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## OPERATIONS, INFORMATION & TECHNOLOGY | RESEARCH ARTICLE

# Competitive support of governments for research, development and innovation and its interaction with knowledge production criteria

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**Abstract:** This study tends to examine effect of support given by government and other private institutions to research, development and innovation on knowledge production criteria. In the contemporary world, research, development and innovation are key factors for improving economic performance and social welfare. Governments which tend to take advantage of this approach need to adopt correct and tested strategies and eliminate limitations in allocating resources to driving factors of innovation process. In this regard, this study addresses various forms of support given by government and private sector to R&D; by analyzing and evaluating effects of these supports on knowledge production criteria, this study tends to rank supportive approaches to research and development in the most industrialized and newly industrialized countries. As the results showed, statistics and ranking of countries in terms of their support for knowledge production are not enough for management and operation of knowledge production and most importantly GNP; thus, it cannot provide necessary information for this matter.

**Subjects:** Science; Technology; Social Sciences; Arts & Humanities

**Keywords:** knowledge production criteria; development and innovation; competitive support of governments; United Nations; industrial and semi-industrial world

### 1. Introduction

In the contemporary world, research, development and innovation are key factors for improving economic performance and social welfare; governments which tend to take advantage of this approach need to adopt correct and tested strategies and eliminate limitations in allocating resources



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### PUBLIC INTEREST STATEMENT

This study addresses different activities and methods of effectiveness in increasing knowledge production in different countries. Results show that a single method of knowledge production development cannot provide similar outcomes in all societies. Moreover, this false belief that the increase in research budget improves production indices is a contingency; this study explains this claim clearly.

to driving factors of innovation process and increasingly accelerate and facilitate research and development (R&D) activities.

In the current era which is called information age, technological innovation is particularly more important than investment; technological innovation has become a main source of productivity and a major tool of economic competitiveness in global markets. Typically, government programs have a significant effect on technological innovation and enhance quality of goods and services (Apak & Atay, 2015). Increasing effect of R&D and innovation on economy has led many governments to use both conventional and new supportive mechanisms for research and development. These mechanisms include networking, science-industry cooperation, scholar mobility between science and industry (as an important channel of interaction), participation in international knowledge resources, intellectual property rights, top technological centers, world class centers, knowledge-based consulting services, multidisciplinary knowledge, investment in information and communication technology (ICT), technological unions of big corporations, promotion of small- and medium-sized enterprises, technology-based entrepreneurship, research insurance, support for risk-taking investors in development projects, cluster-based companies, research cooperatives, knowledge-technology corridors and parks.

A certain number of these mechanism have not been used in different countries; various forms of support used in different countries along with their effects on R&D criteria are discussed below. Institutions and government policy play a potentially important role compared to money in development of innovation in economic enterprises (Cano-Kollmann, Hamilton, & Mudambi, 2016). Recently, productivity has been rising rapidly in innovation of high-tech industries. However, literature shows that financial influence of government has negative effect on these industries, while private R&D funds have a significant positive relationship with productivity of these industries (Ng and Ng, 2016). All competitive support mechanisms tend to promote positive effects of research and development on economy and public welfare. To understand competitive support mechanisms, it is essential to determine comparative advantages and competitive advantages. Michael Porter presents different definitions for comparative advantages and competitive advantages. According to Porter, comparative advantages are based on underlying factors of production and research and development such as labor, natural resources and capital. Most of the studied countries have relatively comparative advantages. Competitive advantages are defined by productivity of factors and R&D functions and value created by productive and effective products, new technology and services. By this definition, all 25 industrialized and newly industrialized countries studied here have focused their supports for R&D activities on productivity of factors rather than comparative advantages.

## 2. Knowledge production criteria

Generally, criteria represent performance levels of a variable and the extent to which a system has achieved these levels regarding that variable. In a comparative study, real performance and real size of a criterion are compared to other actors, rather than standard expression of criteria (Eftekharian, 2006). To obtain useful informance, hence, it is essential to determine mechanisms used by different countries to exercise competitive supports for R&D.

As noted earlier, independent variables include R&D supportive mechanisms and GNP/R&D ratio in industrialized and newly industrialized countries; dependent variable is size of R&D criteria or knowledge production criteria which include:

- (A) number of scientists and engineers involved in research and development (in millions).
- (B) number of scientific and technical publications.
- (C) number of patent application by native citizens.

**Table 1. R&D and knowledge production criteria used in 25 industrial and newly industrialized countries**

Country	Population (Million)	Per capita income (\$)	R&D/GNP (%)	No. of R&D scientists and engineers (Million)	No. of scientific, technical and research publications	Patent application of native citizens
South Africa	46	3,480	0.7	1,031	1,937	1,920
Germany	82	22,900	2.41	2.83	36,233	67,790
Austria	8.1	35,820	1.53	1,627	3432	3,023
Australia	20.2	26,900	1.80	3,357	11,793	3,119
United States	298	41,440	2.63	3,676	166,829	141,342
England	60.27	27,700	1.95	2,448	38,530	28,889
Italy	57.8	28,300	2.21	1,318	16,405	3,167
Ireland	3.9	38,308	1.61	2,319	1,118	1,199
Belgium	10.39	35,479	1.6	2,272	4,717	1,899
Thailand	63.4	2,578	13	103	356	477
Taiwan	+	+	+	+	+	+
China Unit	1,300	1,700	0.66	454	9,081	14,004
Denmark	5.43	37,883	1.95	3,190	3,950	2,897
Russia	144	4,000	88	587	17,147	16,630
Japan	127.4	31,500	2.8	4,909	43,891	360,338
Singapore	4.24	24,560	1.13	2,318	1,164	311
Sweden	9	26,200	3.76	826	8,219	8,599
Swiss	7.3	48,330	2.6	3,006	6,935	6,026
France	62.4	32,340	2.25	2,659	26,509	20,298
Canada	32.4	32,800	1.66	2,719	19,910	4,841
South Korea	48.42	14,162	2.82	2,193	4,619	50,714
Malaysia	25.6	4,352	0.24	93	304	179
Mexico	105	6,517	0.33	214	1,915	472
Nederland	16.3	36,236	2.08	2,219	11,008	5,751
India	1,100	640	0.73	149	8,439	2,111

Reference: (1) World Bank Atlas (2003–2006); (2) UNESCO (2003–2005).

Information related to R&D and knowledge production criteria is summarized in Table 1. Then, supportive mechanisms used in different countries and results of these mechanisms are explained.

### 2.1. South Africa

In South Africa, technologic, scientific and industrial strategies are manifested in framework of national innovation system. Research, development and innovation approaches can be summarized in two levels (Sahraeian, 2002):

(A) government supportive policies for research, development and innovation

- Promotion of different areas of knowledge, science and technology distribution mechanisms, innovative programs to increase public understanding of science and technology and promotion of research and development culture.
- Allocation of funds based on strategic requirement of development, support for local knowledge, intellectual property protection and allocation of resources to new capacities.
- Performance evaluation.

(B) Support for research, development and innovation in South Africa

- Founding National Advisory Council on innovations, founding National Center for Product Development, financing competitive projects, founding Innovation Foundation (Mahdavi, 2007).
- Founding Industrial Development Company supervised by Ministry of Trade and Industry, founding an open licensing system, using research findings which promote institutional capacities for technology transfer and thoughtful management.

In 2006, the South African Government has published its national science and technology document as “White Paper”. In this document, visions and policies of science and technology, research and innovation are well formulated. Results of these supports are listed in Table 1.

### 2.2. Germany

Germany is one of those countries which have the highest private investment in research and development; however, government support for R&D can be divided into direct and indirect supports:

(A) Direct support is often in the form of loans for very important projects in the fields of new materials, information technology, physics technology, biological sciences and environmental technology.

(B) Indirect support involves (Gharehbaghian et al., 2002):

- (1) Improvement of scientific potential of companies.
- (2) Support for participatory research.
- (3) Financial support for innovations.
- (4) Support for new technology-based companies.
- (5) Loans for utilization of new technologies.
- (6) Data application for obtaining information.
- (7) Distribution and development of key technologies.

New initiative plans have been presented by the government to increase R&D criteria in Germany; these plans include innovativeness of SMEs, temporary staff exchange programs between organizations and research institutions, self-employment in universities, international participation in science. Results of these supports are summarized in Table 1.

### 2.3. Austria

In Austria, the Ministry of Innovation and Technology is responsible for research and industrial development, technology development, management and development of innovation funds, research prioritization and implementation of national R&D programs. In Austria, support for R&D activities is organized by three funds:

- (A) Austrian Science Fund is founded for development and promotion of basic research. About 75% of the budget is distributed down-top.
- (B) Austrian Industrial Research Promotion Fund provides budgets in the form of grants, low-interest loans, collateral for bank loans and support for 80% of loans granted to industrial companies (majority of which have less than 500 employees).
- (C) Austrian Innovation and Technology Fund is financed by private revenues of the government; this fund supports budgets related to new materials, environmental technologies, laser technologies, aerospace technologies and international cooperation projects. Other supportive plans of Austria include regional initiatives, development promotion plan and tax incentives (Bolkhari, 2005). Results of these supports are summarized in Table 1.

#### **2.4. Australia**

The government believes that innovation, skill development and new ideas created through research and development and converted into commercial successes are key factors of future advancement. Support mechanism used by the government for R&D and innovation include R&D initiation plan, innovation access plan and inter-organizational collaborations plan to trigger sustainable collaboration of companies, government and industry. Another innovative plan is R&D tax relief by 12.5%, which typically reduces tax for R&D organizations. In general, majority of 2,840 organizations included in R&D tax relief considered tax relief as an important, effective factor on R&D activities. Results of these supports are summarized in Table 1.

#### **2.5. United States**

Like other industrialized countries, US has realized the important role of R&D and innovation in economic plans and has taken effective steps to increase domestic economic return on public and private investment in research and development. The most important supportive policies of US for R&D and innovation include preservation of private sector in application of research, long-term economic growth to maintain its position in the world, strong relationship between science and society which supports science, reliable, valid and objective R&D foundations for world-class technological superiority, increasing investment and resource management, cooperation with private sector in research and development to ensure technological leadership, other supportive efforts such as innovative programs associated with universities, innovative programs associated with federal laboratories (Advanced Technology Program), small-scale business innovation research program, cooperative research and development agreement, establishment of technology office in 1988 to encourage research and development in industry (O' Meara, 2000). Results of these supports are summarized in Table 1.

#### **2.6. England**

In England, research councils and Department of Trade and Industry are responsible for supporting R&D activities. These councils often support education, research programs and projects, research centers, joint projects with industry, patents, and innovations in their areas of expertise. Foreign participation plays an important role in acquisition of knowledge required for innovation in an enterprise (Roper, Becker, Love, & Bonner, 2016). Department of Trade and Industry supports R&D in industry through Link project (joint research), Advanced Technology Program (as US), cooperative research, plan (support for research products), credit rewards for research and technology in small companies, corporate training plan, senior academics, new regional innovation funds. Results of these supports are summarized in Table 1.

#### **2.7. Italy**

In Italy, R&D support is focused on high-risk projects. Applied Research Fund and Technological Innovation Fund are responsible for supporting industrial research and development:

- (A) Applied Research Fund was founded in 1968 to provide low-interest grant and credits for research institutions.
- (B) Technological Innovation Fund, founded in 1982, is managed by the Ministry of Industry to promote technological innovation and develop products and processes. This fund also finances start-ups. The government supports research and development by involving in distribution of technological innovation, promotion of inter-organizational relationships, internal performance of companies and attractive environmental for manufacturing activities. Results of these supports are summarized in Table 1.

### 2.8. Ireland

In Ireland, R&D support is through a certain plan consisting of six major activities, including:

- (1) Industrial R&D support: companies are supervised by a single entity which finances their research and development.
- (2) Target financial support: companies of which R&D activities are purposeful are financed.
- (3) Technological services: production technology, manufacturing, quality, energy, environment and industrial materials are supported.
- (4) Advanced technology plan: core of R&D support in Ireland is advanced technology plans.
- (5) Regional (cluster) centers of technology: R&D activities, technical advice, tests and industrial experiments are done in these centers.
- (6) Higher education-industry interaction: this program tends to implement joint projects between a company or a group of companies and universities. Results of these supports are summarized in Table 1.

### 2.9. Belgium

In Belgium, responsibilities of the government have been increasingly decentralized in the field of R&D activities and generally scientific, technological and industrial policies; in this regard, contribution of the federal government has declined in recent decades, while contribution of provinces has increased. R&D support is focused on plans and practices (Sharif al-Nabi, 2007).

- (A) supportive plans for research, development and innovation include allocation of resources to promising scientific and technological areas, public awareness of R&D advantages, mobility of researchers, promotion of cooperation and promotion of horizontal relationships between provinces, support for intermediaries between universities and industry, cooperation networks for innovation and funds to support public and strategic research.
- (B) R&D support practices: these practices include loans for R&D applied projects, subsidies for feasibility of SMEs, economic-technical studies, participation in collective research centers, support for invention costs and subsidies for prototypes. Results of these supports are summarized in Table 1.

### 2.10. Thailand

Agricultural processing industries and exports of agricultural products are important goals of Thailand. Thailand has become one of the major exporters of agricultural products in the world; currently, Thailand exports more than 70 billion dollars of agricultural products to global markets annually. In Thailand, R&D policies are formulated and implemented by the Ministry of Science and Technology, National Research Council of Thailand and National Science and Technology Development Agency. The National Science and Technology Development Agency supports research and development through three coordinated plans (Steger, 2003).

- (1) The first plan includes research and development of high-priority problems; this plan supports research capabilities of institutions.
- (2) The second plan supports research and development plans of companies and directly finances research and development projects of private companies.
- (3) The third plan supports industrial development; this plan identifies, evaluates and standardizes research needed for industry and controls quality. Identification of research needed for industry involves consulting services and determines requirements of industrial research and development; through these services, trained employees and workshops required for defining research projects consult companies. The most important plan of Thai Government in research and development and technology transfer is industrial consulting services which tend to encourage and direct SMEs in order to promote their technological capabilities through experts and consultants and improve production line and product design. Results of these supports are summarized in Table 1.

### **2.11. Taiwan**

In January 1959, Taiwan formulated and developed its long-term scientific development guidelines. These guidelines were followed by positive outcomes such as permanent funds for development of science and technology and science and technology development leadership agency or the National Science Council. Most R&D supports are given by these two institutions. Government support for R&D in private sector involves direct funds, tax incentives, subsidies and guidelines by providing allowance to purchase patent, franchise, full project, international partnership and consulting services. Foreign direct investment (FDI) has a significant effect on innovative performance in emerging economies both statistically and economically (Li, Strange, Ning, & Sutherland, 2016). Results of these supports are summarized in Table 1.

### **2.12. China**

People's Republic of China promotes development of science and technology as a tool to implement national development strategies; accordingly, it is believed that science and technology are key advantages of China, which should always be kept in the highest strategic level in global competition. The government has focused its R&D support on policies and practices (Brown & Langencker, 1999):

- (A) R&D support policies include encouraging enterprises to play as the main elements of innovation, founding applied research organizations, developing scientific and technological service providers and innovation funds for SMEs along with capital support for these enterprises.
- (B) R&D support practices include key basic research development plan, scientific and technological elevation plan, outstanding scientific and technological research project, advanced technology research and development plan, technological innovation project, joint training development plan, research and production, lightning project, spark or agricultural development project, new key product plan and technology innovation fund for SMEs. Innovation support fund is one of the most important plans of Chinese Government to support research and development process of SMEs (Guo, Guo, & Jiang, 2016). Results of these supports are summarized in Table 1.

### **2.13. Denmark**

In Denmark, coordination between research system and needs of society is one of the formulated principles. Hence, R&D support plans of Danish Government are very important; these plans include:

- (A) Scott program is designed to improve technology transfer to industry. Scott program supports academic research and introduces them to business sectors, acts as consultant, finances researches and operates on intellectual property rights, market capacity and implementation of projects.
- (B) PI schemes operates on patent of research results and scoring for industry. The main objective of this plan is to facilitate patent application by inventors and manufacturers. Results of these supports are summarized in Table 1.

### **2.14. Russia**

Russia formulated its science, technology and industry policy in 2000, through which R&D support policies were determined. Some of these policies include increase in government funds, R&D support in high-priority areas, innovative plans to mobilize innovation through tax mechanisms, innovative plans to introduce and popularize reversible financing for research and practical projects, support for SMEs, regional and local innovation systems and establishment of the Ministry of Industry, Science and Technology. Results of these supports are summarized in Table 1.

### **2.15. Japan**

In Japan, industry still underlies social welfare and economic development. Therefore, it can be predicted that industry is dominant on politics. Research and development are always directed toward economy. Traditionally, there is a close relationship between industry and policy-makers in science and technology. Hence, R&D support plans involve promoting industry-research relationship; reorganizing government research for greater efficiency; supporting creativity, particularly in youth; providing short-term basic research projects for youth under supervision of a scientist; supporting basic research for future industry; supporting scientific and technologic personnel; protecting environment; improving life, health and hygiene; and preventing damages. The same projects and plans implemented in US have been implemented in Japan. Results of these supports are summarized in Table 1.

### **2.16. Singapore**

In its short history as a country, Singapore has shifted from a crowded commercial center to a modern industrial country. Over a five-year plan (2000 to 2004), Singapore has allocated 2 billion dollars for research and development to support industrial research. Traditionally, SMEs are important part of economies, particularly Singapore (this figure is 95% in some countries), associated with employment and national production. Recently, the government has realized the important role of SMEs in innovation (Yahya, Chang, Ng, & Tan, 2016). Results of these supports are summarized in Table 1.

### **2.17. Sweden**

Sweden had realized the role of research, development and innovation in economic growth years ago. R&D support policies of Swedish Government can be summarized in following strategies (Stiglitz, 2006):

- (1) Focus on increasing coordination of R&D policies by reorganizing public financing structures.
- (2) Focus on mobilization of regional economic growth through R&D activities based on regional growth agreements formulated in March 2000.
- (3) Partnerships of research institutions and commercial sectors.
- (4) Improvement of knowledge dissemination, particularly in small quick yielding firms.
- (5) Increasing involvement in R&D programs of the Europe Union.
- (6) Simplification of administrative affairs in industry and elimination of useless regulations.

Results of these supports are summarized in Table 1.

### **2.18. Swiss**

The 1983 Act was the most important step taken by Swiss regarding science and technology. This act requires the government not to intervene in science and technology. In Swiss, private industries, non-profit organizations and federations and the Swiss National Science Foundation are responsible for investing in research and development. National R&D credits are distributed by the Swiss National Science Foundation in two parts:

- (A) general credits including rewards, research grants, publication grants, personal and individual contributions
- (B) special credits including strategic research programs in relation to biotechnology, informatics, material technology, high-performance optical and electronic devices and environmental technologies.

Results of these supports are summarized in Table 1.



### **2.19. France**

One of the important priorities of France is to increase technological level of industrial companies; for this purpose, France has provided many plans including tax exemptions for investment in research and development, support for investments in innovations, support for technological programs and incentives to support researchers, tax credit on research, promotion of innovation in SMEs, support for initiatives, researcher training, mobility of researchers, and scientific innovation transfer which selects, commercializes and organizes technology transfer and finances technologies which are attractive enough to introduce in global market (Mc Gillivray, 2005). Results of these supports are summarized in Table 1.

### **2.20. Canada**

In January 2001, the Canadian Government committed itself to promote investments in science and technology. Canada's vision is to become one of the five leading countries in research and development by 2010. To achieve this goal, Canada considers following supportive policies and practices:

- (A) R&D support policies including knowledge creation and application, training of qualified people who create and use knowledge, work and activity, support for government policies and plans for international cooperation and globalization, and support for promotion of industry-science relationship.
- (B) R&D support practices including Atlantic Innovation Foundation (founded in June 2000; this foundation has invested 300 million dollars in innovative infrastructure, particularly research institutions and universities), annual allocation of 35 million dollars for three years to new generation of internet architecture and allocation of 200 million dollars to indirect costs of academic researches, technology investment fund and annual allocation of 30 million dollars financial aid to students to acquire knowledge and skills. Results of these supports are summarized in Table 1.

### **2.21. South Korea**

In South Korea, a characteristic of industrial development has been development of competitive advantages. Founding scientific institutes and scientific infrastructure had a major role in technological development and competition. South Korea actively promotes a scientific and technological environment in the society. The main objective of this movement is to provide an environment in which public ideas can apply scientific principles in daily life.

R&D support mechanisms used in South Korea include R&D support system, commercialization and distribution of technology, support for R&D units in private industries, support for technological manufacturing companies, annunciation of technologies made in Korea, technology development fund, commercialization plan, national R&D programs, tax incentives and informal technology transfer (Singer, 2004). Results of these supports are summarized in Table 1.

### **2.22. Malaysia**

In Malaysia, research and development is shifting from agriculture to industry. The government has the most important contribution to research and development. Currently, industry is not highly involved in R&D activities. Approval of research projects which strengthen the relationship between universities, research centers and industry is very important. For this reason, many universities and higher education institutions have tended to establish R&D and consulting departments. R&D support policies and practices used in Malaysia include increase in investment in research and development to ensure that R&D costs are proportional to contribution of industrial sector in the economy; contract research system; commercialization of research achievements by focusing on endogenous technologies; research programs focused on new technologies and formation and development of institutions which use new technologies; skill development fund; low-interest loans; regional quality centers for key industrial areas; promotion of industrial culture through national awareness programs, incentives and rewards for research and development; grants for new technologies; national

contract research system, joint R&D centers; national center for development and design of production; quick consulting services for exclusive patent rights; technical and industrial assistance funds; continuous technical human resource training. Results of these supports are summarized in Table 1.

### 2.23. Mexico

In Mexico, National Plan for Modernization of Science and Technology determines supportive policies and practices for scientific researches and technological development. These activities include support for scientific and technological research determined in the national development plan and national unity plan; R&D departments in companies; scientific exchange activities and plans; support for projects which rely on private sector capitals; four funds for promotion of scientific infrastructure, support for domestic researchers, support for superior researchers, promotion of strategic abilities); National Quality Award; protection of industrial property; support for science through private sector participation and tax incentives (Azarang, 2007). Results of these supports are summarized in Table 1.

### 2.24. Netherlands

In 2000, the Dutch Government released documents of science and research policy which focused on responsiveness of research system to national needs, research as an opportunity, investment in knowledge for future, increase in career paths for creative young researchers and research users as major focus of research policy and interaction between research system and industry in line with document of supportive policies and practices of the Dutch Government. These activities include recruitment and retention of talented researchers, expansion of industrial innovation, modification of market failure in investment in private R&D, interaction and cooperation, exchange of knowledge

**Table 2. Ranking of countries in terms of R&D/GNP ratio**

Ranking	Country	R&D/GNP (%)
1	Sweden	3.76
2	South Korea	2.82
3	Japan	2.8
4	United States	2.63
5	Swiss	2.6
6	Germany	2.41
7	France	2.25
8	Italy	2.41
9	Netherlands	2.08
10	England	1.95
11	Denmark	1.95
12	Taiwan	1.81
13	Australia	1.8
14	Canada	1.66
15	Ireland	1.61
16	Belgium	1.6
17	Austria	1.53
18	Singapore	1.13
19	Russia	0.88
20	India	0.73
21	South Africa	0.7
22	China	0.66
23	Mexico	0.33
24	Malaysia	0.24
25	Thailand	0.13

between different actors, improvement of balance between general research and industry, heavy investment in R&D during 2000–2005 (575 million euros), super wages which are directly related to R&D as a tax adjustment in R&D companies. In 2000, 336.7 million euros were allocated to R&D mobilization in SMEs (Goldin & Peinert, 2007). Results of these supports are summarized in Table 1.

### 2.25. India

The Indian Government considers technology as a strategic variable for national development. Allocation of 9 billion dollars to research and development in the last five-year plan indicates commitment of India to activities which focus on legal, financial and tax supports; consulting supports in engineering and management (currently, about 30000 scientists, engineers and technicians are employed in more than 300 engineering and consulting firms); support for technology commercialization; technology development fund and promotion of research cooperatives. Results of these supports are summarized in Table 1.

By reviewing R&D supportive policies and practices of 25 industrialized and newly industrialized countries and outcomes of these policies and practices, this section analyzes data to answer the next questions.

### 2.26. Outcomes of supportive policies and practices used in the studied countries

By analytical review of supportive policies and practices used by the studied governments, common features are observed which are discussed below:

**Table 3. Ranking of countries in terms of knowledge production criteria (These criteria include the number of scientists, the number of scientific publications and the number of patents)**

Ranking	Country	R&D criteria/GNP (%)
1	Japan	22.44
2	United States	21.23
3	Germany	7.64
4	England	5.85
5	France	4.72
6	South Korea	4.09
7	Canada	3.59
8	Australia	3.35
9	Swiss	2.87
10	Denmark	2.64
11	Netherlands	2.62
12	Russia	2.42
13	Italy	2.28
14	Belgium	2.02
15	Taiwan	1.76
16	Ireland	1.75
17	Singapore	1.71
18	China	1.61
19	Sweden	1.57
20	Austria	1.52
21	South Africa	0.95
22	India	0.83
23	Mexico	0.31
24	Thailand	0.12
25	Malaysia	0.1

- (1) All the studied countries use main resources which are common in planned budgets and annual budgets to support research and development. A majority of financial resources of universities, public research institutes, ministries and organizations which are involved in research and development are supplied by these resources.
- (2) Continuation of research using state funds is important for extension of innovation (degree of importance of research budgets to GDP and its effect on R&D criteria is considered in the statistical analysis); however, governments cannot finance all areas of research and development.
- (3) Most of the studied countries emphasize innovation. Innovation is clearly observed in all policies and practices related to science and technology.
- (4) Depending on its particular conditions, a country provides certain supportive practices. This diversity results from economic, social and cultural structures of countries.
- (5) Despite economic, social, cultural, political and geographical differences, all the studied countries have common goals such as:
  - (A) Highlighting research and development and its key role in economic and social development
  - (B) Focusing on innovation and competitiveness
  - (C) Believing that the government is a good support; however, it fails in implementing researches

**Table 4. Efficiency of scientists and engineers in knowledge production**

	Country	$\frac{A}{C}$	$\frac{B}{C}$
1	South Africa	1.86	1.87
2	Germany	32.54	17.39
3	Austria	1.85	2.109
4	Australia	0.92	3.51
5	United States	38.44	45.38
6	England	11.80	15.73
7	Italy	2.40	12.44
8	Ireland	0.51	0.48
9	Belgium	0.83	2.07
10	Thailand	4.63	3.45
11	Taiwan	12.25	0.35
12	China	30.84	20.002
13	Denmark	0.90	1.23
14	Russia	28.33	29.21
15	Japan	73.40	8.940
16	Singapore	0.13	0.50
17	Sweden	10.41	9.95
18	Swiss	2.004	2.30
19	France	7.63	9.96
20	Canada	1.78	7.32
21	South Korea	23.12	2.106
22	Malaysia	1.92	3.26
23	Mexico	2.20	8.948
24	Netherlands	2.59	4.96
25	India	14.16	56.63

- (D) Emphasizing commercialization of R&D outcomes, protection of intellectual property, technology-based entrepreneurship and support for SMEs and clusters
- (E) Using subsidies, tax incentives, and financial support funds
- (F) Emphasizing training of young researchers and mobility of researchers between scientific and industrial centers
- (G) Focusing on globalization of research and development

To develop a framework of analytic review of research and development in 25 industrialized and newly industrialized countries and collect the required data to complete and achieve useful results, it is essential to analyze the collected data. For this purpose, raw data and ranking of countries in terms of R&D criteria in 2004 are individually and collectively presented to determine relative ranking of top countries.

As the Table 2 shows, Sweden, South Korea, Japan, and the United States, respectively, have the highest R&D/GNP ratio, while South Korea has the lowest R&D/GNP ratio.

As Table 3 shows, Japan, the United States, Germany, England, and France, respectively, have the highest knowledge production criteria, while Malaysia has the lowest knowledge production criteria.

**Table 5. Ranking of efficiency of scientists and engineers in knowledge production in 25 countries studied**

Ranking	Country	$\frac{B}{C}$ (ascending)
1	India	53.63
2	United States	45.38
3	Russia	29.21
4	China	20.002
5	Germany	17.39
6	England	15.73
7	Italy	12.44
8	France	9.96
9	Sweden	9.95
10	Mexico	8.948
11	Japan	8.940
12	Canada	7.32
13	Netherlands	4.96
14	Australia	3.51
15	Thailand	3.45
16	Malaysia	3.26
17	Swiss	2.30
18	Austria	2.109
19	South Korea	2.106
20	Belgium	2.07
21	South Africa	1.87
22	Denmark	1.23
23	Singapore	0.50
24	Ireland	0.48
25	Taiwan	0.35

To develop a comparative table and calculate variables, it is essential to calculate two equations  $\frac{A}{C}$  (efficiency of native scientists and engineers in knowledge production) and  $\frac{B}{C}$  (efficiency of native scientists and engineers in recorded knowledge production) (Table 4).

$$\frac{A}{C} = \frac{\text{number of patent application}}{\text{number of native scientists and engineers}}$$

$$\frac{B}{C} = \frac{\text{number of scientific publications}}{\text{number of native scientists and engineers}}$$

As the Table 5 shows, India has the highest number of publications relative to the number of scientists (53.63) and Taiwan has the lowest number of publications relative to the number of scientists (0.35).

As the Table 6 shows, Japan has the highest number of patents relative to the number of native scientists, while Singapore has the lowest number of patents relative to the number of native scientists (0.13).

**Table 6. Ranking of efficiency of native scientists and engineers in knowledge production (recorded and written) in 25 countries studied**

Ranking	Country	$\frac{A}{C}$ (ascending)
1	Japan	73.40
2	United States	38.44
3	Germany	32.54
4	China	30.84
5	Russia	28.33
6	South Korea	23.12
7	India	14.16
8	Taiwan	12.25
9	England	11.80
10	Sweden	10.41
11	France	7.63
12	Thailand	4.63
13	Netherlands	2.59
14	Italy	2.40
15	Mexico	2.20
16	Swiss	2.004
17	Malaysia	1.92
18	South Africa	1.86
19	Austria	1.85
20	Canada	1.78
21	Australia	0.92
22	Denmark	0.90
23	Belgium	0.83
24	Ireland	0.51
25	Singapore	0.13

**Table 7. Number of R&D scientists and engineers in 25 countries studied**

Ranking	Country	C (number of R&D scientists and engineers per million)
1	Japan	4,909
2	United States	3,676
3	Australia	3,357
4	Denmark	3,190
5	Swiss	3,006
6	Canada	2,719
7	France	2,659
8	England	2,448
9	Ireland	2,319
10	Singapore	2,318
11	Belgium	2,272
12	Netherlands	2,219
13	South Korea	2,193
14	Germany	2,083
15	Austria	1,627
16	Taiwan	1,400
17	Italy	1,318
18	South Africa	1,031
19	Sweden	826
20	Russia	587
21	China	454
22	Mexico	214
23	India	149
24	Thailand	103
25	Malaysia	93

This Table 7 shows ranking of countries in terms of the number of scientists per million people.

As the Table 8 shows, Sweden, Ireland, and Switzerland have the highest number of R&D scientists and engineers relative to total population, while China, Thailand, and India have the lowest number of R&D scientists and engineers relative to total population.

**Table 8. The number of R&D scientists and engineers to total population in 25 countries studied**

Ranking	$\frac{C}{D}$	Country
1	91.77	Sweden
2	59.46	Ireland
3	41.17	Swiss
4	25.40	Germany
5	20.08	Austria
6	16.61	Australia
7	13.61	Netherlands
8	12.33	United States
9	8.39	Canada
10	6.16	Taiwan
11	5.87	Denmark
12	5.46	Singapore
13	4.26	France
14	4.07	Russia
15	3.85	Japan
16	2.28	Italy
17	2.21	South Africa
18	2.18	Belgium
19	2.03	Mexico
20	0.45	South Korea
21	0.40	England
22	0.36	Malaysia
23	0.34	China
24	0.16	Thailand
25	0.13	India

### 3. Discussion and conclusion

This study compared outcomes of competitive supports on knowledge production criteria in different countries. As the results showed, Japan, the United States, Germany, England, and France, respectively, had the highest size of criteria. This implies that their support practices were more suitable. This study showed that increase in per capita income of an industrialized country influences R&D/GNP ratio. Moreover, the increase in the number of R&D scientists' engineers influences the number of scientific, technical, and research publications. The increase in R&D/GDP ratio increases patent application of native citizens. Analysis of data available in the comparative table related to efficiency of native scientists and engineers and population of the studied countries provides certain useful information for planners and producers of knowledge worldwide.

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