Relationship between Economic Development and Intellectual Production

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The level of economic development affects the design of different systems. At the country level, scientific outputs are related to the research and developmentexpenditures.In this study,the relationship between economic development and intellectual production was investigated. In this study following research questions were addressed: 1. Is there any meaningful relationship between GDP and the number of patents? 2. Is there any meaningful relationship between GDP and the number of scientific publications? 3. Is there any correlation between R&D expenditures and patent production? 4. Is there any correlation between R&D expenditures and the number of scientific publications?In addition to these research questions, this paper focuses on the changes of economic development and intellectual production indicators throughout time. As a result, it was seen that countries show continuous improvement in years, both for economic development indicators and intellectual production indicators.Findings also showed that Luxembourg, USA, Switzerland, Norway and Israel are far beyond form other countries in terms of national income per person, Scandinavian countries distinctively separated from other countries especially in terms of the number of national patents per population and Switzerland, Sweden, Israel, Denmark and Finland share the first rows in the number of publications per population ranking.

Keywords: *Economic development, intellectual production, research and development expenditures, scientific outputs.*

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1. Introduction

It is widely accepted that countries' scientific and technological progress and Research and Development (R&D) expenditures are related to the economic development levels. The measure of development level for countries,at first, had been natural capital, which is about the wealth of natural resources, rich oil deposits, fertile soils, etc. However, productivity of countries, which includes human capital, physical capital and natural capital, has been taking the place of pure natural capital [1]. The measurements of development levels are accepted as GDP (Gross Domestic Products) and GNP (Gross National Products). GDP is defined as the market value of goods and services produced within a selected geographic area (usually a country) in a selected interval of time (often a year). It is generally about outcomes rather than processes. Although GNP has similar meaning with GDP, multinational corporations are only calculated by GDP. GNP is a more local quantity[2].

Developed countries have large investments on R&D. At the same time, their scientific and intellectual production has been increasing year by year. The most important issues of science policy in each country are the structure and efficacy of R&D activity and its relation to GDP [3].The challenges in cross-national comparisons of R&D expenditure and publication output were also reported in the literature [4].It is also mentioned that some factors, such as the coverage and comparability of countries in the *Web of Science*, differences in national research systems, may affect the validation and comparison [4].

With this study, the relationship between the indicators of economic development (R&D expenditures, GDP) and intellectual production (number of national and triadic patents, and number of scientific publications) was investigated.

2. Literature Review

There are too many publications in the literature that point out the relationship between GDP and science and technology production and expenditures. One of the prior works about this relationship was written by Teitel in 1994 [5]. He used mathematical methods to calculate the relationship, and found statistically significant and meaningful results between patents, R&D expenditures, country sizes and per-capita incomes.

Ye's study [6] found the strongest relationship between country development level and scientometric criteria. The correlation between GDP and scientific production was determined for 24 countries by using IMF, WIPO and UNESCO data. However, the author indicated that the results of study were based on only one year-data (2001) and further studies wereneeded to confirm these results.

Another study in the literature presented a model to test the relationship between R&D expenditures and number of patents, by evaluating case studies in the literature [7]. As a result, a strong positive correlation determined between R&D expenditures and patent applications was found. In addition to this, it was pointed out that the numbers of patents also differ from country to country.

A report [8] indicated that levels of R&D spending were interrelated to levels of economic growth. Findings showed that R&D intensities were temporarily influenced by the levels of GDP growth. However, the development patterns differ strongly among the countries depending on governance structure, policy priorities, and systematic features like industry and academic structures, which means "one size fits all" approach doesnot fit for all the countries.

A new indicator to analyse mean structural differences of different fields was found out in another study [3]. A meaningful correlation was determined between GDP and number of publications in the longitudinal studies for countries. However, no direct relationship between GDP and information production of countries was found. It was noted in this study that R&D expenditures actually did not depend on real needs.However, one should note that,rich countries can always afford to spend more money on scientific researchthan poor countries.

Olwan[9] focused on the correlation between intellectual property systems (IP systems) of countries and their development levels. This paper investigated developing countries from the point of effectiveness of their IP systems and its effects to their economies. As a result, it was found that there was no meaningful correlation between IP systems and economic development levels of developing countries.

Some studies in the literature concentrated on different effects of scientific outputs. Inone of these studies [10], scientific output and its relationship with knowledgeeconomy were examined in 10 South East Asian countries. This study [10] found that there was a strong relationshipbetween scientific output and knowledge economy index among the South East Asian countries. In a more recent study [11], the empirical relationship between educationalindicators and research productivity in top twenty nations of the world in terms of number of publications, citations and patents was examined.The results revealed that educational indicators wereimportant to increase research productivity.

Many previous studies also found that there can be meaningful correlations between economic power and information production. However, it should not to be forgotten that these kinds of evaluations can change from country to country. The situation for The Organisation for Economic Co-operation and Development (OECD) countries is investigatedby this study.

3. Methodology and Data Sources

This study analyses the related data belong to 34 OECD countries. The main aim of this research is to understandthe relationshipbetweenthe indicators of economic developmentand intellectual production.The term "intellectual production" in this study is defined as the number of publications and patents. Patents were also examined according to their types, which were national and triadic. "Economic development" indicators were identified asR&D expenditures and GDP.It would be interesting to see that whether different development levels of countries affect intellectual production. To achieve the aim of this paper, the following research questions areinvestigated:

- Is there any meaningful relationship between GDP and the number of patents (national and triadic)?
- Is there any meaningful relationship between GDP and the number of scientific publications?
- Is there any correlation between R&D expenditures andpatent production?
- Is there any correlation betweenR&D expenditures and the number of scientific publications?

All of the OECD countries were selected to test correlations. GDP per capita, R&D expenditures, and number of patents dataweregathered from*OECDiLibrary'sNational Accounts, Main Science and Technology Indicators* and *OECD Patent Statistics* databases (http://www.oecd-ilibrary.org).The number of scientific publications was collected from *Thomson Reuters' InCites*. The 34 members of OECDwere very different than the others, in terms ofpopulation size. Therefore, all of the indicators were normalized according to population size. The population statistics were also obtained from OECD databases. The data of thestudy showed normal distribution after the normalization process, so the Pearson's correlation analysis was chosen for the correlation tests.To be able to use the Pearson's correlation analysis,median values of all indicators were calculated. Moreover, economic development and intellectual production indicators within a 30-years period (1981-2010) were also analysed within the scope of this study.
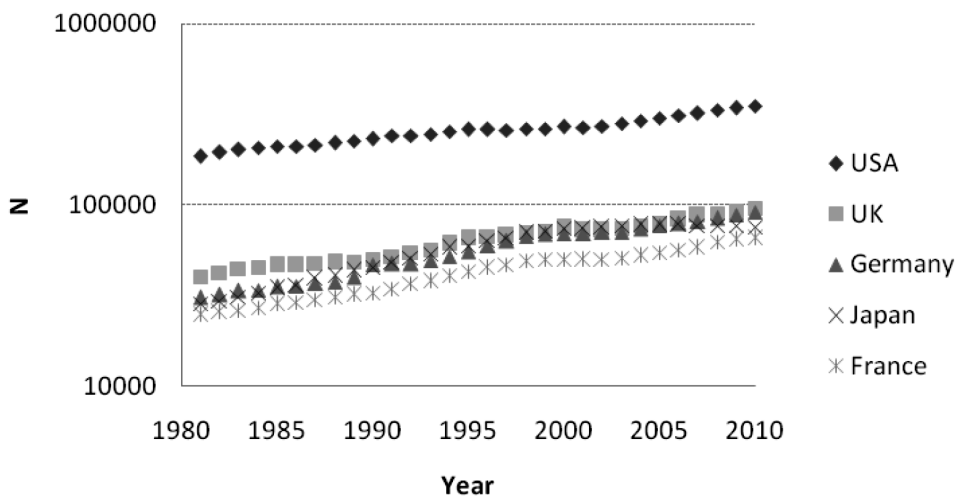
3. Findings

Figure 1

The five most productive countries by year

Table 1

Number of publications by periods

Countries	Periods					
	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010
Australia	57,003	64,710	80,299	105,033	124,051	178,197
Austria	15,721	18,099	23,432	33,888	42,152	52,999
Belgium	24,162	27,977	36,265	48,874	59,658	78,829
Canada	116,329	142,088	165,738	173,180	194,304	261,703
Chile	3,730	4,970	6,366	8,580	12,968	21,299
Czech Republic	3	221	7,678	20,804	26,852	40,551
Denmark	20,498	23,258	29,680	37,546	42,780	53,720
Estonia	4	19	1,112	2,683	3,376	5,621
Finland	15,909	19,060	25,802	34,855	40,435	47,907
France	132,255	155,129	193,356	241,844	258,656	307,133
Germany	165,666	197,023	251,162	328,050	361,529	423,944
Greece	6,062	9,240	14,347	22,070	33,159	50,123
Hungary	14,676	14,746	15,200	19,193	22,824	27,225
Iceland	362	557	1,038	1,457	2,077	3,243
Ireland	5,389	6,451	8,539	12,662	17,187	28,684
Israel	29,505	33,540	39,046	47,096	52,838	59,191
Italy	59,818	78,038	112,544	151,205	186,869	243,143
Japan	156,819	205,040	271,717	346,284	381,107	383,844
Korea	2,025	5,766	17,592	52,950	105,304	171,983
Luxembourg	132	131	253	408	713	1,866
Mexico	5,344	7,108	11,590	21,327	31,172	43,782
Netherlands	43,218	57,910	77,438	94,728	108,303	141,569
New Zealand	12,137	13,334	15,905	21,379	24,551	33,165
Norway	13,247	14,676	19,136	24,041	28,787	42,801
Poland	24,621	28,511	32,039	44,412	63,356	89,239
Portugal	1,700	3,341	6,554	12,948	22,790	39,335
Slovak Republic	2	71	4,535	10,366	10,377	13,894
Slovenia	1	25	2,326	6,064	9,129	14,845
Spain	24,180	41,269	67,972	104,109	136,859	202,237
Sweden	40,932	49,107	59443	74,151	81,914	95,030
Switzerland	36,058	40,301	52635	67,649	77,618	102,996
Turkey	2,014	3,865	9175	22,249	53,971	97,619
UK	219,062	241,188	289777	352,238	375,505	450,002
USA	1,000,825	1,102,604	1245611	1,318,469	1,416,532	1,660,017

Today, OECD has 34 member countries [12]. It was seen that within the 30-years period that we have dealt in this study, these countries progressed at various levels, in terms of the GDP, R&D expenditures,number of patents, and number of scientific publications indicators. There is no doubt that this progress should be considered as normal.However, the number of publications had been increased enormously within the years (Figure 1& Table 1). Although this can be based on the regional development policy of citation indexes [13], there can be also different reasons for each country.

In Table 1, the number of publications of the 34 countries for a six period of five-year intervals was given. These numbers showed that the number of publications of the countries has been increasing over time. Although such amount of increase was not observed, it is known that the number of patents was also escalating. In addition to this, a substantial increase in the share of R&D expenditures and national incomes of the countries was also recognized. To be able to make meaningful comparisons, population information of the countries was used.

In Figure 2, the relationship between the number of publications per 1000 people and GDP per head was shown in the country level. The numbers in the Figure represents the median values of the 30-years data. Scandinavian countries (such as, Sweden, Denmark, Finland) were recognized in the Figure, in terms of both for the number of publications per 1000 people and GDP per head. Along with these countries, Switzerland and Israel were also came to the forth, in terms of the number of publications per population. On the other handLuxembourg, which has the highest national income, located in the bottom of
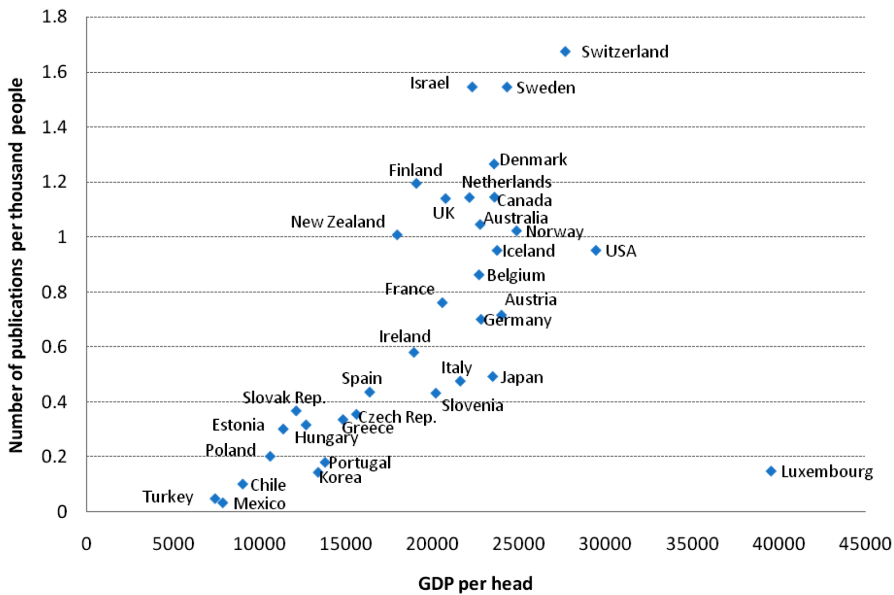

Figure 2

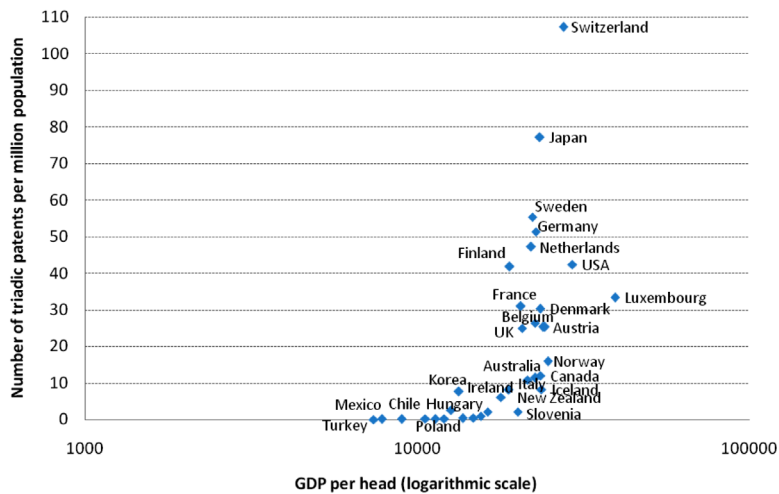**Number of publications per thousand people and GDP per head**

Figure 3

Number of triadic patents per million population and GDP per head

the list in terms of the number of publications per population, like Mexico, Turkey, Chile and Korea. In general, it was observed that, the countries which have the highest number of publications per 1000 peoplehave also the highest GDP per head.

Switzerland, Japan, Sweden, Germany, Netherlands, USA and Finland are leading countriesin terms of the number of triadic patent per country population. Turkey and Mexico has the worst performance in terms of the number of triadic patents per million population along with Estonia, Chile, Poland, Slovak Republic, Portugal, Greece and Czech Republic. These countries have less than one triadic patent per million population (Figure 3).

Luxembourg, Israel, Sweden, USA and Japan are the first five countries that have the highest R&D expenditures per person (Figure 4). The general trend shows that the countries (such as, Mexico, Turkey, Chile) that has limited shares for R&D expenditures has also the lowest numbers of publications per population.

In this study the values that were obtained from the division of R&D expenditures to triadic patent numbers were also compared. In other words, we tried to see the amount of money that the countries spend for triadic patents. It was found out that, Switzerland, Japan, Netherlands, Germany and Finland are the most remarkable countries in terms of the ability to transform the R&D expenditures to patents. Contrary to this, it was identified that Estonia, Turkey, Chile, Mexico and Poland are the ones which spent the most money to have a triadic patent. Figure 5 revealed that R&D expenditures per population and the number of triadic patents per million population are similar to each other.

Some statistical tests were conducted on the raw data that forms Figure 2, 3, 4 and 5.According to this, significant correlations were observed amongall of theeconomic development indicators and all of the intellectual production indicators (Table 2).
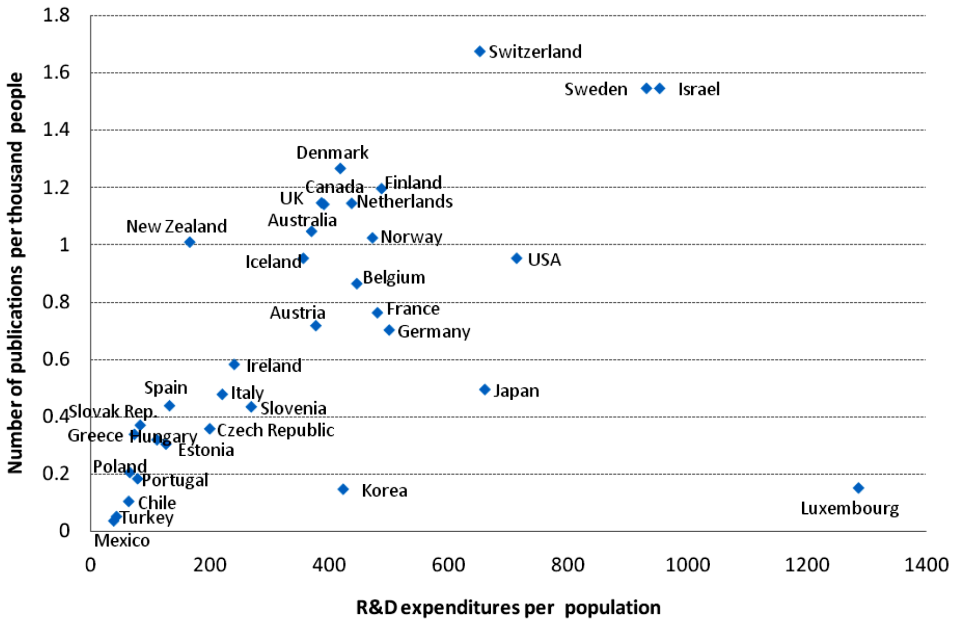
Figure 4

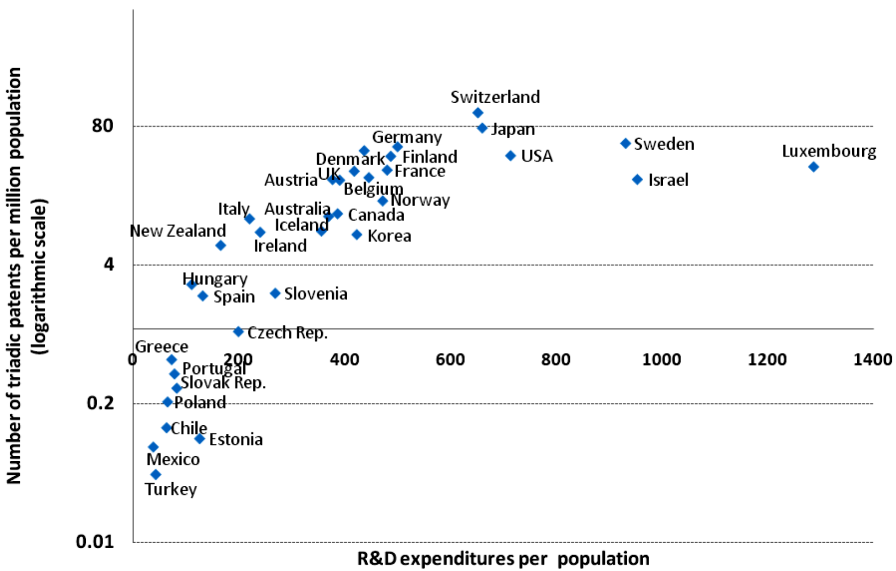**Number of publications per thousand people and R&D expenditures perpopulation**

Figure 5

Number of triadic patents per million populationand R&D expenditures perpopulation

Table 2

Pearson correlation coefficients among variables

Economic development indicators	Intellectual production indicators		
	Number of publications per population	Number of triadic patents per million population	Number of national patents per million population
GDP per head	0.561	0.604	0.567
R&D expenditures per population	0.524	0.667	0.674

Note: Correlations are significant at the 0.01 level.

In the light of the statistical evaluations, the answers of our research questions are as follows:

- There is a positive correlation between GDP per head and thenumber of publications per population was statistically significant (Pearsons'sr = .561, $p<.01$).
- There is a positive correlation between GDP per head and the numberof triadic patents per million population was statistically significant (Pearsons'sr = .604, $p<.01$).
- There is a positive correlation between GDP per head and the numberof national patents per million population was statistically significant (Pearsons'sr = .567, $p<.01$).
- There is a positive correlation betweenR&D expenditures per population and the number of publications per population was statistically significant (Pearsons'sr = .524, $p<.01$).
- There is a positive correlation betweenR&D expenditures per population and the number of triadic patents per million population was statistically significant (Pearsons'sr = .667, $p<.01$).
- There is a positive correlation betweenR&D expenditures per population and the number of national patents per million population was statistically significant (Pearsons'sr = .674, $p<.01$).

Conclusion

The relevant investments showthe importance given by the countries to science and R&D. There is no doubt that scientific productivity level of the countries is affected by not only qualified manpower but also by the economic development levels. Today, parallel to the increase of the importance of knowledge as an economic value, it is witnessed that most of the countries increase their investments for the production of theoretical knowledge which is aimed to be transformed to product and services and develop some new policies towards this goal. Patents and scientific publications, which are the products of labour-intensive work, clearly show the level of investments of the countries for science and

scientists. From this point, it can be said that competitive advantage of the countries is also parallel to their productivity level of information. From a systems approach perspective, when we take the expenditures as an input, the cost of patents and scientific publications, which can be counted as outputs, must be questioned.

With this research, it is seen that most of the "rich countries" make some important contributions to the world literature, in terms of publications and patents.In this context, some results of this study are similar to the literature. The correlation was observed between GDP per head, R&D expenditures per population, number of publicationsper population,number of national patents per million population and number of triadic patents per million population.

Country-based findings that we obtained from this research are as follows:

- It was seen that countries show continuous improvement in years, both for economic development indicators and intellectual production indicators.

- Luxembourg, USA, Switzerland, Norway and Israel are far beyond the OECD countries such as Hungary, Slovak Republic, Estonia, Poland, Chile, Mexico and Turkey in terms of national income per person. Similar situation is observed for the R&D expenditures of the countries. R&D expenditures of Luxembourg, Israel, Sweden, USA and Japan per person are 10 to 25-fold higher than that of Greece, Poland, Chile, Turkey and Mexico.

- Scandinavian countries such as Sweden, Finland, Denmark,distinctively separated from other countries especially in terms of the number of national patents per population.Switzerland and Japan are two leading countries in terms of the number of triadic patents per population.

- Switzerland, Sweden, Israel, Denmark and Finlandshare the first rows in the number of publications per population ranking, where Luxembourg, Korea, Chile, Turkey and Mexico are in the bottom among the 34 OECD countries.

Such topics like, the effect of the number of researchers in the countries to the number of research outputs, the contribution of the universities to the national intellectual production, the effects of patents to science, technology and innovation policies of the countries can be considered for the future studies.

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