# Exploring the Relationships Between Science and Technology Input and Output Indicators: A Comparison Between Developed, Fast Developing World and Turkey

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*Abstract*--**From a scientometric perspective, this paper aims to discuss the relationships between the financial Science and Technology input indicators like R&D Expenditures and Payments for external technology transfer (royalties and License fees) to the Science and Technology output indicators like Patents/patent applications and receipts from technology transfer (Royalties and licence fees). Although the efficiency of R&D and economical returns of R&D spendings has always been questioned and searched by the scholars from developmental economics, scientometrics and technology and innovation management fields, the performance of developing countries for utilizing R&D investments is still worth searching. In this study, we explored the trends of and relationships between Science and Technology Input indicators like R&D expenditure, Payments (royalties and License fees) and Science and Technology output indicators like Patents/patent applications and receipts from technology transfer (Royalties and licence fees) for developed countries that are called as G-7 countries, fast developing countries that are called as BRIC (Brazil, Russian federation, India and China) and Turkey. Based on the data of World Bank, S&T input and output indicators are analyzed by calculating the spatial-index of each country for each indicator between the years of 1996-2010 where data of all countries are available. Indicators are tested for their correlations. The differences between G-8, BRIC countries and Turkey are also outlined.**

## İ. INTRODUCTİON

For nations, sustainable economic growth that leads to economic development and improved welfare of people is dependent on the science and technology development [11][6]. Science and technology development is enabled by technology transfer (internal by R&D or external by technology purchasing, imports, licensing etc.) (Çetindamar, 2012). The effectiveness of technology transfer defines the absorption capacity of a country and opens the path to produce high value added, competitive innovative products and services that can create high and sustainable national income in the long run. To improve this capacity, national S&T or innovation policies of these countries generally refer to funding R&D, educating technicians and researchers etc. However technology transfer is a hard task for developing countries that have limited financial and human and knowledge resources within their dependent and follower position. So these countries are in need of

S&T indicators are classified as input and output indicators, and sometimes called as innovation indicators. Input indicators like expenditures, researchers, high-tech imports and license payments are utilized for understanding the orientation of an economy for S&T development. On the other hand, output indicators refer to the performance of a country in terms of R&D expenditures and high tech imports are expected to create patents, high-technology exports, or receipts from licenses are importanre funded by governments In order to design effective policies and setting appropriate goals for technological capability building and improving innovativeness, well-structured, systematic, objective and comparable information on the is needed as inputs to strategy making processes on national level. These inputs can be obtained through systematic evaluation of the results of the previous policies and actions by measuring the recent economic performanceç.

To help nations to position themselves in terms of their Science and Technology development in the global scale, it is not sufficient to compare or benchmark the level of the investments to Science and Technology development. Understanding the level of productivity and return on investment of S&T inputs also matters, as these returns points out the national competency for providing the sustainability of science and technology development that can lead to economic growth, development and welfare.

Not only the level and quantity of the resources of S&T, but also the maturity of the S&T development processes that enable effective use of limited resources is a determinant of technological advancement for developing countries. Linkages between science and technology development inputs and outputs must also be considered by policy makers of developing countries to utilize their limited resources in the maximum level. R&D spendings and technology payments are believed to have a positive effect on economic growth. Hence, the efficiency of spending in technology has always been questioned and searched by the scholars from various fields. Also the level of patents and patent applications, high-tech exports also attracted the attention of scholars. The evaluation of R&D productivity is an important issue that has received significant attention in the literature [33]. However, there is only limited research on the relationships between the S&T inputs and outputs from a developing perspective. So there is still room for resarch about these relations and the benchmark the linkages of S&T inputs and outputs in developed and developing world. In a previous research [39], we tried to examine the relationships between R&D inputs and economic growth indicators of GDP and GNI. To complement this study, we felt the need of understanding the interactions between S&T input and output indicators, and differences between developed and developing countries. These studies can provide hints to national S&T policy design processes and priority setting in developing countries.

In this context, this paper aims to discuss the relationships of Science and Technology input and output indicators developed, developing countries and explore the differences between developed and developing countries in terms of the productivity and return on investment of inputs in science and technology development activities. In the study, relationships between Science and Technology Input indicators (R&D expenditure, Payments (royalties and License fees)) and Science and Technology output indicators (Patents/patent applications, receipts from technology transfer (Royalties and licence fees), High-tech exports) are explored for developed countries that are called as G-7 countries (USA, UK, Canada, France, Italy, Germany and Japan), fast developing countries that are called as BRICS (Brazil, Russian federation, India, China and South Africa) and Turkey. Some indicators of S&T that are mentioned are excluded (like Nr and % of Researchers from input indicators nd Nr and quality of Scientific publications from output indicators). Based on the data of World Bank [40], relationships between the S&T input and output indicators are tested using correlation analyses between the years of 1996-2010 where data of all countries are available. Relationships between input and output indicators are also explored for their significant differences between G-7, BRICS countries and Turkey are also explored. The basic aim of this research is to to find out the productivity of science and technology development activities in these countries and point out the importance of the "process" of S&T development in technological capability building.

In the first section of the paper, a brief literature background on Science and Technology (S&T) indicators, R&D indicators as inputs and outputs are presented. Also in this section, theoretical discussions on the relationship between R&D input and output ndicators are mentioned. Methodology section includes sampling, data analysis methods and limitations of the study. Findings present the outputs of the correlation analyses calculations and comparisons of studied countries together in terms of the linkages between ST input and output indicators. In conclusion, the findings are discussed and complementary topics for further research are recommended.

## İI. SCİENCE AND TECHNOLOGY INDİCATORS

Various scholars emphasized the emphasize the significant impact science and technology development activities in promoting sustainable economic growth and development in both developed and the developing countries [25] [9] [6] [14] [5] [3]. The new economic growth theory paid a considerable amount of effort to 'endogenize' technological change in the production function [31] [1]. According to the "endogenous growth theory", endogenously determined technological change generates sustainable economic growth, assuming constant returns to innovative research [16]. Expenditures on research and development (R&D), skilled human resources, scientific and technical infrastructure and a good education system are among the triggering activities of and technology production that enable economic growth and improvement of the welfare of people [23]. That is why governments in developed and developing world have supported and even funded R&D, however all these funders explored the ways to understand the return on investment of S&T expenditures for achieving the effective usage of their limited resources.

Multiple studies tried to explore and link S&T investments to productivity and economic growth [14]. Freeman played a key role in developing an analytical basis of science policy and became one of the designers of the Frascati Manual. Frascati manual of OECD has been a guide to measure and compare R&D efforts in terms of inputs and outputs across countries [27] [19]. In this manual, previous measurements about R&D and external technology transfer by licensing is examined for evaluating innovation policy, though they are not sufficient to understand the innovative performance of an economy. In accordance with the definitions of Frascati Manual [27], National Science Foundation USA (2010), European Innovation Scoreboard of EU (Pro-Inno Europe, 2012), Eurostat of EU [9], innovation related statistics and in particular, science and technology statistics on indicators are grouped in two broad categories as inputs and outputs of R&D [27] [3].

In fact the quantitative analysis of trends, performance and structures in technology development have various technical artefacts and processes [20] [34] [22] that makes them complex to understand and elaborate. Referring to the 'scientometrics' which is the quantitative approach of the development of science, Grupp (1992) collected specification measures and derived integrated indicators in his "technometrics" approach, Also indicators that are related to the diffusion of every type of innovation are measured by innovation surveys (like Yale Survey and Business R&D Intensity Survey (USA), NISTEP and CMU Survey (Japan), The Community Innovation Surveys (CIS) (EU)) [19] [13] that measure the detailed level and type of innovation activities and characteristics of innovative firms, hence they generate valuable, useful data sets [9] [24].

### *A. R&D input and output as S&T Indicators*

R&D is an activity involving significant transfers of resources among units, organisations and sectors and especially between government and other performers. Therefore, it is important for science policy advisors and analysts to know who finances R&D and who performs it [27]. In this sense, measurable input indicators include R&D investments (expenditures), Human Resources in R&D (researchers), Payments as License Fees or royalties, while output indicators generally refer to patents and patent applications, scientific technical publications, receipts from license fees or royalties, and as well high technology exports.

Technological innovation, often fueled by government-led research and development (R&D), has been the driving force for industrial growth. The best opportunities to improve living standards come from science and technology. Countries able to access, generate, and apply scientific knowledge have a competitive edge. And high-quality scientific input improves public policy (WorldBank, 2013).

In science and technology indicators reported by World Bank Data bank [40], input indicators and their explanations and sources are listed as follows:

1) S&T Input Indicators:

For statistical purposes, two main inputs are measured: R&D expenditures and R&D personnel that are normally measured on an annual basis [27].

- Research and development expenditure (% of GDP): Expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development. "R&D expenditures/investments is among the four indicators of "Knowledge creation" dimension. Figures on R&D expenditures have become the most widely cited national indicators for technological performance and some basic and widely accepted measures like the Lisbon target of a GERD/GDP ratio of 3 per cent have been effective over the years [38] [12][7]. According to Frascati Manual [27], there are 2 types of R&D expenditure The basic measure is "intramural expenditures"; i.e. all expenditures for R&D performed within a statistical unit or sector of the economy. Another measure, "extramural expenditures", covers payments for R&D performed outside the statistical unit or sector of the economy. For R&D purposes, both current costs and capital expenditures are measured.
- Royalty and license fees, payments (BoP, current US$) : Royalty and license fees are payments and receipts between residents and nonresidents for the authorized use of intangible, nonproduced, nonfinancial assets and proprietary rights (such as patents, copyrights, trademarks, industrial processes, and franchises) and for the use, through licensing agreements, of produced originals of prototypes (such as films and manuscripts). Payments for licence fees address the level of activities that are directed to technology transfer through the common way of licensing. Intellectual Property (IP) regimes are closely tied to payments for licence fees and royalties [4] [8] [17].
- Researchers in R&D (per million people): Researchers in R&D are professionals engaged in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned. Postgraduate PhD students (ISCED97 level 6) engaged in R&D are included. R&D personnel data is based on physical persons ("headcount") , full-time equivalent (FTE) or person-years spent on R&D.
- Technicians in R&D (per million people) : Technicians in R&D and equivalent staff are people whose main tasks require technical knowledge and experience in engineering, physical and life sciences (technicians), or social sciences and humanities (equivalent staff). They participate in R&D by performing scientific and technical tasks involving the application of concepts and operational methods, normally under the supervision of researchers.

2) S&T Output Indicators:

- Patent grants and applications : Patent applications are worldwide patent applications filed through the Patent Cooperation Treaty procedure or with a national patent office for exclusive rights for an invention--a product or process that provides a new way of doing something or offers a new technical solution to a problem. A patent provides protection for the invention to the owner of the patent for a limited period, generally 20 years. Most countries have systems to protect patentable inventions. The international Patent Cooperation Treaty (PCT) provides a two-phase system for filing patent applications. An applicant files an international application for which eligible countries are automatically designated. The application is searched and published, and, optionally, a supplementary international search or preliminary examination can be conducted. In the national or regional phase the applicant requests national processing of the application and initiates the national search and granting procedure in the countries where protection is sought. International applications under the treaty provide for a national patent grant only—there is no international patent. The national filing represents the applicant's seeking of patent protection for a given territory, whereas international filings, while representing a legal right, do not accurately reflect where patent protection is sought. Resident filings are those from residents of the country concerned. Nonresident filings are from applicants abroad. For regional offices such as the European Patent Office, applications from residents of any member state of the regional patent convention are considered nonresident filings. Some offices (notably the U.S. Patent and Trademark Office) use the residence of the inventor rather than the applicant to classify filings. Patents are used to measure innovation resulting from investment in the R&D sector. [41] [37].
- Scientific and technical journal articles: refer to the number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences. (National Science Foundation, Science and Engineering Indicators.) Scientific and technical article counts are from journals classified by the Institute for Scientific

Information's Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Counts are based on fractional assignments; articles with authors from different countries are allocated proportionately to each country. The SCI and SSCI databases cover the core set of scientific journals but may exclude some of local importance and may reflect some bias toward English-language journals.

- Royalty and license fees, receipts (BoP, current US$) : Royalty and license fees are payments and receipts between residents and nonresidents for the authorized use of intangible, nonproduced, nonfinancial assets and proprietary rights (such as patents, copyrights, trademarks, industrial processes, and franchises) and for the use, through licensing agreements, of produced originals of prototypes (such as films and manuscripts
- High-technology exports (current US$; % of manufactured exports): High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery. The internalisation of the economy has different aspects such as the increasing foreign trading with technology-intensive goods, production in foreign countries, or the growing R&D activities in foreign countries [22]. The method for determining high-technology exports was developed by the Organisation for Economic Co-operation and Development in collaboration with Eurostat. It takes a "product approach" (as distinguished from a "sectoral approach") based on R&D intensity (expenditure divided by total sales) for groups of products from Germany, Italy, Japan, the Netherlands, Sweden, and the United States. Because industrial sectors specializing in a few high technology products may also produce low-technology products, the product approach is more appropriate for international trade. The method takes only R&D intensity into account, but other characteristics of high technology are also important, such as knowhow, scientific personnel, and technology embodied in patents. Considering these characteristics would yield a different list.

*B. Relationship between R&D input and output indicators*

The evaluation of R&D productivity is an important issue that has received significant attention in the literature [33]. R&D input and outputmeasures and their interaction associate with the level and variability of future earnings and operating cash flows were investigated by Pandit et al. [29]. The associations that these scholars examined helped to determine whether the relationship between firm-level innovation and operating performance is conditional on the success of a firm's R&D efforts. (The key incremental contribution of this study was the examination of the relationship between the variability of future earnings and patent count and citations that has not been examined in prior studies [33]. The relationship between the level of future earnings and patent count and citations has also been examined in some other studies [15] [21]. R&D intensity has a positive impact on the rate of patenting [42]. Firms with highly cited patents exhibit superior and less volatile (i.e., more stable) net income and operating cash flows over the next five years [33]. On the other hand innovation is positively related to human capital in the R&D sectors and national knowledge stock [30]. Odagiri [26] analyzed the correlation among R & D expenditures (per sales revenue), patent royalty payments (per sales revenue), and the rate of sales growth, for Japanese manufacturing corporations; and found positive correlations between R&D intensity and sales growth.

For US, number of patent applications is found to be strongly correlated with the level of output or, in the case of capital goods industries, with investment in physical capital Schmookler [32]. From Turkey, Guloglu and Tekin [16] found strong evidence that relations between R&D intensity, technological change, and the rate of growth of output are all positive, and they suggested that R&D intensity triggers innovation measured as triadic patents, while this latter enables economic growth, as presumed by endogenous growth theory. There are also studies which conluded that the larger OECD countries increase their innovation through R&D investments, while lower income OECD countries promote their domestic technological progress by using the know-how generated in other OECD countries [36].

## III. METHODOLOGY

Study aimed to explore the relationships of Science and Technology input and output indicators developed, developing countries and Turkey, and find out the differences between developed and developing countries in terms of these relationships

The sample includes 13 countries that are in different stages of development [10] [2]

- G-8 (USA, UK, France, Italy, Germany, Canada, Japan, Russia) countries that are taken as a sample of developed countries
- BICS (Brazil, India, China and South Africa – BRICS excluding Russian Federation ) countries (which are taken as sample of emerging national economies or fast developing countries)
- Turkey as a fast growing economy

We used the latest available version of the World Bank's Databank on Economic Policy and S&T Indicators [40]. For most of the countries, data on R&D expenditures and Payments for IP, Patent Applications and Publications is available only for years between 1996-2010. Based on the data of World Bank [40], relationships between the S&T input and output indicators are tested using regression analyses between the years of 1996-2010 (where data of all countries are available).

Indicators that are used as variables in the study is as follows:

1) Science and Technology Input indicators
   a) R&D expenditure: (% of GDP): (Source:United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics (Variable : EXPENDITURE)
   b) Payments (royalties and License fees): (BoP, current US$) : Data are in current U.S. dollars. (source: International Monetary Fund, Balance of Payments Statistics Yearbook and data files.) (Variable: PAYMENT)
2) Science and Technology output indicators
   a) Patent applications, residents: Numbers (Source:World Intellectual Property Organization (WIPO), World Intellectual Property Indicators and www.wipo.int/econ_stat.) (Variable: PATENTAPP)
   b) Receipts from technology transfer (Royalties and licence fees (BoP, current US$): Data are in current U.S. dollars. (International Monetary Fund, Balance of Payments Statistics Yearbook and data files.) (Variable: RECEIPT)
   c) High-tech exports : (current US$) : Data are in current U.S. dollars. (United Nations, Comtrade database.) (Variable: EXPORT)

The previous research results show that firms with highly cited patents exhibit superior and less volatile (i.e., more stable) net income and operating cash flows over the next five years [33]. Due to the limitations on availability of previous years' data, from this respect we used the data of the 2 years after the S&T input indicators for analyzing Patents and exports for output indicators.

Limitations:

- Though it is more useful to consider a country's business R&D performance by sector, rather than looking at aggregated figures [35], we used averages by country instead of sectors due to lack of historical data especially in developing countries. Hence, the qualitative side of the S&T inputs are not considered, the total numbers for S&T indicators are referred without any qualitative analysis on them. Only R&D spending levels do not really present these outputs' actual performance and effectiveness and other innovation expenditures that can be derived from innovation surveys worth analyzing. Therefore there is the risk of taking only the quantitative measures as the economic yields from each field of science and technology can differ a lot, while the impact of an investment can be much higher or lower than another.
- Some indicators of S&T that are mentioned are excluded (like Nr and % of Researchers from input indicators nd Nr and quality of Scientific publications from output indicators).

## IV. FINDINGS

Research is based on the following two groups of Countries:

- Group 1: G8 countries (USA, UK, Japan, Germany, France, Canada, Italia and Russia Federation) as a sample of high-income, developed economies,
- Group 2: BICS Countries excluding Russian Federation (that has no sufficient data available for analysis) and Turkey as a sample of developing economies.

Three different models are developed for each country. $R^2$ value is the explanatory variable of the models. It is a statistical measure that shows the level (as a percentage) that the changes in dependant variable (Y) are explained by independent variable/s ($X_{1,}$ $X_2$). For example, the $R^2$ value of France is found as 0,682, meaning that the changes in High-Tech Exports can be explained by the impact of / changes in Royalty and Licence Payments in the past periods.

Multi-regression models are constructed. The validity of the model is tested by ANOVA, and then two independent variables in each model is tested by –test.

### *A. MODEL 1: Impacts of R&D Expenditure and Payments (royalties and License fees) on High Tech Exports*

In this model, R&D Expenditures as % of GDP ($X_1$) and technology Payments (royalties and License fees, BoP, current US$) ($X_2$) are explored for their impacts on High Tech Exports (current US$) (Y). Data of countries between the years of 1996 and 2010 was provided from Database of World Bank [40]. The main assumption was that the impact of ($X_1$) and ($X_2$) will take place with a lag of 2 years. Therefore, R&D Expenditure ($X_1$) and Royalty Fees Payment ($X_2$) data between 1996 – 2008 and High Tech Exports (Y) data between 1998 – 2010 are used.

TABLE 1. IMPACTS OF R&D EXPENDİTURE ($X_1$) AND ROYALTY FEES PAYMENT ($X_2$) ON HİGH TECH EXPORTS (Y) FOR GROUP 1: G8 COUNTRİES

| G8 Countries | Model | Interpretation of the Model | R2 Value | Interpretation of Coefficients(X1, X2) |
|---|---|---|---|---|
| Canada | $Y = 2{,}86.10^{10} - 2{,}1.10^{9}X_1 + 0{,}055X_2$ | Non-significant | 0,008 | Non-Significant For both coefficients |
| France | $Y = 1{,}73.10^{11} – 6{,}1.10^{10}X_1 + 10{,}012X_2$ | significant | 0,682 | Significant only for $X_2$ |
| Germany | $Y = -3{,}99.10^{11} + 2{,}11.10^{11}X_1 + 0{,}686X_2$ | significant | 0,726 | Significant only for $X_1$ |
| Italia | $Y = -3{,}50.10^{10} + 5{,}38.10^{10}X_1 – 0{,}561X_2$ | significant | 0,649 | Significant only for $X_1$ |
| Japan | $Y = -5{,}10.10^{10} + 6{,}51.10^{10}X_1 – 3{,}369X_2$ | Non-significant | 0,212 | Non- Significant for both coefficients |
| Russia Federation | $Y = -7{,}90.10^{8} + 4{,}22.10^{9}X_1 + 0{,}327X_2$ | Non-significant | 0,383 | Non- Significant for both coefficients |
| UK | $Y = 6{,}48.10^{11} – 3{,}1.10^{11}X_1 – 4{,}255X_2$ | significant | 0,437 | Significant only for $X_1$ |
| USA | $Y = 9{,}91.10^{11} – 3{,}2.10^{11}X_1 + 1{,}175X_2$ | significant | 0,584 | Significant only for $X_1$ |

TABLE 2. IMPACTS OF R&D EXPENDİTURE ($X_1$) AND ROYALTY FEES PAYMENT ($X_2$) ON HİGH TECH EXPORTS (Y) FOR GROUP 2: BICS COUNTRİES AND TURKEY

| BICS Countries and Turkey | Model | Interpretation of the Model | $R^2$ Value | Interpretation of Coefficients ($X_1$, $X_2$) |
|---|---|---|---|---|
| Brazil | $Y = -4{,}5.10^8 + 4{,}65.10^9 X_1 + 1{,}799X_2$ | Non-significant | 0,336 | Significant for both coefficients |
| Republic of China | $Y = -1{,}5.10^{11} + 2{,}59.10^{11} X_1 + 16{,}641X_2$ | significant | 0,972 | Significant for both coefficients |
| India | $Y = -2.10^9 + 3{,}64.10^9 X_1 + 7{,}103X_2$ | significant | 0,938 | Significant for both coefficients |
| South Africa* | $Y = 9{,}06.10^8 + 0{,}544X_2$ | significant | 0,459 | Significant only for $X_2$ |
| Turkey | $Y = 7{,}7.10^8 – 4{,}9.10^8 X_1 + 1{,}871X_2$ | significant | 0,719 | Significant Only for $X_2$ |

** As the data on R&D Expenditures of South Africa is not available, the model is constructed by only one variable (Royalty and License Payments.)*

As can be seen from Table 1, in G8 countries, Canada, Japan and Russian Federation, R&D Expenditure (X1) and Royalty Fees Payment (X2) do not have any relationship with high Tech exports (Y). However, among other G8 countries,

- In France, Technology Payments (royalties and License fees, BoP, current US$) ($X_2$) has a positive impact on High-Tech Exports (Y).
- In Germany, Italy, UK and USA, R&D Expenditure ($X_1$) has impact on High-Tech Exports (Y). It must be noted here that, while R&D Expenditure ($X_1$) has positive impact on High-Tech Exports in Germany and Italy, from the model it is concluded that these expenditures has negative impact in UK and USA.

For the BICS countries, no significant relationship is found between two variables and one independent variable in Brazil, while both dependent variables of R&D Expenditures and Technology Payments have showed significant impacts on High-Tech exports in China and India. However in Turkey, only technology payments is found to have significant impact on high-tech exports. As the data on R&D Expenditures was not available for South Africa, only the relationship between technology payments and high-tech exports were tested and a positive impact of Payments on high-tech exports was found.

*B. MODEL 2: Impacts of R&D Expenditures and Payments (royalties and License fees) on Nr. Of Scientific Publications*

In this model, R&D Expenditures as % of GDP (X1) and Payments (royalties and License fees, BoP, current US$) (X2) are explored for their impacts on Publications (number of scientific and engineering articles published) (Y). Data of countries between the years of 1996 and 2010 was provided from Database of World Bank [40]. The main assumption was that the impact of (X1) and (X2) will take place with a lag of 2 years. Therefore, R&D Expenditure (X1) and Payments (royalties and License fees) (X2) data between 1996 – 2008 and Publications (Y) data between 1998 – 2010 are used in the model.

As can be seen from Table 3, only in one G8 country (UK), R&D Expenditure (X1) and Royalty Fees Payment (X2) do not have any relationship with nr of scientific publications (Y). However, among other G8 countries, in Italy, Japan, Russian Federation and USA, both R&D Expenditure (X1) and Technology Payments (royalties and License (X2) have significant impacts on nr of scientific publications (Y).

- In Italy and Japan, impact of R&D Expenditure (X1) on scientific publications (Y) is positive, while in Russian Federation and USA, it is negative.
- Impact of Technology Payments (royalties and License (X2) on publications is positive in İtaly and USA, while it is negative in Japan and Russia.

In the remaining G8 countries, Canada, France and Germany, only Technology Payments (royalties and License (X2) is found to be significantly and positively affecting scientific publications (Y).

For the BICS countries, it is notable that only in China both independent variables have positive impact on Publications. Both in Brazil and India, R&D Expenditures (X1) do not have a significant impact on nr of scientific publications, while Payments (royalties and License fees) have significant positive impacts. In Turkey, R&D Expenditures (X1) have positive impacts on publications. For South Africa, one dependent variable model showed a significant impact of Payments (royalties and License fees) on Y.

TABLE 3. IMPACTS OF R&D EXPENDİTURE (X1) AND ROYALTY FEES PAYMENT (X2) ON PUBLİCATİONS (Y) FOR GROUP 1: G8 COUNTRİES

| G8 Countries | Model | Interpretation of the Model | R2 Value | Interpretation of Coefficients (X1 and X2) |
|---|---|---|---|---|
| Canada | $Y = 21434{,}36 – 1605{,}04X_1 + 1{,}36.10^{-6}X_2$ | significant | 0,944 | Significant only for $X_2$ |
| France | $Y = 26050{,}67 + 1426{,}95X_1 + 6{,}71.10^{-7}X_2$ | significant | 0,553 | Significant only for $X_2$ |
| Germany | $Y = 37102{,}3 + 1769{,}38X_1 + 3{,}32.10^{-7}X_2$ | significant | 0,588 | Significant only for $X_2$ |
| Italia | $Y = -7070{,}68 + 22876{,}05X_1 + 4{,}29.10^{-6}X_2$ | significant | 0,967 | Significant for both coefficients |
| Japan | $Y = 45606{,}66 + 7904{,}99X_1 -1{,}3.10^{-6}X_2$ | significant | 0,811 | Significant for both coefficients |
| Russia Federation | $Y = 22439{,}74 – 5923{,}43X_1 – 9{,}4.10^{-7}X_2$ | significant | 0,780 | Significant for both coefficients |
| UK | $Y = 78464{,}94 – 17226{,}1X_1 – 2{,}4.10^{-7}X_2$ | Non- significant | 0,339 | Non- Significant for both coefficients |
| USA | $Y = 287339{,}90 – 42664{,}1X_1 + 1{,}35.10^{-6}X_2$ | significant | 0,933 | Significant for both coefficients |

TABLE 4. IMPACTS OF R&D EXPENDİTURE ($X_1$) AND ROYALTY FEES PAYMENT ($X_2$) ON PUBLİCATİONS (Y) FOR GROUP 2: BICS COUNTRİES AND TURKEY

| BICS Countries and Turkey | Model | Interpretation of the Model | $R^2$ Value | Interpretation of Coefficients ($X_1$ and $X_2$) |
|---|---|---|---|---|
| Brazil | $Y = 2448,54 – 484,31X_1 + 5,38.10^{-6}X_2$ | significant | 0,589 | Significant only for $X_2$ |
| Republic of China | $Y = 4917,26 + 12457,35X_1 + 6,38.10^{-6}X_2$ | significant | 0,994 | Significant for both coefficients |
| India | $Y = 705,13 + 11425,25X_1 + 1,04.10^{-5}X_2$ | significant | 0,924 | Significant only for $X_2$ |
| South Africa* | $Y = 2120,52 + 5,44.10^{-7}X_2$ | significant | 0,916 | Significant only for $X_2$ |
| Türkiye | $Y = -3024,72 + 17226,58X_1 + 8,85.10^{-7}X_2$ | significant | 0,508 | Significant only for $X_1$ |

** As the data on R&D Expenditures of South Africa is not available, the model is constructed by only one independent variable (Royalty and License Payments.)*

*C. MODEL 3: Impacts of R&D Expenditures and Payments (royalties and License fees) on Nr. Of Patent Applications*

In this model, R&D Expenditures as % of GDP ($X_1$) and Payments (royalties and License fees, BoP, current US$) ($X_2$) are explored for their impacts on the number of Patent Applications , residents (Y). The main assumption was that the impact of ($X_1$) and ($X_2$) will take place with a lag of 2 years. Therefore, R&D Expenditure ($X_1$) and Payments (royalties and License fees) ($X_2$) data between 1996 – 2008 and Patent applications (Y) data between 1998 – 2010 are used in the model.

As can be seen from Table 5, in France and Germany, R&D Expenditures ($X_1$) and Payments (royalties and Licenses) ($X_2$) do not have any significant relationship with nr of Patent applications (Y).

- In Japan differs from the other countries in this model. While the impact of R&D Expenditures ($X_1$) is positive on Patent applications, the impact of Payments (royalties and License ($X_2$) is negative.
- In Canada, Russian Federation, UK and USA, Payments (royalties and License ($X_2$) were found to have positive significant impacts on Patent Applications (Y). Only in UK, payments have negative impacts on (Y).
- The analysis for Model 3 could not be conducted for Italy as the available data on Patent Applications was not sufficient for time-series.

For the BICS countries, it is seen that in Brazil, non of the independent variables of R&D Expenditures (X1) and Payments (royalties and Licenses) (X2) have significant impacts on Patent applications (Y). In China and India, only Payments (royalties and Licenses) (X2) have positive impacts on patent applications, residents. In Turkey, both of the independent variables had showed significant positive impact on (Y).

TABLE 5. IMPACTS OF R&D EXPENDİTURE (X1) AND ROYALTY FEES PAYMENT (X2) ON PATENT APPLİCATİONS (Y) FOR GROUP 1: G8 COUNTRİES

| G8 Countries | Model | Interpretation of the Model | R2 Value | Interpretation of Coefficients (X1 , X2) |
|---|---|---|---|---|
| Canada | $Y = 896,29 + 1567,91X_1 + 1,38.10^{-7}X_2$ | significant | 0,624 | Significant only for $X_2$ |
| France | $Y = 21617,18 – 3721,19X_1 + 1,61.10^{-7}X_2$ | Non-significant | 0,393 | Non- Significant for both coefficients |
| Germany | $Y = 56417,04 – 3002,66X_1 – 8,3.10^{-8}X_2$ | Non-significant | 0,158 | Non- Significant for both coefficients |
| Italia | Not enough available data on patent applications for time series. | | | |
| Japan | $Y = 302834,8 + 67433,22X_1 – 1,3.10^{-5}X_2$ | significant | 0,931 | Significant for both coefficients |
| Russia Federation | $Y = 15622,15 + 6529,26X_1 + 1,59.10^{-6}X_2$ | significant | 0,463 | Significant only for $X_2$ |
| UK | $Y = 41898,25 – 6786,38X_1 – 1,4.10^{-6}X_2$ | significant | 0,819 | Significant only for $X_2$ |
| USA | $Y = 183624,7 – 30251X_1 + 4,94.10^{-6}X_2$ | significant | 0,959 | Significant only for $X_2$ |

TABLE 6. IMPACTS OF R&D EXPENDİTURE (X1) AND ROYALTY FEES PAYMENT (X2) ON PATENT APPLİCATİONS (Y) FOR GROUP 2: BICS COUNTRİES AND TURKEY

| BICS Countries and Turkey | Model | Interpretation of the Model | $R^2$ Value | Interpretation of Coefficients ($X_1$ , $X_2$) |
|---|---|---|---|---|
| Brazil | $Y = -378,32 + 4799,43X_1 – 5,5.10^{-7}X_2$ | Non-significant | 0,336 | Non- Significant for both coefficients |
| Republic of China | $Y = 16465,53 – 21179,4X_1 + 2,98.10^{-5}X_2$ | significant | 0,992 | Significant only for $X_2$ |
| India | $Y = -3362,46 + 7349,49X_1 + 4,35.10^{-6}X_2$ | significant | 0,898 | Significant only for $X_2$ |
| South Africa* | $Y = 725,87 + 9,94.10^{-8}X_2$ | Non-significant | 0,036 | Significant only for $X_2$ |
| Türkiye | $Y = -1892,65 + 4009,13X_1 + 2,68.10^{-6}X_2$ | significant | 0,932 | Significant for both coefficients |

** As the data on R&D Expenditures of South Africa is not available, the model is constructed by only one independent variable (Royalty and License Payments.*

## V. CONCLUSİON

Exploring the characteristics and trends of S&T input and output indicators can provide insights to the return on investment levels and technological capability development in countries. Though excluding the political frameworks like national innovation systems, national S&T policies and education policies, and economical performance indicators like GDP and GNI in such research effort possibly cause some insensitivities of findings, time-related impacts of efforts' linkages with economic growth and wealth creation.

In developed countries, impact of Payments for Licenses and IP on High Tech Exports seems to less than the developing economies. This finding can be linked to the differences in technological dependency levels. For the EU member countries of G8, impact of R&D expenditures is significant on High-tech exports, while it is not in other economies. This may be due to the current exports are resulted from the R&D performance in past periods (more before than 2 years). Significance of impacts of R&D expenditures and Payments for licenses and royalties on Publications is more often in developed countries when compared with developing economies.

On the other hand, relationships between Payments for licenses and royalties and patent applications are more considerable when compared to relationships between R&D expenditures and patent applications in both developed and developing countries. This result may be due to the fact that return of R&D expenditures as patents requires a longer term than utilizing licensing and needs further research.

Also, in some countries this impact of payments for licenses is negative in some developed countries (Japan, UK). In this respect, it is worth analyzing whether licensing challenges or demotivates R&D efforts in these countries.

It is true that scientometrics aims to represent the multiple facets of scientific activity in models of use to science policy makers [43] [18], using advanced, robust quantitative tools and methods. Despite all these advantages and benefits, it must be noted that S&T input and output indicators are not sufficient to explaint the process of innovation. But still, though they need customized interpretations, the findings of this study can help the national policy makers to have an overall understanding about the motives of relationships between S&T inputs and outputs, and differences between countries from different levels of national income.

To fully explore the implications of them for S&T policies, further research on the efficiency and effectivenes of innovation processes has to be explored. As discussed in previous research, the main and most challenging gap between developed and developing world in terms of technology development and innovativeness has its roots in investment, financial funding, human resources base. However, developing countries S&T policies must cover not only increasing the level of S&T inputs but also the action plans for the improvement of the processes, systems and structures of S&T development in technological capability building. Governance plays a major role here to link, integrate and synchronize the S&T efforts as well as monitoring and auditing the resource allocation and usage in S&T activities in the country. In this sense, offering financial incentives and physical and information infrastructure must be taken as necessary but not sufficient for expanding technology development capability in these countries.

Hence, improving the capabilities that are required for higher level of effectiveness in innovation processes like project management, R&D management, strategic technology management, and higher utilization of entrepreneurial capacity must be prioritized in the agenda of developing countries' policy makers and companies and institutions should be encouraged to apply intense and focused programmes on learning and acquiring these competencies.

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