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OECD ÜLKELERİNDE AR-GE HARCAMALARININ YENİLİK ÖLÇÜMLERİNE VE İKTİSADİ BÜYÜMEYE ETKİSİ

THE IMPACT OF R&D ON INNIVATION AND ECONOMİC GROWTH IN OECD COUNTRIES

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ÖZ

Bu çalışmanın amacı 23 OECD ülkesinin, 2007-2016 yılları arasındaki Ar-Ge faaliyetleri ile inovasyon çıktıları arasındaki ilişkiyi incelemektir. Bu amaca yönelik olarak Ar-Ge harcamasının gayri safi yurt içi harcama içerisindeki payı Ar-Ge faaliyetlerinin başat ölçütü olarak kabul edilmiştir. İnovasyon çıktıları olarak ülkelerin bilim ve mühendislik alanında hakemli dergilerde yayımlanan makale sayısı, patent başvuru sayıları (yerleşikler), mobil uygulama ve yazılım alanında kurulan girişim şirketi sayısı ve yüksek teknolojili ürün ihracatı verileri alınmıştır. Spearman Sıralama Korelasyonu testi ile analiz edilerek ampirik bir araştırma gerçekleştirilmiştir. Araştırmanın sonucunda, seçilen OECD ülkelerinde Ar-Ge harcamalarının gayri safi yurt içi hâsıladaki payı ile inovasyon çıktıları arasında pozitif ve istatistiksel olarak anlamlı bir ilişki olduğunu gözlemledik. Ar-Ge harcamalarının gayri safi yurt içi hâsıladaki payı görece daha yüksek olan OECD ülkelerinde hakemli dergilerde yayımlanan makale sayısı, patent başvuru sayıları, mobil uygulama ve yazılım alanında kurulan girişim şirketi sayısı ve yüksek teknolojili ürün ihracatı hacminin de yüksek olduğu tespit edilmiştir.

Anahtar Kelimeler: Araştırma ve Geliştirme, İnovasyon, Patent, Yüksek Teknoloji İhracatı.

ABSTRACT

The aim of this paper is to study the impact of research and development on innovation in 23 OECD countries by examining how innovation outputs vary among countries over the period 2007-2016. In order to examine the relation we use R&D expenditure as percentage of GDP as the main measure for R&D in a country and apply Spearman Rank Correlation to see how it is related to innovation outcomes such as number of articles published in science and engineering, number of patent applications by residents, number of start-ups in mobile apps and software, and high technology exports. We find that there exists a positive, statistically significant relation between innovation variables and R&D

expenditure (as % of GDP) in selected countries. OECD countries that have higher R&D expenditure (as% of GDP) tend to have higher number of scientific publications, higher number of patent applications, higher number of start-ups in mobile technologies and higher volume of high technology exports.

Keywords: Research and Development, Innovation, Patent, High TechnologyExport.

Introduction

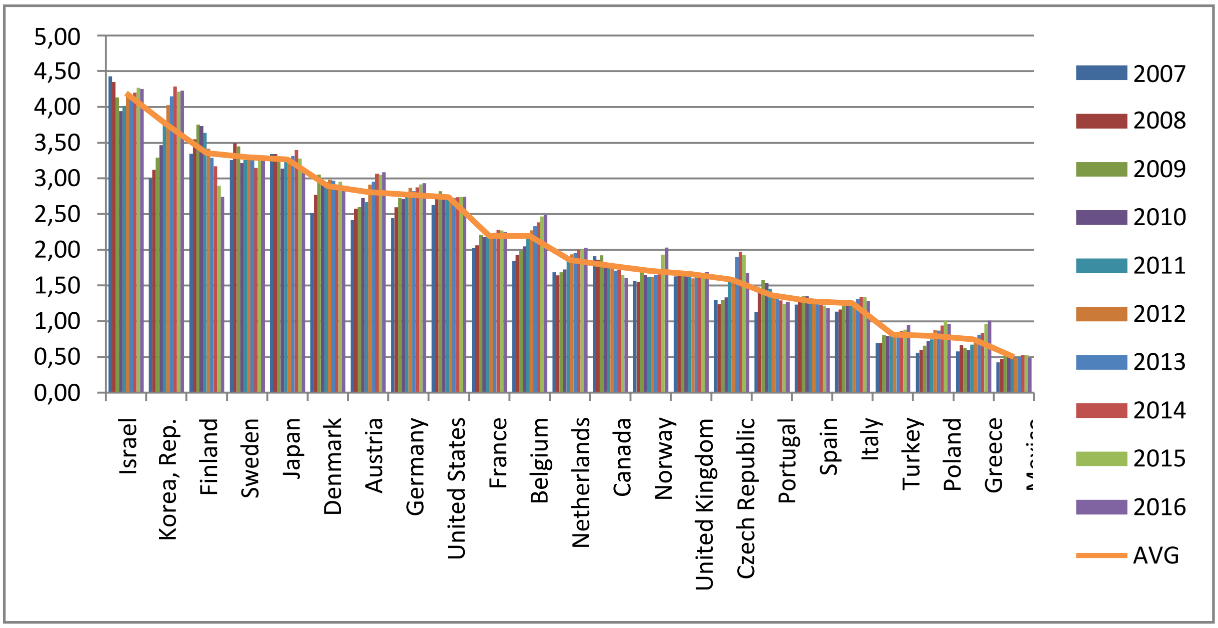
Over the last several decades, there has been great technological development and catching up in terms of economic growth around the world. Governments and private corporations have been looking for ways to increase their knowledge and adopt technological progresses to increase competitiveness and productivity. This has increased interest in studies on research and development and innovation in the academic field. In this research project, we aim to study the impact of research and development (R&D) on innovation and economic growth in OECD countries by examining how innovation outputs vary with R&D expenditure over the period 2007-2016.

Research and development is defined as creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications (OECD, 2015). R&D is generally performed in universities, publicly funded research institutions, private institutions and corporations. Innovation is recognized as a major incentive to economic growth in industrial, newly industrialized, and developing economies and also there is widespread agreement among most economists on the positive link between innovation and growth(Niranjala & Jianguo, 2015). Therefore how R&D contributes to innovation and growth is essential to asses for policy makers.

In order to study the link between R&D and innovation we will focus on 23 OECD countries4. We assume R&D expenditure as percentage of GDP is the main measure of level of R&D activities in a country. Graph-1 below demonstrates R&D expenditure as % of GDP in selected countries.

[4] Austria, Belgium, Canada, Czech Republic, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Israel, Italy, Japan, Korea, Mexico, Netherlands, Norway, Poland, Portugal, Sweden, Turkey, United States

Graph-1: R&D Expenditure (as % of GDP)



Source: OECD Science, Technology and R&D Statistics: Main Science and Technology Indicators (2018)

As we look at R&D as percentage of GDP, the mean for OECD countries is 2,18% by the year 2016. Average R&D Expenditure over the 10 year period is 2.12%. Israel, Korea have the highest R&D expenditure (% of GDP) whereas lower income countries such as Mexico, Greece, Turkey and Poland have the lowest R&D expenditure. Finland has experienced persistent and significant decrease after 2008. Czech Republic and Korea have significantly increased its expenditure persistently in the last few years. If the trend continues OECD average is likely to increase in the following years.

Following the assumption that R&D (% of GDP) is the main measure of level of R&D activities in a country, we further assume that innovation is measured by outputs such as number of articles published in science and engineering, number of patent applications by residents, and volume of high technology exports in a country. Through application of Spearman Rank Correlation, we examine how these innovation outputs are related to level of R&D in each country. Following the findings, we further examine how this might contribute to economic growth in OECD countries in the discussion section.

1. Literature Review

There are many studies that examine the relationship between R&D, innovation and growth. In this literature review, we discuss these previous findings. We also discuss previous scientific work regarding R&D expenditure and innovation outputs used in our model.

In early literature main endogenous growth theories such as that of Romer(1990), Aghion and Howitt(1996) suggest that R&D activities are the main driver of economic growth. However Jones(1995) argues that R&D focused growth models are inconsistent with time-series data from industrialized economies and that the long-run growth rate depends on parameters that are exogenous in the models.

In more recent studies, Inweke(2015) examines the link between R&D and economic growth among 66 developing countries within the period of 2000-2009 and finds that R&D expenditures have significant impact on economic growth in developing countries with higher and mid income levels, while there is no significant relationship between variables with lower and medium income levels. Guloglu & Tekin (2012) show that relations between R&D and innovation, R&D and economic growth, and economic growth and innovation are all positive and significant. Granger-causality test results also provide insights regarding the causal relationships among R&D, innovations and economic growth in high income OECD economies.

Another study on OECD countries is that of Falk (2007). He studies the impact of R&D expenditure on long term economic growth in OECD countries from 1970 to 2004. His research indicates that both the R&D expenditure ration of businesses to GDP and the share of R&D spending in the high tech sector have significant positive long-term effects on GDP per capita and GDP per hour. On the other hand, Samimi and Alerasoul (2009) study the impact of R&D on economic growth in 30 developing countries within 2000-2006 years and find that low R&D expenditure of developing countries have no significant impact on economic growth. Similarly Howard (2011) also studies impact of R&D on long term growth. He applies Bayesian Model Averaging to overcome uncertainity and examines the relation in 72 developing and developed countries. He finds that there is a positive effect of R&D investment on long term growth.

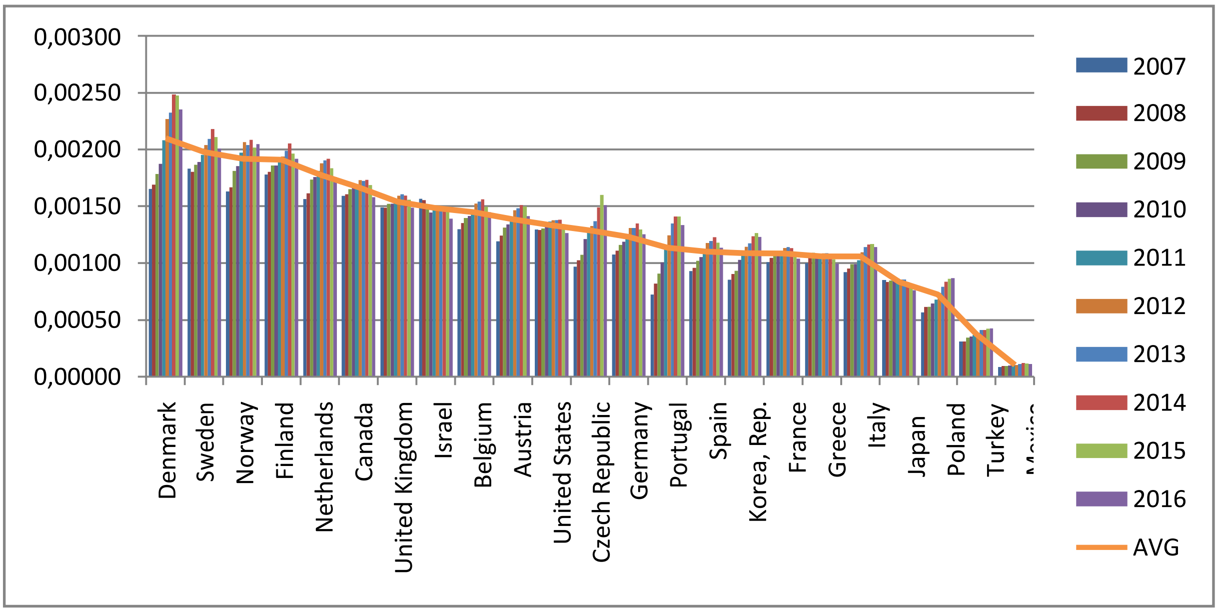
Bayarcelik & Tasel (2012) empirically examine the relationship between innovation and growth in Turkey by using endogenous economic growth theory. Using panel regression model with microeconomic data from chemical firms the relations between R&D expenditure, patents and GDP is investigated in Turkey. They find that there is a positive and significant relationship between variables. On another study on microeconomic data, Czarnitzki & Hussinger (2004) analyze the effect of public subsidies on R&D in German firms and its indirect impact on patent application as innovation output and find that publicly financed R&D increases productivity; hence increases growth.

Gocer (2013) studies effects of R&D expenditures on high technology exports in 11 developing Asian countries by using data of 1996-2012 period with panel data analysis. The results show that 1% increase in R&D expenditure increases high technology exports by 0.6%. Prodan(2005) using Kondo's linear model shows that the increase in R&D expenditure in business sector increases the number of patent applications more than initial increase in R&D expenditure. Zachariadis(2003) uses US manufacturing industry data to estimate three growth equations that relate R&D to patenting, patenting to innovation and innovation to economic growth. It shows that in all three cases there is a positive relationship among variables.

2. Data

In this study we aim to study the link between level of R&D and innovation outputs such as number of articles published in science and engineering, number of patent applications, number of start-ups in Mobile Apps and Software business, and high technology exports in OECD countries over the period of 2007-2016. There are 36 OECD countries, however due to insufficient data our sample is limited to 23 countries. We use annual data for the period of 2007-2016. Our data source for R&D expenditure is OECD Science, Technology and R&D Statistics. We used World Bank Database for innovation variables. Population data from the World Bank Database is also used to calculate per capita data to adjust for differences in size of population among countries.

Graph-2: Number of Articles Published in Science and Engineering(PP)



Source: National Science Foundation, Science and Engineering Indicators, World Bank (2018)

Academic publication is the main means of disseminating and validating research results(OECD, 2010). Number of publications in science and engineering is a fair measure of innovation and innovation capacity of a country as it tells a great deal about the active scientific manpower. For knowledge and technology intensive industries, collaboration between science and engineering researchers and corporations is the main source of creation of new applications.

Graph-2 above demonstrates number of articles published in science and engineering in OECD countries between years 2007-2016. From Graph-2 we observe that overall all countries have increasing number of articles published over the ten years. Apart from funds and grants, differences between countries maybe due to differences in number of universities and research institutions, number of research assistants and phd graduates, as well as quality of research personnel and degree of academic freedom in each country. European, mainly Nordic countries are the top countries with highest number of publications per capita whereas mid-income countries such as Turkey, Mexico, and Poland are countries with the lowest number of publications in science and engineering.

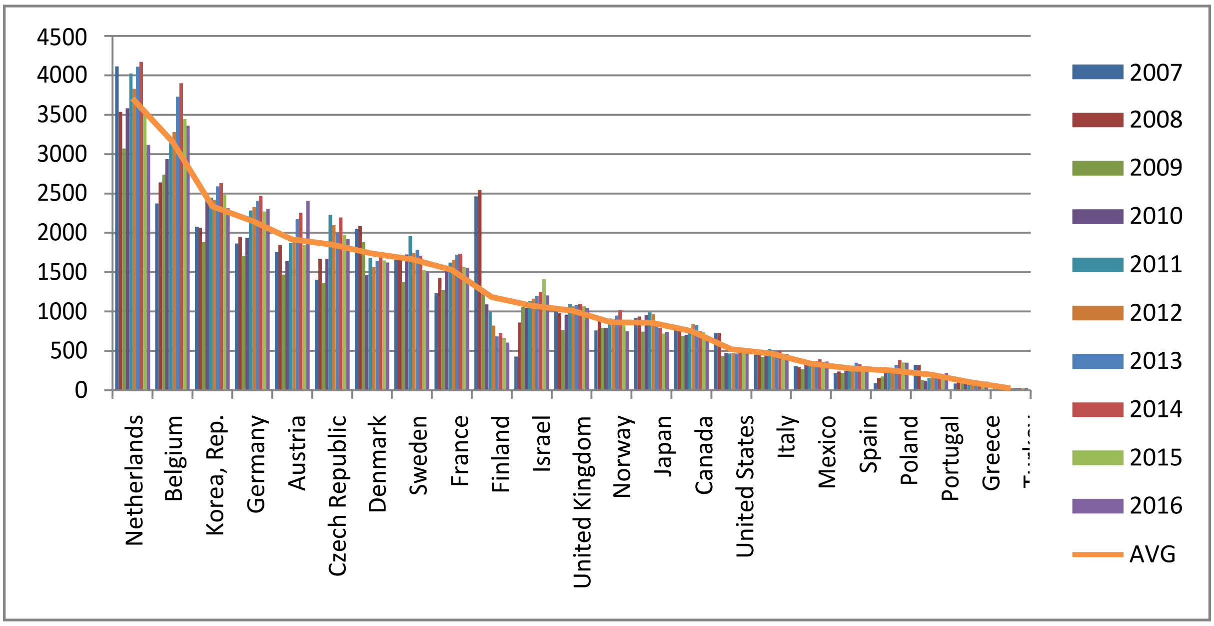
Even though number of articles published in science and engineering is a good indicator for innovative capacity, there are certain weaknesses attached. Quantity of publications does not specify whether the work conducted is an output of basic or applied research. Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of underlying foundation of phenomena and observable facts, without any particular application or use in view, whereas applied research is original investigation undertaken in order to acquire new knowledge (OECD, 2015). Applied research is more associated with development of new applications or products. Hence it might overstate the innovative nature or capability of the work.

High technology products mainly refer to products that are manufactured within aerospace, computers, pharmaceuticals, electrical machinery, chemistry, electronics and telecommunications industries(Sandu & Ciocanel, 2014). High technology exports are good measures of innovation as the production requires use of intensive knowledge of technology. Firms have high incentive to apply existing knowledge and create new technological applications to increase their competitiveness of exports.

High technology export (in constant USD) in selected OECD countries is given in Graph-3 below. When we look at countries overall we observe they experience a significant fall in high technology exports following 2008 global financial crisis. Finland has experienced a significant fall within the ten years. The key reason for this decline is that Nokia, a Finnish leading mobile technology and electronics company that had constituted major part of Finnish exports, has failed to catch up with technological developments and lost competitiveness in highly competitive and intense international market. European countries such as the Netherlands, Belgium, Germany and Republic of

Korea are the top countries with highest high technology exports whereas mid-income countries such as Turkey, Greece, Portugal, Poland, and Mexico have the lowest.

Graph-3: High Technology Exports (in constant USD, PP)

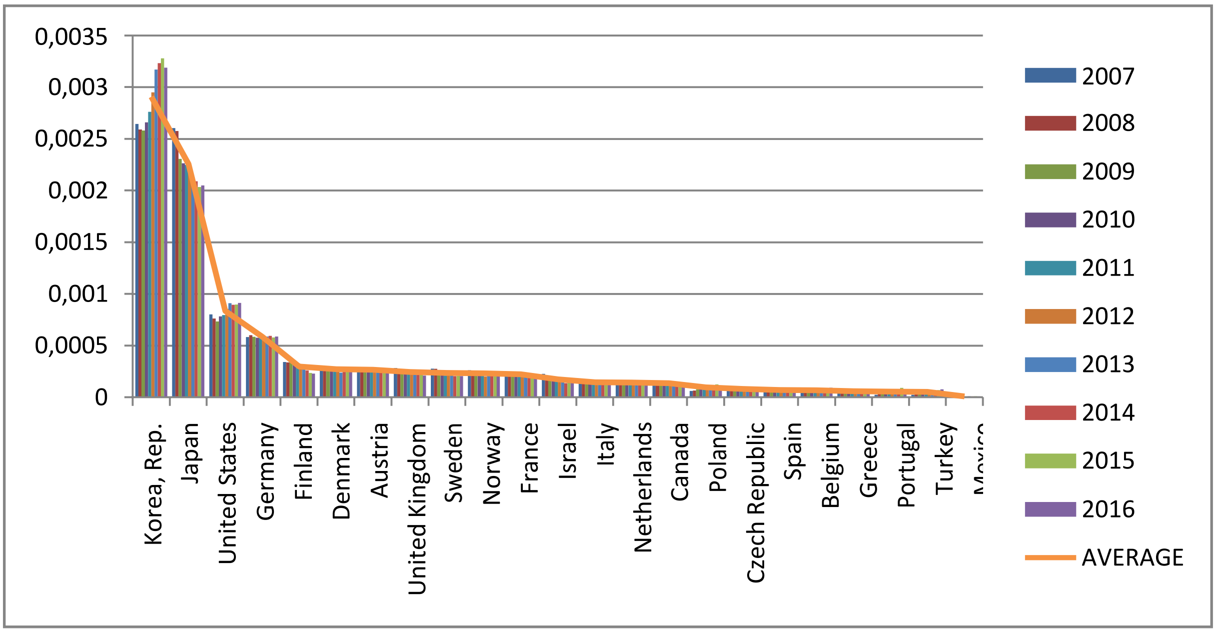


Source: United Nations, Comtrade database through the WITS platform,World Bank (2018)

High technology exports are widely accepted and used as a good measure of innovation. However there are also recent case studies that argue innovation might have less to do with changes in high technology exports in some countries. Labor market rigidness, trade and protectionism also affect the level of high technology exports. For instance, Haung, Zhang, Zhao & Varum show that low labor costs, change in trade and protections policies play a major role that explain the change in Chinese' high technology exports(2008). Beveren and Vandenbussche also studied and concluded that in Belgium and Slovenia product and process innovation has not increased the likehood of firms' export participation using innovation survey data(2010).

Patent is a right to knowledge asset and has been viewed as good measure for innovation for decades. It gives economic incentive to firms to innovate and increase productivity. It also indicates how many new applications, products are developed and that they may potentially lead to increase in creation of new business and sectors in the economy. We use patent application data rather than number of granted patents as there can be long timelags between the year applied for a patent and the year it is granted.

Graph-4: Number of Patent Applications by Residents (PP)



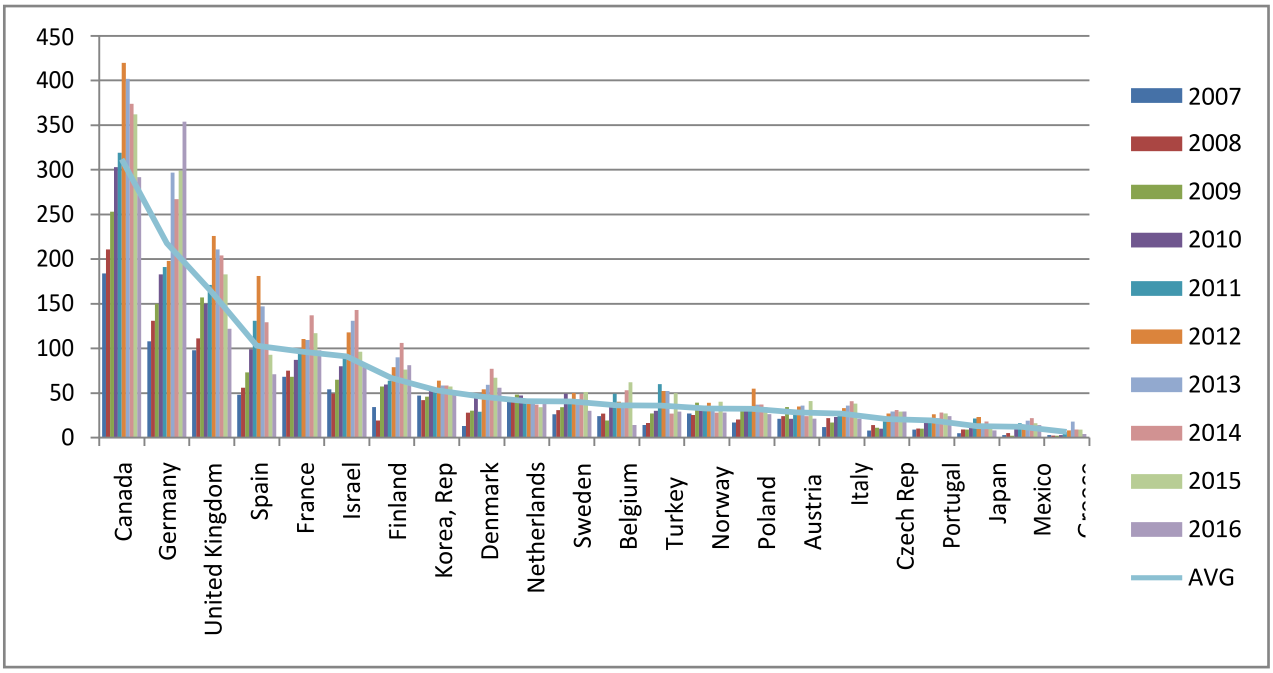
Source: WIPO, World Bank (2018)

Graph-4 above demonstrates number of patent applications by residents in OECD countries. We observe that Korea and Japan perform significantly better than the rest of OECD countries. They are outliers. This is due to the fact that Korea and Japan provide grants for patent application funded by government has been high over the 10 years(Sinha, 2008). Hence it is less costly to apply for patents by residents. USA and Germany follow them, with moderately high number of applications. However there is a huge gap between these countries and the rest. Differences among countries might be due to differences in regulations, patent laws and costs.

Even though there is a wide agreement that patent applications are good measures for innovation, there are also limitations. There are differences among countries in terms of patent laws and regulations. Such regulations might make it more costly in some countries while grants may work as subsidies in others. Secondly, not all innovations that materialize, for instance facebook, acquire patents and not all patents materialize in the market vice versa(Akcomak & Kalayci, 2016).

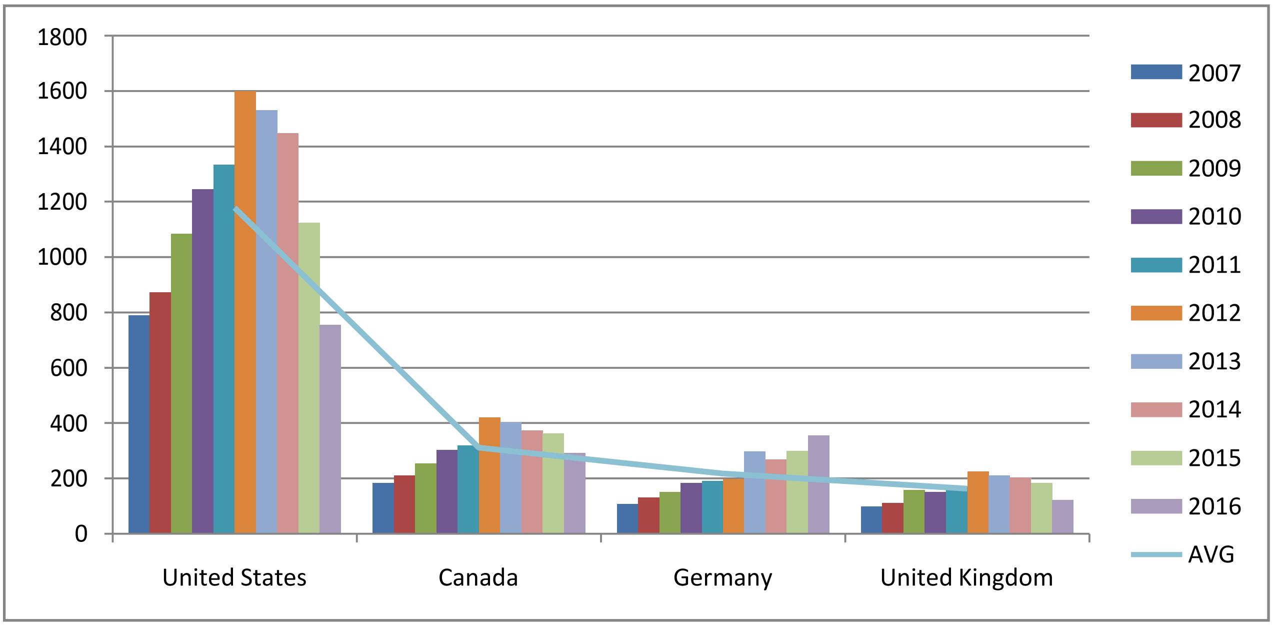
Many economists argue following Joseph Schumpeter(1934) that there is a positive link between a country's start-up rates and innovation as he defines entrepreneurs as innovators. Start-ups are by nature innovative and drive economic growth. ICT and mobile technology start-ups especially use existing knowledge to create new applications to find solutions to basic needs and necessities from daily life of the consumers to corporations. They also require, as well as increase, digital literacy of the users. For this reason they are good indicators for innovation.

Graph-5: Number of Start-Ups in Mobile Apps and Sofware in OECD Countries



Source: Crunchbase & DealRoom Start-Up Database (2018)

Graph-6: Top 4 Countries, Number of Start-Ups in Mobile Apps and Sofware in OECD Countries



Source: Crunchbase & DealRoom Start-Up Database (2018)

Graph-5 and 6 above demonstrates number of start-ups in Mobile Apps and Software category in OECD countries. We observe that the US[5], Canada, Germany and UK perform significantly better than the rest of the OECD countries. Number of start-ups tends to increase in almost all countries within the 10-year period. Differences among the countries may be related to different urbanization and digital literacy level.

One weakness of using start-up numbers as an innovation measure is that for one not all start-ups are innovative. A firm may copy and use the know-how of existing products and business models. Another weakness is that Crunchbase and DealRoom start-up databases where data is derived from, while are the most comprehensive databases for start-ups all around the world, may lack and understate regional data. Lastly, start-up ecosystem may vary from one country to another. For instance public and private grants and funds, political and social environment, competition and risks and start-up exit rates all differ across the countries.

In order to examine the relationship among variables we express the data as average over the period of 2007-2016[6]. Our methodology is to apply Spearman Rank Correlation to find the strength and direction of relation between the variables. Rank correlation (rs) is expressed as:

$$r_s = 1 - 6 \quad \frac{d^2}{(n^3 - n)};$$

where n is the number of measurements in each of the two variable in the correlation and $d^2 = \; {}_{i=1}^{n} d_i^2$, and d^i is the ranked difference between the ith measurements for the two variables(Zar, 1972). We further examine significance of the correlation. P-value < 0.05 was considered significant.

3. Results

Correlation coefficients between average R&D expenditure as % of GDP and number of articles published in science and engineering, R&D expenditure as % of GDP and number of patent applications, R&D expenditure as % of GDP and high technology exports in selected OECD countriesare given on Table-1 below.

[5] Omitted on the first graph as it causes disruption, outlier.
[6] Summary of Data is included on Table-1 in appendix.

Table-1: Spearman Correlation Coefficient Between Variables in OECD Countries

VARIABLES[7]	Number of Articles Published in Science & Engineering PP	Number of Patent Applications (residents) PP	High Technology Exports (USD) PP	Number of Start-Ups in Mobile Apps, Software
AVG R&D (% GDP)	r=0.545 t=2.975 p=0.0072	r=0.785 t=5.799 p=0.000…	r=0.659 t=4.016 p=0.0006	r=0,432 t=2.194 p=0,0396

Note: p<.05 is significant

Through application of Spearman Rank Correlation, we found that there exists a positive, strong, and statistically significant relation between R&D expenditure (% of GDP) and number of patent applications in selected OECD countries(r=0.785, p=.00..). We also found that R&D (% of GDP) is positively and statistically significantly correlated with number of articles published in science and engineering(r=0.545, p=.0072), and high technology exports (r=0.659, p=.0006) and number of start-ups in mobile apps and software (r=0.432, p=.0396).

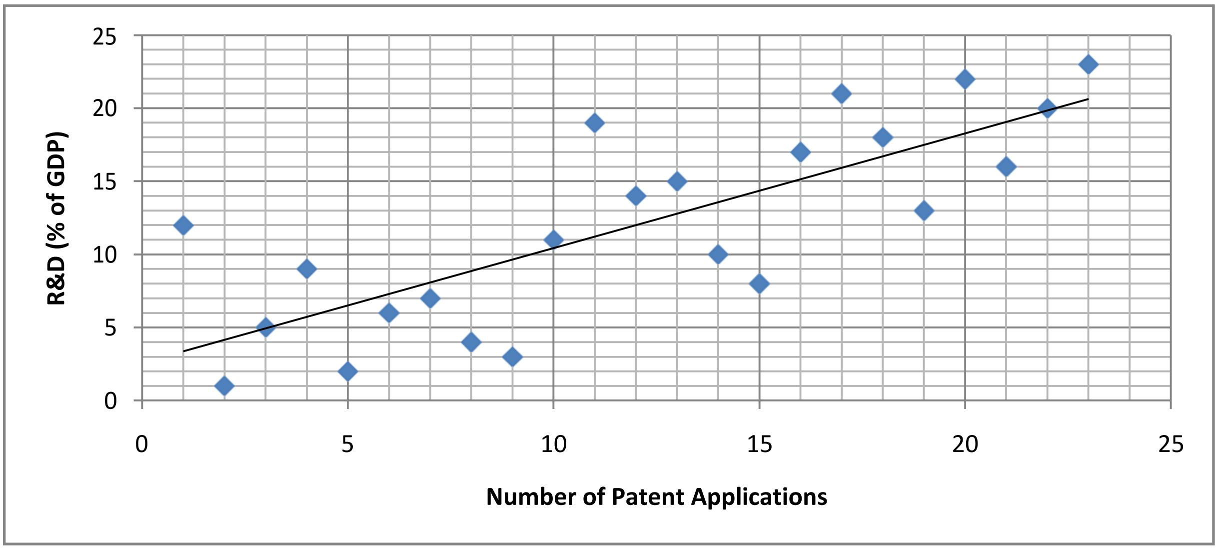
The rank correlation between R&D (% of GDP) and number of articles published is shown on the Graph-7 below. Despite moderately high and positive correlation, Japan and Republic of Korea have high R&D expenditure (as% of GDP) however the number of articles published in science and engineering are below OECD average. Norway on the other hand is ranked as the 3rd country with highest number of articles published per capita but has relatively small R&D expenditure (as % of GDP).

Graph-7: Correlation between Number of Articles Published in Science & Engineering, in OECD Countries

[7] Variables are expressed as mean. (AVG:average)

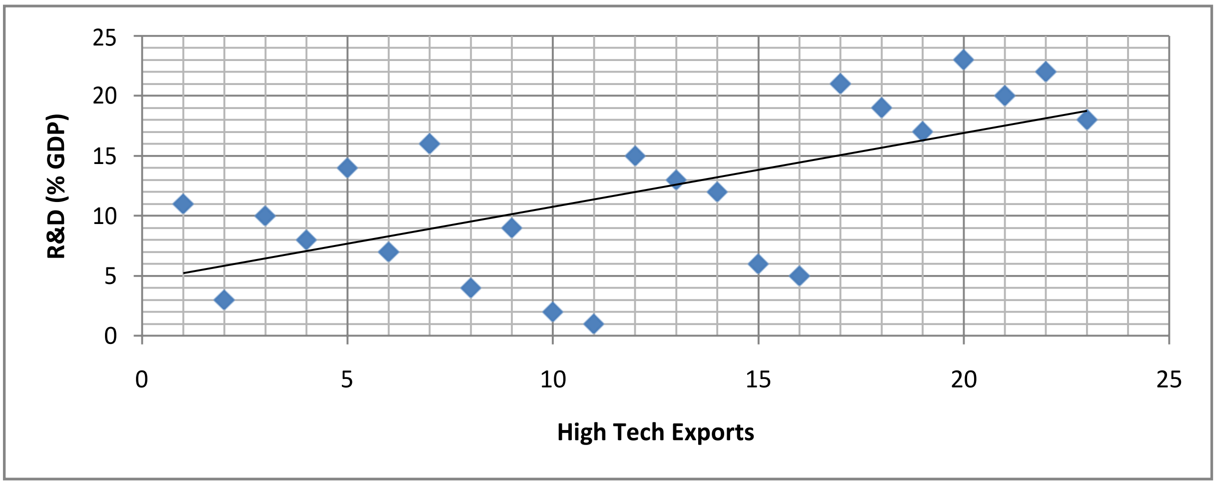
The correlation between R&D expenditure and number of patent applications by residents is shown on the Graph-8 below. Israel that has the highest R&D expenditure (as% of GDP) relatively has less patent applications by residents.

Graph-8: Correlation between Number of Patent Applications by Residents, & R&D, in OECD countries



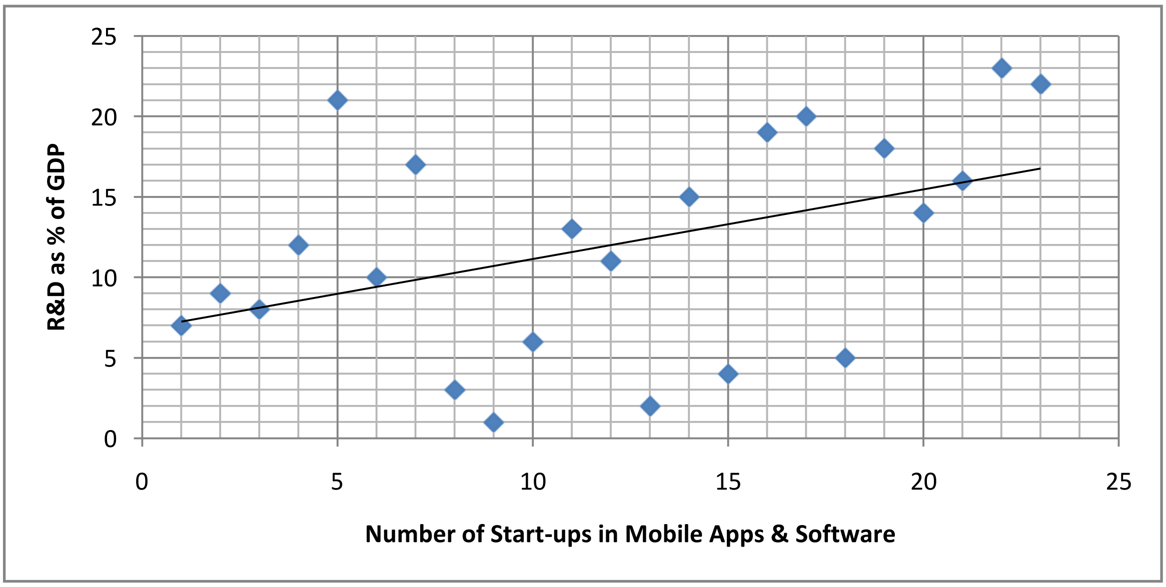
The correlation between R&D expenditure and high tech exports is shown on the graph-9 below. Israel has the highest percentage of GDP spent on R&D but is ranked below OECD average at high technology exports (PP). Czech Republic and the Netherlands on the other hand have relatively high level of High Technology exports, despite ranking lower on R&D expenditure.

Graph-9: Correlation between High Technology Exports & R&D Exp. in OECD Countries



The rank correlation between R&D expenditure and number of start-ups in mobile apps and software is shown on the graph-10 below. The US is leading with highest number of start-ups in mobile apps and software. While Canada is the second among the countries with start-ups, R&D intensity is relatively lower. Japan, on the other hand, while has high R&D intensity, the number of start-ups are relatively low. This might be due to lack of data availability in online databases.

Graph-10: Correlation between Number of Start-ups in Mobile Apps, Software & R&D Expenditure in OECD Countries



3. Summary

Technological development, tremendous catching up of developing world has brought attention to importance of research and development and innovation and how they factor in economic growth. Firms are looking for ways to increase their productivity and competitiveness; governments aim to achieve sustainable economic growth. On the other hand, investment in research and development is costly. Therefore policymakers must carefully asses how research and development may contribute to innovation and growth.

The aim of this paper is to contribute to discussion in growth theory by studying whether existing literature regarding research and development and innovation applies to OECD countries. We use annual data over the period of 2007-2016 and express them in means. Even though R&D expenditure over time is smooth, using mean values might distort variations. Therefore the results only provide an overview of how research and development might be linked to innovation outputs in general and further panel data analysis might be helpful to investigate causality. Applying spearman rank correlation we conclude that there exists a positive and statistically significant relationship between research and development expenditure (as percentage of GDP) and innovation outputs such as number of articles published in science and engineering(r=0.545, p=.0072), number of patent applications(r=0.785, p=.00..), number of start-ups in mobile apps and software software (r=0.432, p=.0396), and high technology exports(r=0.659, p=.0006).

As a whole this paper supports the existing literature and emphasizes that there is a positive and strong link between research and development investment and innovation in OECD countries. OECD countries that tend to have higher R&D expenditure, in other words high R&D intensity, have higher number of articles published in science and engineering, higher number of patent applications and start-ups in mobile and software and higher level of high technology exports. Based on the assumptions in our model, this concludes as OECD countries that tend to have higher level of R&D activities achieve higher level of innovation. Policymakers and private corporations might benefit taking this into account while developing innovation and growth strategies.

4. Discussion

This paper gives insight on the role of R&D expenditure to level of innovation in OECD countries by examining innovation outputs such as scientific publications, patents, start-ups and high technology exports. The findings are consistent with theories and earlier studies in literature. Countries with higher R&D expenditure tend to produce higher innovation outputs and increase innovative capacity of the economy. Especially for developing OECD countries that hope to achieve sustainable economic growth the results are important, as innovation tends to increase productivity which in turn leads to economic growth (Guloglu & Tekin, 2012).

Even though there is a strong and positive relation among variables, whether research and development activities lead to productivity and returns as innovation depends on few other factors. While discussing and comparing R&D expenditures, one thing to consider is the difference in composition of expenditure among countries. Increasing R&D expenditures in business sectors such as manufacturing, electronics will foster higher innovation in comparison with sectors such as agriculture or tourism. Secondly, research and development activities have different impact depending on whether it is publicly funded or by private institutions. As mentioned earlier, public funded research tends to be basic research while private funded research tends to be conducted with a specific aim. Therefore private funded research and development activities tend to foster higher innovation and innovation potential(Bilbao-Osorio & Rodriguez-Pose, 2004). Another point to consider is time lags associated with impacts of research and development on innovation. Knowledge creation and its reflection on newly developed applications require not only qualified research and development personnel but also skilled workforce within industries. Therefore measuring the impact of increase in research and development expenditure will take time. As we use average values to carry out the study, time lags cannot be observed. Further causality tests and panel data analysis might give a better insight.

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Appendix-1

Table-1: Summary of Data

List of Countries	R&D Expenditure as % of GDP	Number of Patent Applications by Residents (*10^{-5}, PP)	Number of Articles Published in Science & Engineering (*10^{-2}, PP)	High Technology Export (PP, in constant USD)	Number of Start-ups in Mobile Apps and Software
Austria	2,805	2,642	0,13863	1917	28
Belgium	4,381	0,661	0,14484	3153	36
Canada	3,554	1,342	0,16661	754	312
Czech Republic	3,162	0,792	0,12865	1851	21
Denmark	5,780	2,714	0,20979	1737	46
Finland	6,705	2,978	0,19084	1185	67
France	4,385	2,217	0,10833	1531	67
Germany	5,138	5,857	0,12303	2151	218
Greece	1,490	0,589	0,10587	102	6
Israel	8,380	1,743	0,14847	1074	91
Italy	2,500	1,457	0,10586	470	27
Japan	6,527	22,560	0,08334	858	13
Korea, Rep.	7,507	29,065	0,10861	2333	23
Mexico	0,997	0,088	0,01030	339	12
Netherlands	3,714	1,417	0,17779	3704	41
Norway	3,412	2,304	0,19183	864	33
Poland	1,590	0,956	0,07215	252	32
Portugal	2,728	0,565	0,11337	201	19
Spain	2,555	0,696	0,10997	278	103
Sweden	6,584	2,335	0,19772	1664	40
Turkey	1,626	0,516	0,03733	26	36
United Kingdom	3,314	2,446	0,15414	1015	163
United States	5,471	8,345	0,13306	521	1178

Appendix-2

Table-2 Ranks of OECD Countries

LIST OF COUNTRIES	GERD	ARTICLES (PP)	PATENT APP. (PP)	HIGH TECH (in constant USD, PP)	START-UPS
Austria	7	10	7	5	17
Belgium	11	9	19	2	13
Canada	13	6	15	15	2
Czech Republic	16	12	17	6	19
Denmark	6	1	6	7	10
Finland	3	4	5	10	8
France	10	17	11	9	6
Germany	8	13	4	4	3
Greece	22	19	20	22	23
Israel	1	8	12	11	7
Italy	19	18	13	17	18
Japan	5	20	2	14	21
Korea, Rep.	2	16	1	3	9
Mexico	23	23	23	18	22
Netherlands	12	5	14	1	11
Norway	14	3	10	13	15
Poland	21	21	16	20	16
Portugal	17	14	21	21	20
Spain	18	15	18	19	5
Sweden	4	2	9	8	12
Turkey	20	22	22	23	14
United Kingdom	15	7	8	12	4
United States	9	11	3	16	1