflected in innovation performance. The policy efficiency of Beijing and Hebei is mainly reflected in the number of domestic invention patent applications, while Tianjin is mainly reflected in the turnover of the technology market. In terms of the policy efficiency and comprehensive output indicators of the government guidance funds, the policy efficiency of Tianjin and Hebei has reached a relatively perfect state, and there is a small gap. In terms of policy intensity, objectives, measures and the efficiency of comprehensive output indicators, Beijing's policy intensity, objectives, measures and its policy output are relatively inefficient, which may be due to the fact that the policies of government guidance funds are only one of reasons that promotes the output of policy results but not the main reason. There is still a certain gap between the efficiency of policy targets and policy output in Hebei Province. The intensity and efficiency of measures in Tianjin and Hebei are relatively high, achieving a relatively ideal effect. There is still a big gap between the two regions to fully play the policy efficiency of the government guidance funds. Therefore, there is still room for improvement in the efficiency of policies of government guidance funds in Beijing, Tianjin and Hebei. To sum up, the efficiency of the policies of government guidance funds in Tianjin and Hebei is relatively satisfactory. The efficiency of Beijing's policies of government guidance funds is relatively low. There is still room for improvement in the policy efficiency of government guidance funds.

Based on the above research results, this paper provides the following recommendations for improving the policy efficiency of government guidance funds in Beijing–Tianjin–Hebei: (1) Accelerate the construction of inter-regional coordinated policies and strengthen the continuous influence of the policies. Local governments should raise the level of policy promulgation, increase the policy intensity, clarify policy objectives, create a good innovation environment and enable government guidance funds to play a leading role in regional innovation and development. In accordance with the development of different policies of government guidance funds in Beijing, Tianjin and Hebei, the government will take measures according to local conditions, give play to regional advantages and promote integrated development among regions to complement each other's advantages. As far as Beijing is concerned, it is necessary to make the policies of government guidance funds play a leading role in innovation, establish the leading position of the government guidance funds, form the main driving force for innovation and give full play to the role of policies. (2) Speed up the establishment of a unified performance evaluation system for the government guidance funds in the Beijing–Tianjin–Hebei region. The government of the Beijing–Tianjin–Hebei region should establish a unified and comprehensive policy-related performance evaluation system for government guidance funds and construct an evaluation framework from aspects such as innovation and economy so as to timely know the weaknesses of policy output performance and carry out targeted improvements. Under the condition of equal emphasis on policy efficiency and policy output, more reasonable policies of government guidance funds should be promulgated to promote the further development of government guidance funds. (3) Improve the capital usage efficiency of the government guidance funds and give greater play to the role of funds. According to the actual needs of the invested enterprises, appropriately increase the government guidance fund's investment in innovation and development, give play to the guiding role of policies and solve the problem of market failure in adjusting the market allocation of venture capital so as to promote the economic and innovative development of the enterprises and promote the optimisation and upgrading of industrial structure to improve policy output and efficiency and the maximisation of fund benefits.

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