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Yoon D.

THE EXPECTED EFFECT ANALYSIS FOR THE GOVERNMENT R&D INVESTMENT OF RESEARCH EQUIPMENT

Yoon D.[*]

Abstract: The propriety review and choice and concentration of R&D investment and government R&D investment effectiveness verification are essential for science and technology global competitiveness enhancement. This study focused on the government R&D investment in research equipment and attempted to analyze its expected effects through cost-benefit analysis using the actual research equipment utilization record. Cost-benefit analysis is classified into cost reduction effect analysis and basic research effect analysis. In this study, the expected effects (i.e., cost reduction and basic research effects) were analyzed for the research equipment utilization record analysis, using the new research method. Based on the research results, the new research method is proposed to be used for the government R&D investment expected effect analysis as it is expected to contribute to the said research. The research result and the new research method for the government R&D investment also have academic value and originality.

Key words: research equipment, government, R&D investment, expected effect, science and technology, analysis research, R&D policy

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Introduction

This study focused on the infrastructure construction efficiency in the government R&D investment direction. Expected effect analysis was performed for the research equipment government R&D investment. South Korea's Ministry of Science and ICT (MSIT) used the government R&D budget to shoulder the transfer cost (transfer, repair, and education) of idle or underutilized research equipment. This will raise the utilization capacity of research equipment. In the preceding research, an attempt was made to determine the effectiveness of the efforts to improve the efficiency of the transferred research equipment through the economic analysis of the said research equipment (Yoon, 2018). In the current study, the expected effects of the completed transfer process of idle or underutilized research equipment were analyzed for the use of the government R&D budget to shoulder the transfer cost, based on the research equipment utilization record (2011-2012). The research equipment utilization record consists of data regarding the equipment operation personnel expenses, equipment maintenance costs, sample costs, travel expenses, fees, papers, patents, etc. In other words, in this study, the expected

[*] **Donghun Yoon**, DhD, Korea Basic Science Institute, Seoul Center
✉ Corresponding author: ydh0@kbsi.re.kr

effects of the government R&D investment were analyzed through cost-benefit analysis, using the research equipment utilization record. The cost-benefit analysis consisted of the cost reduction and basic research benefits. The existing economic analysis method was not applied in this research. The expected effects were analyzed using the new research method and the research equipment utilization record. The research result and the new research method will contribute to the academic value and originality of this expected effect research. In this paper, the actual cost reduction effect and the basic research effect occurred for the government R&D investment in research equipment, through the normal operation of the transferred research equipment. The transfer cost (transfer cost, repair cost, and education cost) is supported for the idle or underutilized research equipment through the government R&D investment. This can increase the rate of operation of research equipment and can lead to cost reduction and basic research effects. It was found that benefits were created and sales occurred for 5 years after the government R&D investment was made, through the gestation period (5 years) of the basic research. This paper is expected to have academic value and to make a great contribution through its research result and the new research method presented in it. The results of this study will be very useful to scientists, researchers, engineers, policymakers, etc.

Literature Review

The characteristics of the direction of and standard for government R&D investment emphasize the R&D life cycle system advancement and propose the investment strategy that considers not only the quantity of the investment but also its quality. The investment strategy considering the quality is realized through choice and concentration (Lewellyn and Bao, 2015; Santen and Anadon, 2016). The smart technology creation of the existing industry through information and communications technology (ICT) and other technologies, the growth engine for future creation (Internet of Things [IoT], big data, deep-ocean marine plants, etc.), and the commercialization of R&D achievements are initially supported through government R&D investment. The effectiveness of the government R&D openness expansion will be raised through market demand reflection strengthening. Industry participation is induced for the life cycle of the government R&D planning, management, and evaluation (Carboni, 2017; Del Bo, 2016). The strategic investment direction of the government R&D is supported through the establishment of a medium-term technology investment portfolio based on the result analysis, technology trend, future outlook, etc. New R&D investment resources will be created and secured through high R&D efficiency (Asch et al., 2016; Gu, 2016; Vo and Le, 2017). Similar projects will integrate the core project as the center. Non-R&D projects (science and technology education and training, science and technology service, etc.) are maintained. Long-term projects (more than 10 years) are restructured through project construction improvement. The government direct investment should be reduced in the industry of conglomerates, such as the memory semiconductor, display, large-scale plant, etc. The research equipment purchase budget should be separated into separate subprojects to secure the operation efficiency of research equipment and facilities. The new projects should be based on pre-planning through the technology trend and outlook, and the ongoing projects should be thoroughly reviewed through the evaluation and execution results (Han et al., 2015; Zona, 2016). In terms of the infrastructure construction efficiency related to the research equipment, the efficiency of research equipment and the introduction validity should be strengthened. The high-cost research equipment should strengthen the pre-enforcement phase (advanced planning, budget deliberation, etc.) as the center until the next year's budget is set (Steinbach et al., 2017). The distributed budget of distributed research equipment should be integrated and managed to enable their mutual utilization. The construction of research institutes should be reduced. Ongoing facilities should also reflect the appropriate requirements through the review of the annual requirements, total cost, design, and quotation price. The aged research facilities should be improved through safety inspections. The government support for global technology-level and private R&D infrastructure should be gradually reduced. The local government performs a local R&D project by considering the ripple effect (Colombo et al., 2017; Shekar et al., 2017). The R&D related to many ministries should strengthen the collaboration and role-sharing through joint pre-planning and project linkage among the different government ministries.

Analysis Framework and Basic Data

First, idle and underutilized research equipment was defined. Idle equipment was defined as that which had been shut down for more than six months and that had a 0% annual research equipment utilization rate. Underutilized research equipment, on the other hand, was defined as research equipment capable of normal operation but with a very low utilization rate (annual research equipment utilization rate: less than 10%). Since 2010, South Korea's MSIT has been given an annual government R&D budget for transferring the idle and underutilized research equipment from the research institutes and universities to other institutes that need them, for their normal operation and efficiency improvement. It has been focusing on research equipment management and result management in its government R&D policy. The expected effects of the government R&D budget investment in research equipment are shown in Figure 1.

The costs include the equipment transfer cost incurred in the process of transferring the idle and underutilized research equipment, the new research cost incurred for the utilization of the transferred research equipment, and the operation costs (research equipment operation manpower cost, research equipment maintenance cost, sample cost) incurred by the research equipment utilization. The benefits, on the other hand, consist of the savings acquired from the utilization of the transferred research equipment and the R&D benefits from the R&D process.

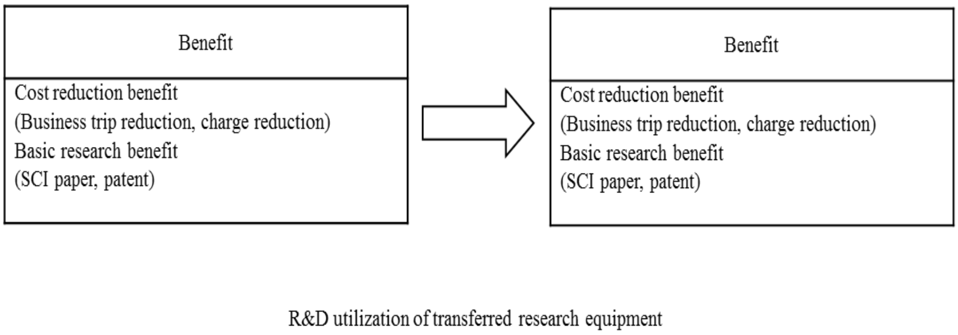

Figure 1. Expected Effects of the Purchase and Use of Research Equipment for the Government R&D Budget Investment

The social discount rate for the main parameters is 5.5%, based on the general guidelines for the preliminary feasibility survey from Korea Development Institute (KDI) of the Ministry of Strategy and Finance (MOSF) of South Korea. The discount rate is necessary for determining the current value of the future costs and benefits. This refers to the current exchange rate of the resources for the future resources. Also, it is used and measured in terms of the true price, the shadow price, and the opportunity cost of the input resource. The social discount rate is the discount rate applicable to a public project. In the case of developing countries, a low discount rate is applied as much as possible, considering the effects of public work projects. The research equipment utilization record was for the years 2011 (2012.4-2012.3) and 2012 (2012-2013.3). The research equipment utilization record is the record of the periodic mandatory research equipment utilization results submitted to MSIT for the research institutes and universities that have transferred their research equipment through the government research equipment R&D budget investment. When the research institutes and universities have transferred their research equipment through the government research equipment R&D budget investment, they are required to submit their respective research equipment utilization results to MSIT. It was hoped that utilization data for more than the research equipment utilization record mandatory period would be obtained, but it was difficult to obtain the utilization results because the research equipment utilization record mandatory period of the institutions, universities, etc. had ended. Therefore, the analysis period was set at 2011-2012. In this study, the basic research was done within a 5-year period, from the time that the government R&D investment was made to the time that the benefits occurred. The gestation period of basic research is based on a preliminary feasibility survey standard guideline research of the R&D Division of the Korea Institute of Science & Technology Evaluation and Planning (KISTEP) of MSIT. The transferred research equipment is described in Table 1.

Table 1. Research Equipment Transferred (2010)

Research equipment	Institution where the research equipment was transferred	Undertaking institution	Government R&D investment cost (USD/transfer cost)
Melting and casting furnace for the manufacture of metal rods from simulated metallic spent fuels	Korea Atomic Energy Research Institute (KAERI)	Chungnam National University	34,766
Heat flow measuring plant	Research Institute of Industrial Science & Technology (RIST)	Pusan National University	34,153
Atomic absorption spectiometer	Korea Basic Science Institute (KBSI)	Chonbuk National University	24,790
X-ray diffraction	Korea Basic Science Institute (KBSI)	Chonbuk National University	17,414

Methodology

Cost-benefit analysis is generally a method of estimating and assessing the net benefits associated with alternatives for achieving the established public objective. Also, it analyzes the public interest of the proposed project and the decision of mutually exclusive projects. In this study, the practical cost method and the benefit method were utilized. The most representative criteria for classifying the costs and benefits are the real and pecuniary costs and benefits. In the cost-benefit analysis, only the actual costs and benefits are considered. The actual benefits mean that the people (consumers) actually received benefits through the increase in the national production or social welfare, and the actual costs pertain to the opportunity costs of the generated resources through the promotion of public works. Monetary costs and benefits occur through changes in the monetary prices for the public sector. When these are included in the calculations, duplication or overt calculation errors occur. If a public project gains benefits through losses in other sectors, the benefits do not mean the benefits of the society as a whole. When the costs and benefits incurred through public works occur due to monetary price changes, these should not be reflected in the cost-benefit analysis.

Results Discussion

Cost Analysis

The cost data and research fund were surveyed for the analysis of the expected effects of research equipment utilization from the institution utilizing the research equipment. The cost survey data (USD) are shown in Table 2, and the research cost data (USD) are shown in Table 3. The research fund data shows a large value when the questionnaire data on the cost is compared with the research-fund-related data. The research fund data is considered the total of the new research funds and those that have existed for many years.

Table 2. Cost Survey Data (USD)

Research equipment	Year	New research fund	Personnel expense	Maintenance cost	Sample cost
Melting and casting furnace for the manufacture of metal rods from simulated metallic spent fuels	2011	0	0	0	4,137
	2012	0	0	0	7,518
Heat flow measuring plant	2011	0	872	0	5,427
	2012	3,489	872	436	8,229
Atomic absorption spectiometer	2011	26,167	0	0	12,500
	2012	43,611	872	0	6,850
X-ray diffraction	2011	26,167	1,744	0	5,783
	2012	43,611	0	0	1,601

Table 3. Research Cost Data (USD)

Year	Melting and casting furnace for manufacturing metal rods from simulated metallic spent fuels	Heat flow measuring plant	Atomic absorption spectiometer	X-ray diffraction
Research cost	122,111	174,444	95,944	261,666

The cost data is only considered the new research fund. The research cost data was absent for the melting and casting furnace for the manufacturing of metal rods from simulated metallic spent fuels. The heat flow measuring plant needed confirmation for the new research fund data. This data was analyzed through the scenario. Scenario 1 was not included in the heat flow measuring plant data for the new research fund data estimation, but Scenario 2 was included. This study considered the research funds for the atomic absorption spectrometer, the X-ray diffraction, and the heat flow measuring plant. The research funds for the manufacturing of metal rods from simulated metallic spent fuels and the heat flow measuring plant were also estimated. Scenario 1 is described in Table 4 while Scenario 2 is described in Table 5.

Table 4. Scenario 1 (USD)

Research equipment	New research fund total (2011-2012)	Research fund	New research fund rate (%)
Atomic absorption spectiometer	69,778	95,944	72.7
X-ray diffraction	69,778	261,666	26.7
Total	139,556	357,610	39.0

The research fund was 39% of the total research fund in Scenario 1 and 26.9% of the total research fund in Scenario 2. The new research fund for each year was estimated through the utilization of the research fund and the new research fund data. In both 2011 and 2012, the research funds were equally distributed.

Table 5. Scenario 2 (USD)

Research equipment	New research fund total (2011-2012)	Research fund	New research fund rate (%)
Heat flow measuring plant	3,489	174,444	2.0
Atomic absorption spectiometer	69,778	95,944	72.7
X-ray diffraction	69,778	261,666	26.7
Total	143,045	532,054	26.9

The revised research fund for Scenario 1 is described in Table 6 while that for Scenario 2 is described in Table 7. The cost analysis result could be obtained through this research result. The cost analysis result for Scenario 1 is shown in Table 8 while that for Scenario 2 is shown in Table 9.

Table 6. Revised Researh Fund Scenario 1 (USD)

Research equipment	Year	New research fund	Personnel expense	Maintenance cost	Sample cost
Melting and casting furnace for the manufacture of metal rods from simulated metallic spent fuels	2011	23,826	0	0	4,137
	2012	23,826	0	0	7,518
Heat flow measuring plant	2011	34,038	872	0	5,427
	2012	34,038	872	436	8,229
Atomic absorption spectiometer	2011	26,167	0	0	12,500
	2012	43,611	872	0	6,850
X-ray diffraction	2011	26,167	1,744	0	5,783
	2012	43,611	0	0	1,601

Table 7. Revised Researh Fund Scenario 2(USD)

Research equipment	Year	New research fund	Personnel expense	Maintenance cost	Sample cost
Melting and casting furnace for the manufacture of metal rods from simulated metallic spent fuels	2011	16,415	0	0	4,137
	2012	16,415	0	0	7,518
Heat flow measuring plant	2011	0	872	0	5,427
	2012	3,489	872	436	8,229
Atomic absorption spectiometer	2011	26,167	0	0	12,500
	2012	43,611	872	0	6,850
X-ray diffraction	2011	26,167	1,744	0	5,783
	2012	43,611	0	0	1,601

Table 8. Cost Analysis Results for Scenario 1 (USD)

Year	Transfer cost	Research fund	Personnel expenses	Maintenance cost	Sample cost	Total
2010	111,124	0	0	0	0	111,124
2011	0	110,198	2,617	0	27,846	140,661
2012	0	145,086	1,744	436	24,199	171,465

Table 9. Cost Analysis Results for Scenario 2 (USD)

Year	Transfer cost	Research fund	Personnel expenses	Maintenance cost	Sample cost	Total
2010	111,124	0	0	0	0	111,124
2011	0	68,748	2,617	0	27,846	99,211
2012	0	107,126	1,744	436	24,199	133,505

Benefit Analysis

In this study, the cost reduction benefits are the business trip reduction and the charge reduction. The business trip reduction is the reduction in the number of business trips made. The annual business trip reduction number is shown in Table 10. The cost reduction benefit is shown in Table 11.

Table 10. Annual Business Trip Reduction Number

Research equipment	Year	No.
Melting and casting furnace for the manufacture of metal rods from simulated metallic spent fuels	2011	55
	2012	39
Heat flow measuring plant	2011	77
	2012	84
Atomic absorption spectiometer	2011	51
	2012	12
X-ray diffraction	2011	50
	2012	10

Table 11. Cost reduction benefit (USD)

Year	Annual business trip reduction no.	Average no. of persons per business trip	Average business trip cost	Per charge	Benefit
2011	233	2	87	174	81,290
2012	145	2	87	174	50,589

Below is the detailed formula for the cost reduction benefit:

Cost reduction benefit = Business trip reduction + Charge reguction

Cost reduction benefit = Annual business trip number x (Mean business trip person x Meann business trip cost + per charge)

The basic science benefit considered the added value of the economic creation when the SCI paper was converted to a patent and the patent was succeeded by commercialization. The SCI paper value is USD 62,102 per paper. This is based on the basic research support project and the manpower training project (2015) of MSIT. The basic research benefit is the economic value per SCI paper. The SCI paper result is shown in Table 12.

Table 12. SCI Paper Result

Research equipment	Year	SCI paper no.
Melting and casting furnace for the manufacture of metal rods from simulated metallic spent fuels	2011	1
	2012	0
Heat flow measuring plant	2011	0
	2012	0
Atomic absorption spectiometer	2011	0
	2012	0
X-ray diffraction	2011	3
	2012	2

Below is the detailed formula:

Basic science benefit = SCI paper result x Economic value for per a SCI paper

Basic science benefit = SCI paper result x SCI paper value x Patent conversion ratio for SCI paper x Commercialization succsess rate of patent x Economic impact effect x Added value ratio

The patent conversion ratio for the SCI paper is shown in Table 13. The patent conversion ratio for the SCI paper is based on the preliminary feasibility survey report of the promotion support business for the local science research park (2017) of Korea Development Institute (KDI)..

Table 13. Patent Conversion Ratio for the SCI Paper

Year	2015	2016	Total
SCI paper no.	39,294	48,192	87,486
Patent no.	13,997	18,391	32,388
Patent/SCI paper rate(%)	35.6	38.2	37.0

Below is the detailed formula:

Commercialization success rate of patent = Inductry utilization rate of patent x Commercialization rate of transfer technology

The commercialization success rate of a patent is calculated through the Korean Small Business Innovation Research Program result report (2016) of the Ministry of SMEs and Startups (MSS) of South Korea. Below is the detailed formula:

Commercialization success rate of patent = 29.3% x 27% = 7.9%

Below is the detailed formula of the economic impact effect:

Economic impact effect = Scale inducement multiple of commercialization success technology x Added effect of different route

The economic impact effect is based on the links and impacts: the influence of public research on industrial R&D (Wesley et al., 2002). Below is the detailed formula:

$$\textit{Economic impact effect} = 7.87 \times 4.70 = 36.99$$

The added value ratio is based on the inter-industry relation table of MOSF. The added value ratio is shown in Table 14.

Table 14. Added Value Ratio

Year	Added value ratio (%)
2010	36.9
2011	35.4
Average	36.1

The basic benefit goes through a gestation period (5 years) when the research fund is invested. Also, the basic benefit occurs equally during the sale continuity period (5 years). In 2011, the research fund benefit went through a gestation period (5 years, 2012-2016) when the research fund was invested. The basic benefit occurred during the sale continuity period (5 years) from 2017. The research fund benefit is described in Table 15. In this study, the cost reduction and basic research effects were analyzed as the expected effects. The cost reduction effect was USD 131,879 in the research equipment utilization record (2010) for 2 years (2011-2012).

Table 15. Research Fund Benefits (USD)

Year	2011	2012	Total
2011	0	0	0
2012	0	0	0
2013	0	0	0
2014	0	0	0
2015	0	0	0
2016	0	0	0
2017	19,444	0	19,444
2018	19,444	9,722	29,166
2019	19,444	9,722	29,166
2020	19,444	9,722	29,166
2021	0	9,722	9,722
2022	0	9,722	9,722

In the analysis result, the cost reduction effect was USD 65,940 per year and USD 329,698 for 5 years. The basic research effect was USD 116,664 for 5 years, from 2017, through the gestation period (5 years, 2012-2016), when the research equipment research fund (2010) was invested (2011-2012). Therefore, when the research equipment (2010) was utilized for 5 years, the expected effects were the cost reduction effect (USD 131,879) and the basic research effect (USD 116,664). The government R&D investment cost was USD 111,123 and the expected effect was USD 248,543 for the transferred research equipment (2010).

Managerial Implication of Results

Cost-benefit analysis is the economic analysis method for the government R&D investment decision. It is quantified for the government R&D investment in research equipment as the monetary value of the social economic benefits and costs. It is a very efficient method for making an R&D policy decision and an efficiency judgment. Its objective is pursing the efficiency of the government R&D investment in research equipment through a quantifying method. The benefits and losses are compared in terms of the government's public policy using such analysis method. When the net benefit is negative, it can abolish the related regulation or action. Also, it can help in the efficient regulation or action development.

Cost-benefit analysis's analysis subjects are the following: awareness of the project or regulation, decision on the analysis period, estimation of the benefits and costs, monetary value conversion for all the effects, decision on the discount rate, the present value of the benefits and costs, determination and comparison of alternative selection criteria, sensitivity analysis, etc. In this paper, the actual cost reduction effect and the basic research effect occurred for the government R&D investment in research equipment, through the normal operation of the transferred research equipment. The transfer cost (transfer cost, repair cost, and education cost) is supported for the idle or underutilized research equipment through the government R&D investment. This can increase the rate of operation of research equipment and can lead to cost reduction and basic research effects. It was found that benefits were created and sales occurred for 5 years after the government R&D investment was made, through the gestation period (5 years) of the basic research.

The government R&D investment in research equipment is currently in its early phase and needs steady expansion for the normal operation of the idle or underutilized research equipment. It can reduce the government R&D budget and provide opportunities for research and experimentation to professors, scientists, researchers, and engineers. Also, it is very important for science and technology development. The government R&D investment prevents the disposal of idle or underutilized research equipment and can promote research result creation and provide analysis support. The idle or underutilized research equipment should be transferred to the universities, public institutes, hospitals, enterprises, etc. that need these, for their normal operation, through the expansion of the government R&D investment in research equipment. When the transfer of idle or underutilized research equipment is completed, the research equipment utilization record should be monitored steadily for the normal operation of the research equipment.

Summary

The government research & development (R&D) investment should focus on the new growth power (Internet of Things [IoT], big data, advanced semiconductor, basic research, etc.). The next-generation industry strategy is very important for reversing the growth rate decrease trend, the decrease of the export increase rate, the weak yen phenomenon, etc. An integrated support system should be established for the core technology development of promising new industries. The R&D support efficiency and government R&D investment in research equipment are essential.

In this paper, the results of the analysis of the expected effects of the government R&D investment in research equipment are presented and discussed. The expected effects were based on the research equipment utilization record for the government R&D investment effects. The new method of determining the expected effects was carried out using the research equipment utilization record (2011-2012). The expected effects were analyzed through cost-benefit analysis. The effects were classified into the cost reduction effect and the basic research effect. Based on the analysis results, the cost reduction and basic research effects were determined, and it was found that benefits and sales occurred for 5 years since the government R&D investment was made, through the gestation period (5 years) of the basic research.

The idle and underutilized research equipment should be transferred steadily to the institutes that need them through the government R&D investment in research equipment. This paper is expected to have academic value and to make a great contribution through its research result and the new research method presented in it. The results of this research will be very useful to professors, scientists, researchers, engineers, and science and technology policymakers.

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OCZEKIWANA ANALIZA EFEKTÓW DLA INWESTYCJI RZĄDOWYCH R&D DOTYCZĄCYCH SPRZĘTU BADAWCZEGO

Streszczenie: Ocena przydatności oraz wybór i koncentracja inwestycji w badania i rozwój oraz weryfikacja efektywności inwestycji rządowych w badania i rozwój mają zasadnicze znaczenie dla globalnego wzrostu konkurencyjności nauki i technologii. Badanie to koncentrowane jest na rządowych inwestycjach w badania i rozwój w zakresie sprzętu badawczego. Podjęto próbę przeanalizowania spodziewanych efektów poprzez analizę kosztów i korzyści, wykorzystując rzeczywisty zapis dotyczący użytkowania sprzętu badawczego. Analiza kosztów i korzyści została zaklasyfikowana do analizy efektu redukcji kosztów i analizy podstawowego efektu badawczego. W niniejszym badaniu spodziewane efekty (tj. redukcja kosztów i podstawowe efekty badawcze) zostały przeanalizowane pod kątem analizy zapisu wykorzystania sprzętu badawczego przy użyciu nowej metody badawczej. W oparciu o wyniki badań, do oczekiwanej analizy skutków inwestycji rządowych na badania i rozwój, zaproponowano zastosowanie nowej metody badawczej, ponieważ oczekuje się, że przyczyni się ona do wspomnianych badań. Wyniki badań oraz nowa metoda badawcza rządowych inwestycji w badania i rozwój mają również wartość akademicką i są oryginalne.
Słowa kluczowe: sprzęt badawczy, rząd, inwestycje w badania i rozwój, spodziewany efekt, nauka i technologia, badania analityczne, polityka w zakresie badań i rozwoju

研究设备政府R＆D投入的效果分析

摘要：研发投入的合理审查与选择与集中与政府研发投入效益的确认对科技全球竞争力的提升至关重要。这项研究侧重于研究设备的政府研发投资，并试图通过使用实际研究设备利用率记录的成本效益分析来分析其预期效果。成本效益分析分为成本削减效果分析和基础研究效果分析。在这项研究中，使用新的研究方法分析了研究设备利用率记录分析的预期效果（即成本降低和基础研究效果）。基于研究结果，提出了一种新的研究方法，用于政府研发投资预期效应分析，因为它有望为上述研究做出贡献。政府研发投入的研究成果和新的研究方法也具有学术价值和独创性
关键词：研究设备，政府，研发投资，预期效应，科技，分析研究，研发政策