International Journal of Innovation and Scientific Research
ISSN 2351-8014 Vol. 27 No. 1 Oct. 2016, pp. 50-59

http://www.ijisr.issr-journals.org/

Patent Development of OECD Countries: A Panel Data Study

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ABSTRACT: Today, the technology has become a substantial factor that affects a country's competitiveness and economic growth. It is considered that the classical factors of production –capital, labor, land- do not provide an efficient growth in countries without the human capital accumulation and the technology. Thus far, the literature has widely examined the interaction between economic growth and the innovation level of the countries. The main contribution of this study has been to demonstrate the impact of human accumulation and the government’s research and development (R&D) policies to patent development, which is a proxy for measuring the technological improvement. By exploiting the intensity of R&D researchers and R&D expenditure policy among 28 OECD countries in panel data for years 1998-2013, this paper provides the policy suggestions for governments by taking into consideration also the patent stock depreciation through years. According to our comparisons among pooled OLS, fixed and random effect models, the R&D expenditure policy and the patent stock have an obvious effect on the patent development of these 28 countries. Nevertheless, the R&D researchers and government researchers do not seem ensuring statistically significance. It would better for the governments to strengthen the human capital factor by applying more inclusive education policy to see its efficiency in the economic growth.

KEYWORDS: Research and Development, Patent, Economic Growth, OECD, Panel Data

1 INTRODUCTION

In modern world, competitiveness through technology is a major feature for countries. Not only the government but also the society itself contributes to the development of this technology which brings them much more dynamism. In this context, patents became an important measure for a country to show its competitiveness. A patent is a right granted to the owner of an invention that prevents others from making, using, importing or selling the invention without his permission. A patentable invention can be a product or a process that gives a new technical solution to a problem. It can also be a new method of doing things, the composition of a new product, or a technical improvement on how certain objects work. It is believed that the number of patents can reflect the scientific level and economic level of a country. As a consequence of this, patent development has become important to governments which try to raise the number of patents by many ways. The principal solution is increasing the R&D expenditure. Of course, there are other solutions such as rising R&D researchers. The ideas-driven model, with the assumptions made in [1], predicts that expansion in the number of researchers leads to a permanent increase in total factor productivity growth rate. In contrast, the empirical evidence suggests that most OECD economies have increased the size of their R&D workforce, while experiencing constant total factor productivity growth rates. This weak relationship between the number of researchers and this type of growth rate has led some to question the impulse of ideas-driven growth for the long run [2].

The question in this paper is that at which level the patent development can be interpreted with the indicators of R&D researchers and R&D expenditure policy. In addition to that we will use the patent counts to generate a stock of them. This stock of patents, together with the number of researchers, will allow us to evaluate the determinants of the flow of new ideas directly. This work's results will be used in order to contribute to the limited literature about the pattern of patents in Turkey. We analyze the relationships on the country level by using the data from 28 OECD countries between the years 1998-2013. Based on the idea-based growth model, we will use the panel data model on STATA.

In the second section, we will introduce the literature review and the theoretical framework with the ideas-based growth model. In the following section, we interpret our variables and methodology on assessing the relationship between them. In the fourth section, the empirical analysis and regression tables will be presented by interpreting the results. In the conclusion part, we will point out the results obtained from the model and the policy suggestions.

2 LITERATURE REVIEW

In this section, first we will present the empirical literature concerning to the contribution of R&D related variables to innovation and growth. Secondly, after summarizing the ideas-based growth model as our theoretical framework, we will introduce our model to be estimated in the following section.

2.1 EMPIRICAL LITERATURE

In patent literature, the researches generally aim to analyze empirically the causal relations among R&D expenditures, innovation, and economic growth. As suggested in [3], a positive relationship between R&D expenditures and productivity growth, by introducing the stock of technological knowledge into the neoclassical growth model as an explanatory variable of international differences in productivity growth. In [4], it is found a positive long-term relationship between R&D expenditures and total factor productivity. By making use of aggregate level patent data, [5] made it clear that innovation is positively related to human capital in the R&D sectors and national knowledge stock, having a significant impact on total factor productivity growth. Although R&D expenditure was obviously increasing from about 1950s, no one made sure of the return rate. In 1958, [6] first estimated the social return of R&D expenditure. Then in 1964, that work was the first one to use a production function of Cobb-Douglas type, adding the education and public research expenditure variables. In 1984, [7] found the relationship of the R&D expenditure, R&D employment and the output of the patent. It is used the Poisson distribution model with the panel data from 121 firms of America in 1968 to 1975. [8] and [9] also found the relationship with the R&D expenditure and patents. [10] has made an empirical analysis and concluded that both the research and propensity to patent can lead to increase in the number of patents. Differences in innovation capacity and potential are largely responsible for persistent variations in economic performance and hence wealth among the nations in the world [11]. It is also argued that the effects of innovation on economic growth cannot be fully understood without considering the social and institutional conditions in an economy. As an illustration, [12] showed how the interaction between 3 research and social-economic and institutional conditions shapes regional innovation capacity.

2.2 THEORETICAL FRAMEWORK

Most recently, the theoretical literature can be broadly divided into two champs, i.e. the first generation models such as [1] and [13] and the second generation models such as [2] and [14]. In the neoclassical framework, the impact of innovation is treated as part of the Solow residual and hence a key contributing factor to economic progress and long-term convergence [15], [16].

Reference [1] implies that the cumulative nature of the knowledge is a really important condition. This production process is as follows:

$$Y = F(A, X)$$

where Y is the total production in the economy, A is stock of knowledge and X is the other factors. If A results as productive then,

$$F(\lambda A, \lambda X) > \lambda F(A, X)$$

then, he shows knowledge function is as follows:

$$\dot{A} = \delta H_A A$$

where H_A means the total human capital of research, A means the stock of knowledge and $\dot{A}$ means the new ideas and $\delta > 0$ is a constant. Comparing to Romer's model, [2] uses a similar model with a minor difference:

$$\dot{A} = \delta L_A^{\lambda} A^{\varphi}$$

where $\dot{A}$ represents the number of new ideas created, L_A represents the amount of human capital, or the number of researchers, devoted to innovation, A represents the stock of ideas, and $\delta > 0$ is a constant again. Actually, the only difference between the two models is the value of the parameter ϕ. In Romer's model, ϕ is constant and is equal to 1, while [2] asserts that there are other possibilities: ϕ is larger than 1 or smaller than 1. When it comes to the question which value of ϕ is closer to the reality, there is still no definitive answer.

In 1999, [18] use R&D expenditure instead of human capital, "From society's standpoint, the productivity of R&D may be varied because of the amount of R&D expenditure and the stock of ideas." Their model is as follows, where R is the R&D expenditure:

$$\dot{A} = \delta R^{\lambda} A^{\varphi}$$

[17] shows the R&D production function is a knowledge process which is determined by labor, capital and the first stock of knowledge as the function below,

$$I = f(L,K,I_0)$$

where I means the output of R&D and I_0 means the stock level. Based on that theory and the model in [2] and [18], we build the model in this paper is as follows,

$$P_{it} = \beta_0 H_{it}^{\beta 1} * R_{it}^{\beta 2} * PS_{it}^{\beta 3} \quad (1)$$

where P means the number of patents authorized during year t and in country i, H means the human capital; R means the R&D expenditure while PS means the cumulative stock of patents. The parameters $\beta 1$, $\beta 2$, $\beta 3$ measure the elasticity of human capital, R&D expenditure and the stock level to affect the output of patents. Taking the logarithm of equation (1), we get the equation (2) which we will use in order to answer our research question.

$$\ln(P_{it}) = \ln\beta_0 + \beta 1 * \ln(H_{it}) + \beta 2 * \ln(R_{it}) + \beta 3 * \ln(PS_{it}) + \varepsilon_{it} \quad (2)$$

The number of patents is a common proxy for measuring the technology and it has advantages as it is easy to quantify. Usually it is easy to measure and the data is easy to access [19]. The number of patent is also easy to compare across countries since, looking at patent applications in the US or Europe one can compare differences in innovation levels between nations or regions [20]. Of course patents are not optimal and it is important to know the limitations of a proxy. Patents measure output of innovation and are not likely to cover all that innovations should contain due to the fact that not all innovations are patented. Since innovations is only one way to measure total factor productivity and can be seen as only one component, it is important to know that there are setbacks using innovation proxies [19]. Patents can be seen as the output from another variable also frequently used as a proxy for innovation, namely research and development (R&D), in that case it is more suitable to use patents than R&D expenditure [17]. It is not only patents that are used as proxy for innovations. There are intramural and extramural R&D expenditures, operational R&D expenditure, turnover from innovation, degree of collaborators qualification etc. [21].

3 DATA & METHODOLOGY

3.1 PARTICULAR VARIABLES AND DATA SOURCES

As the purpose of this paper is comparing the data concerning to a huge group of countries, it is necessary to normalize the variables due to the fact that populations of them vary. We put account the number of patents as triadic patent families. We use the R&D expenditure as a percentage of GDP instead of absolute value of R&D expenditure. Because the purpose here is to give policy advice, we treat the R&D researchers as the human capital and the government researchers. The stock of patents, together with the number of researchers, will allow us to evaluate the determinants of the flow of patents directly.

Patent is the dependent variable in this model. When measuring innovation, it is widely accepted that the number of patents issued during a year is used. In order to get away from many limitations such as the difficulty to compare the different levels of patents all over the world, OECD has developed triadic patent families. The definition of triadic patent family is that a set of patents registered in various countries (i.e. patent offices) to protect the same invention [22]. Triadic patent families are a set of patents filed at three of these major patent offices: the European Patent Office (EPO), the Japan Patent Office (JPO) and the United States Patent and Trademark Office (USPTO). Triadic patent family counts are attributed to the country of residence of the inventor and to the date when the patent was first registered. This indicator is measured as a number. We use the data from 1998 as the initial year, and because it is really difficult to find a general depreciation rate of the 28 countries, we will assume the depreciation rate is 5%, 10%, 15% based on [23]. The equation is as follows, where d is the depreciation rate, PS represents the patent depreciation and P is the number of triadic patent families for country i at time t+1.

$$PS_{it+1} = (1\text{-}d) * PS_{it} + P_{it+1} \quad (3)$$

R&D researchers are another variable concerned in this paper. It is defined as the professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, as well as in the management of the projects concerned [24]. This indicator is measured in per 1 000 people employed. Besides, we chose government researches as another variable. Its definition is that professionals working for government institutions engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned. This indicator is measured in per 1000 people employed and in number of researchers [25].]

Another explanatory variable of the model is the data of R&D intensity which represent gross domestic expenditure on R&D as a percentage of GDP. The source of expenditure on R&D is OECD (2014), Main Science and Technology Indicators which defines as gross domestic spending on R&D is defined as the total expenditure (current and capital) on R&D carried out by all resident companies, research institutes, university and government laboratories, etc., in a country [26]. It includes R&D funded from abroad, but excludes domestic funds for R&D performed outside the domestic economy. This indicator is measured as percentage of GDP.

3.2 Descriptive Statistics

It will be useful to check descriptive statistics in order to observe the significance and adequateness of sample group. We have 414 observations concerning to 28 countries between the years 1998-2013. Panel data used in this work is strongly balanced which defines as "A longitudinal or panel dataset is said to be strongly balanced if each panel has the same number of observations, and the observations for different panels were all made at the same times" [27]. Besides, the data provides a compact panel.

When it comes to within and between variations, our variables show an adequate within variation to use panel data. For instance within variation for the R&D expenditure as a % of GDP, is 60 per cent, for the other variables respectively R&D researchers is 44 per cent, for Government researchers is 40 per cent.

Number of patents is in a wide range in our sample as its minimum value is 1, while its maximum is 18712. The R&D expenditure as a percentage of GDP represents percentage values. The minimum expenditure is 0.01 per cent while it represents a maximum level as 4.1 per cent. The R&D researcher per 1000 employer varies between 0.08 and 17.67 whereas the government researchers are in absolute values and changing between 1.676 and 36.574.

We show in Figure1 (see Appendix), the graphs concerning to the variation of patents through time and other variables. All the variables are in logarithmic form assessed on STATA. As seen from the graphs, R&D researchers and the R&D expenditure as a percentage of GDP are related to patent development in many countries. The patent stock has a linear form as expected from its formulization.

In the following section, we will share empirical analysis of our model implemented into 3 different models, afterwards we will present a comparison table on purpose of choose the best fit model for our research question.

4 Empirical Analysis

Based on the theoretical framework presented in section 2, we use the following model to estimate in order to estimate our research question. We will show the results for pooled OLS, FE and RE Models respectively.

$$\ln(Patent_{it}) = \ln\beta_{0} + \beta 1 * \ln(RDGDP_{it}) + \beta_2 * \ln(Rp000emp_{it}) + \beta 3 * \ln(GovR_{it}) + \beta 4 * \ln(PD_{it}) + u_i + \varepsilon_{it} \quad (4)$$

4.1 Polled OLS Regression

In order to test the best model for patent development of 28 OECD countries, we pool the data first to fit the OLS regression model. The major problem with this model is that it does not distinguish between the various countries that we have. In other words, by combining 28 countries by pooling, we deny the heterogeneity or individuality that may exist among

28 countries. Assuming respectively the depreciation rates as 5 per cent, 10 per cent and 15 percent, we summarize the results below in Table 1.

The pooled OLS results suggests that by ignoring 28 different countries' heterogeneity or individuality that may occur, these explanatory variables could explain approximately 95 percent of patent development among these sample. Besides, if the patent stock depreciation rate dismissed, the power of the model in sense of the ability to explain the patent development declined to 32 per cent. R&D researcher per 1000 employer is the most efficient estimator according to t-statistics among all models both including and not including the patent stock depreciation rate, by explaining the patent development, ceteris paribus, at 1 per cent significance level. In addition to this, the power of the model increases when the patent stock depreciation rate is 15 per cent.

In the aim of analyzing the countries' heterogeneity or individuality, in the following sub sections, we will show the fixed effect (FE) and random effect (RE) regressions respectively.

Table 1. Pooled OLS Model Results

Variables	No depr	5% depr	10% depr	15% depr
Intercept	17.555***	-0.306	-0.514	- 0.646
	(1.587)	(0.611)	(0.542)	(0.480)
logRDGDP	0.528***	0.049	0.039	0.031
	(0.126)	(0.042)	(0.037)	(0.033)
logRemp	0.522***	-0.228***	-0.209***	- 0.189***
	(0.164)	(0.056)	(0.049)	(0.043)
logGovR	-1.450***	-0.051	-0.031	- 0.016
	(0.156)	(0.057)	(0.050)	(0.045)
logPD5		0.922***		
		(0.016)		
logPD10			0.942***	
			(0.014)	
logPD15				0.960***
				(0.012)
# observation	414	414	414	414
Prob > F	0.0000	0.0000	0.0000	0.0000
Adj R-squared	0.325	0.925	0.941	0.953

Notes: - ***, ** and * represent significance at the level of 1%, 5% and 10%, respectively.
- "depr" is the abbreviation of depreciation rate.

4.2 FIXED EFFECT MODEL I

In FE Model I, F statistic is significant for all 4 situations which differ according to the patent stock depreciation rate. When we check the t-statistics for each estimated variables, only the patent stock depreciation rates are significant at 1 per cent significance level.

Table 2 summarizes the results obtained by FE Model I. Another point from the results is that RDGDP and Remp are significant at 5 per cent significance level whereas GOVR provides 1 per cent significance level if the patent stock depreciation rate is excluded from the model. According to the model, an increase of 1 percent of R&D expenditure as a % of GDP, ceteris paribus, comes with an increase of 6 percent in triadic patent families. Furthermore, a rise of 1 per cent in R&D researchers causes a rise as well in patent development with a percentage approximately 13 per cent.

Besides these interpretations, it could be important to mention R-sq values. Although the patent stock excluded model seems more explicative as its coefficients are significant, its within variation is lower than included ones. We know from the literature that within variation is essential for panel- data analysis. Hence it would be better to keep the patent stock depreciation rate in the model. After giving a brief interpretation of FE Model I, now we will present RE Model results in the next sub-section.

4.3 RANDOM EFFECT MODEL

In RE Model, chi2 statistic is significant for all situations which differ according to the patent stock depreciation rate. Remp and the patent stock depreciation rates are significant at 1 per cent significance level when we check the t-statistics for each estimated variables. In Table 2, we show the results obtained from RE Model. RDGDP and Remp are significant at 5 per cent significance level whereas GOVR provides 1 per cent significance level if the patent stock depreciation rate is excluded from the model.

According to the model, an increase of 1 percent of R&D expenditure as a % of GDP, ceteris paribus, comes with an increase of 6 percent in triadic patent families. Furthermore, a rise of 1 per cent in R&D researchers causes a rise as well in patent development with a percentage approximately 13 per cent. Hence, the interpretation seems same for the previous FE Model with no patent stock depreciation rate.

R-sq values have also the same patterns. The main difference between FE and RE models is that the coefficients of variables are higher for the latter. In order to decide between two of them, we will implement a statistical hypothesis test in the next section.

Table 2. FE Model I and RE Model Results

	FE Model I				RE Model			
Variables	No depr	5% depr	10% depr	15% depr	No depr	5% depr	10% depr	15% depr
Intercept	7.001***	3.265***	2.812***	2.338***	7.113***	0.536	-0.117	-0.519
	(0.705)	(0.714)	(0.699)	(0.679)	(0.797)	(0.859)	(0.748)	(0.639)
logRDGDP	0.060**	0.032	0.030	0.027	0.064**	0.054	0.045	0.036
	(0.028)	(0.024)	(0.024)	(0.023)	(0.028)	(0.040)	(0.037)	(0.033)
logRemp	0.126**	-0.042	-0.055	-0.066	0.130**	-0.229***	-0.225***	-0.211***
	(0.053)	(0.049)	(0.048)	(0.046)	(0.054)	(0.068)	(0.060)	(0.060)
logGovR	-0.241***	0.002	0.020	0.038	-0.264***	-0.043	-0.011	0.006
	(0.071)	(0.067)	(0.065)	(0.062)	(0.071)	(0.080)	(0.070)	(0.059)
logPD5		0.262***				0.782***		
		(0.024)				(0.024)		
logPD10			0.315***				0.856***	
			(0.026)				(0.021)	
logPD15				0.375***				0.910***
				(0.028)				(0.018)
# observation	414	414	414	414	414	414	414	414
Prob > F / Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R-sq within	0.070	0.280	0.320	0.366	0.070	0.278	0.318	0.364
R-sq between	0.389	0.994	0.995	0.995	0.390	0.994	0.995	0.996
R-sq overall	0.325	0.925	0.941	0.953	0.326	0.926	0.941	0.954

Notes: - ***, ** and * represent significance at the level of 1%, 5% and 10% respectively.
- "depr" is the abbreviation of depreciation rate.

4.4 COMPARISON OF MODELS AND MODEL SELECTION

In order to choose between the regressions models, we used Hausmann Test. In this test, H_0: FE model is not appropriate. H_a: FE model is appropriate. According to the results, when the patent stock depreciation rate is null, the probability value is less than 5 per cent, we can reject the null hypothesis. That means the data fails to satisfy the assumption of the Hausman test, so we keep considering the condition when the depreciation rate is 5, 10 and 15 percent respectively. The hypothesis of no systematic difference is rejected, so the FE model is preferred. In other words, the FE model is useful for the research question therefore we estimate the FE model again by cluster countries (see Table 3 for results).

In FE Model II, F statistic is significant for the patent stock depreciation rate included models. When we check the t-statistics for each estimated variables, on the contrary of FE Model I, not only the patent stock depreciation rate but also R&D researchers are statistically significant. RDGDP is significant at 5 per cent significance level for 10 per cent depreciation rate model whereas this significance level changes to 10 per cent for 5 and 15 per cent depreciation rates.

According to the model, an increase of 1 percent of R&D expenditure as a percentage of GDP, ceteris paribus, result in an increase of 3 percent in triadic patent families with different significance levels.

Table 3. FE II Model Results

Variables	No depr	5% depr	10% depr	15% depr
Intercept	7.001***	3.265**	2.812**	2.338**
	(1.259)	(1.278)	(1.219)	(1.140)
logRDGDP	0.060**	0.032*	0.030**	0.027*
	(0.026)	(0.017)	(0.017)	(0.016)
logRemp	0.126	-0.042	-0.055	-0.066
	(0.139)	(0.070)	(0.064)	(0.059)
logGovR	-0.241*	0.002	0.020	0.038
	(0.126)	(0.107)	(0.100)	(0.092)
logPD5		0.262***		
		(0.068)		
logPD10			0.315***	
			(0.071)	
logPD15				0.375***
				(0.073)
# observation	414	414	414	414
Prob > F	0.0290	0.0022	0.0007	0.0002
R-sq within	0.070	0.280	0.320	0.366
R-sq between	0.389	0.994	0.995	0.995
R-sq overall	0.325	0.925	0.941	0.953

Having revised FE model and given some interpretation, we will compare two selected model: Pooled OLS and FE model II therefore we will decide which model fits best our research question. Table 4 provides a comparison between two models: Pooled OLS and FE Model II where the former doesn't take into account the within variation as it reflects an OLS model with panel data even though F statistics shows the significance. To be able to answer our research question, we revised the FE Model allowing for arbitrary correlation over time for each individual it is used clustered standard errors. Standard errors increased but the estimated coefficient for R&D expenditure as a percentage of GDP became significant at 5 per cent for 10 per cent depreciation rate and 10 per cent for both 5 and 15 per cent depreciation rates.

We have chosen the biggest within variation in FE Model II which corresponds to the model with 15 per cent patent stock depreciation rate. An interesting interpretation is that, R&D researchers and Government Researcher are not significant in FE Model. As seen from Table 4, the coefficient of R&D patent stock is positive and significant. An increase of 1 percent of this variable, ceteris paribus, there will be an increase of 38 per cent in the number of triadic patent families at 1 per cent significance level. In addition, a rise of 1 per cent in R&D expenditures as a percentage of GDP, ceteris paribus, causes an increase of 2 per cent in triadic patent families. In summary, FE model considers within variation and F statistics is 0.0002 according to the model with 15 per cent depreciation rate of the patent stock. R&D expenditure as a percentage of GDP is also statistically significant at 10 per cent significance level.

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Table 4. Comparison of Pooled OLS and FE II Model

	Pooled OLS Model	FE Model II
Variables	15% depr	15% depr
Intercept	- 0.646	2.338**
	(0.480)	-1.140
logRDGDP	0.031	0.027*
	(0.033)	(0.016)
logRemp	- 0.189***	-0.066
	(0.043)	(0.059)
logGovR	- 0.016	0.038
	(0.045)	(0.092)
logPD15	0.960***	0.375***
	(0.012)	(0.073)
# observation	414	414
Prob > F	0.0000	0.0002
R-sq within	-	0.366
R-sq between	-	0.995
R-sq overall	0.953	0.953

5 Conclusion and Policy Suggestions

In this paper, we tried to find if R&D expenditure policy and the count of researchers have obvious effects on the development of patents. Based on the idea-growth model, we change the model by treating R&D researchers, government researchers, R&D expenditure as a percentage of GDP and patent stock as input while treating number of patents as output. We used the panel data model to analyze 28 countries in OECD during 1998 to 2013.

In pooled OLS model, the heterogeneity or individuality has been denied that may exist among 28 countries. Even though adjusted R-square has a power to explain patent development, because of these ignored points, we implemented FE and RE models respectively and to decide which model is better, we used Hausman Test. After the test resulted as FE model is feasible, we revised FE model by clustering the standard errors which allowed for arbitrary correlation over time for each individual therefore we could decide which model fits best our research question.

After reinvestigating the FE regression model, we have compared it with Pooled OLS model and the results imply that R&D expenditure policy and the patent stock has an obvious effect on the patent development of these 28 countries. Nevertheless, the coefficient of R&D researchers and government researchers are not significant, therefore it is better for the government to strengthen education policy to have R&D researchers more qualified. In addition to this, the results show government researchers has no impact on increasing number of triadic patent families. There could be a non-productive group of researchers among the staff which should be cared about. For future work, one can study the turnover from innovation and the economic growth interaction.

Acknowledgment

We thank the participants of the 2nd International Graduate Student Conference on Social Sciences in Istanbul, Turkey for their valuable comments.

References

[1] P.M. Romer, "Endogenous Technological Change", *The Journal of Political Economy*, vol. 98, no. 5, pp. S71-S102, 1990.
[2] C.I. Jones, "Time Series Tests of Endogenous Growth", *Quarterly Journal of Economics,* vol. 110, pp. 495–526, 1995.
[3] F.R. Lichtenberg, "R&D investment and international productivity differences" NBER Working Paper Series, no. 4161, 1992.
[4] D.T. Coe and E. Helpman, "International R&D spillovers", *European Economic Review*, vol. 39, no. 5, pp. 859-887, 1995.
[5] M.E. Porter and S. Stern, "Measuring the 'ideas' production function: Evidence from international patent output", NBER Working Paper, no. 7891, 2000.

[6] Z. Griliches, “Research Costs and Social Returns: Hybrid Corn and Related Innovations”, *Journal of Political Economy*, vol. 66, pp. 419-431, 1958.

[7] Z. Griliches et al., “Econometric models for count data with application to the Patents-R&D relationship”, *Econometrica*, vol. 52, no. 4, pp 909-938, 1984.

[8] H. Ernst, “Industrial research as a source of important patent”, *Research Policy*, vol. 27 no. 1, pp. 1-15, 1998.

[9] D. Popp, “Induced Innovation and Energy Price”, *American Economic Review*, vol. 92, pp. 160-180, 2002.

[10] G. Rassentosse and B. Potterie, “A policy Insight into the R&D - Patent relationship”, *Research Policy, Elsevier*, vol. 38, no. 5, pp. 779-792, 2008.

[11] Grossman and Helpman, *Innovation and Growth in the Global Economy*, Cambridge: MIT Press, 1991.

[12] P. Rodriguez et al., “Research and Development, Spillovers, Innovation Systems, and the Genesis of Regional Growth in Europe”, *Regional Studies,* vol. 42, no.1, pp. 51–67, 2008.

[13] P. Aghion, P. and P. Howitt, "A Model of Growth through Creative Destruction", *Econometrica Econometric Society*, vol. 60, no. 2, pp. 323-51, 1992.

[14] P. Segerstrom, “Endogenous Growth with Scale Effects”, *American Economic Review,* vol. 88, no.5, 1290–1310, 1998.

[15] R. Solow, “A Contribution to the Theory of Economic Growth.” *The Quarterly Journal of Economics*, vol. 70, no. 1, pp. 65-94, 1956.

[16] J. Fagerberg, “Technology and International Differences in Growth Rates”, *Journal of Economic Literature*, vol. 32, pp. 1147–1175, 1994.

[17] K.Y. Cheung and P. Lin, “Spillover effects of FDI on innovation in China: Evidence from the provincial data”, *China Economic Review*, vol. 15, pp. 25-44, 2003.

[18] C. I. Jones and J.C. Williams, "Measuring the Social Return to R&D”, *The Quarterly Journal of Economics*, vol. 113, no. 4, pp. 1119-1135, 1998.

[19] Smith, K.H., *Measuring innovation*, In: The Oxford Handbook of Innovation, Oxford University Press, New York, pp. 148-177, 2005.

[20] M. Connolly, “Technology, Trade and Growth: Some empirical Findings”, Federal Reserve Bank of New York: Research paper, vol. 9727, 1997.

[21] M.L. Manhaes, “The Challenge of Measuring innovation In Emerging Economies’ Firms: A Proposal of a new Set of Indicators on Innovation”, Working Paper, vol. 044, 2008.

[22] OECD, Triadic patent families (indicator), 2015. [Online] Available: http://www.oecd-ilibrary.org/industry-and-services/triadic-patent-families/indicator/english_6a8d10f4-en?isPartOf=/content/indicatorgroup/09614029-en (December 24, 2015)

[23] A. Pessoa, “Ideas driven growth: the OECD evidence”, The Portuguese Economic Journal, vol. 4, pp. 46-67, 2005.

[24] OECD, Researchers (indicator), 2015. [Online] Available: http://www.oecd-ilibrary.org/content/indicator/20ddfb0f-en (December 26, 2015)

[25] OECD, Government researchers (indicator), 2015.
[Online] Available: http://www.oecd-ilibrary.org/content/indicator/c03b3052-en (December 26, 2015)

[26] OECD, Gross domestic spending on R&D (indicator), 2015. [Online] Available: https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm (December 26, 2015)

[27] StataCorp, *Stata Longitudinal-Data/Panel-Data Reference Manual Release 12,* College Station, TX: StataCorp LP, pp.506, 2011.

APPENDIX (FOR 3.2. DESCRIPTIVE STATISTICS)

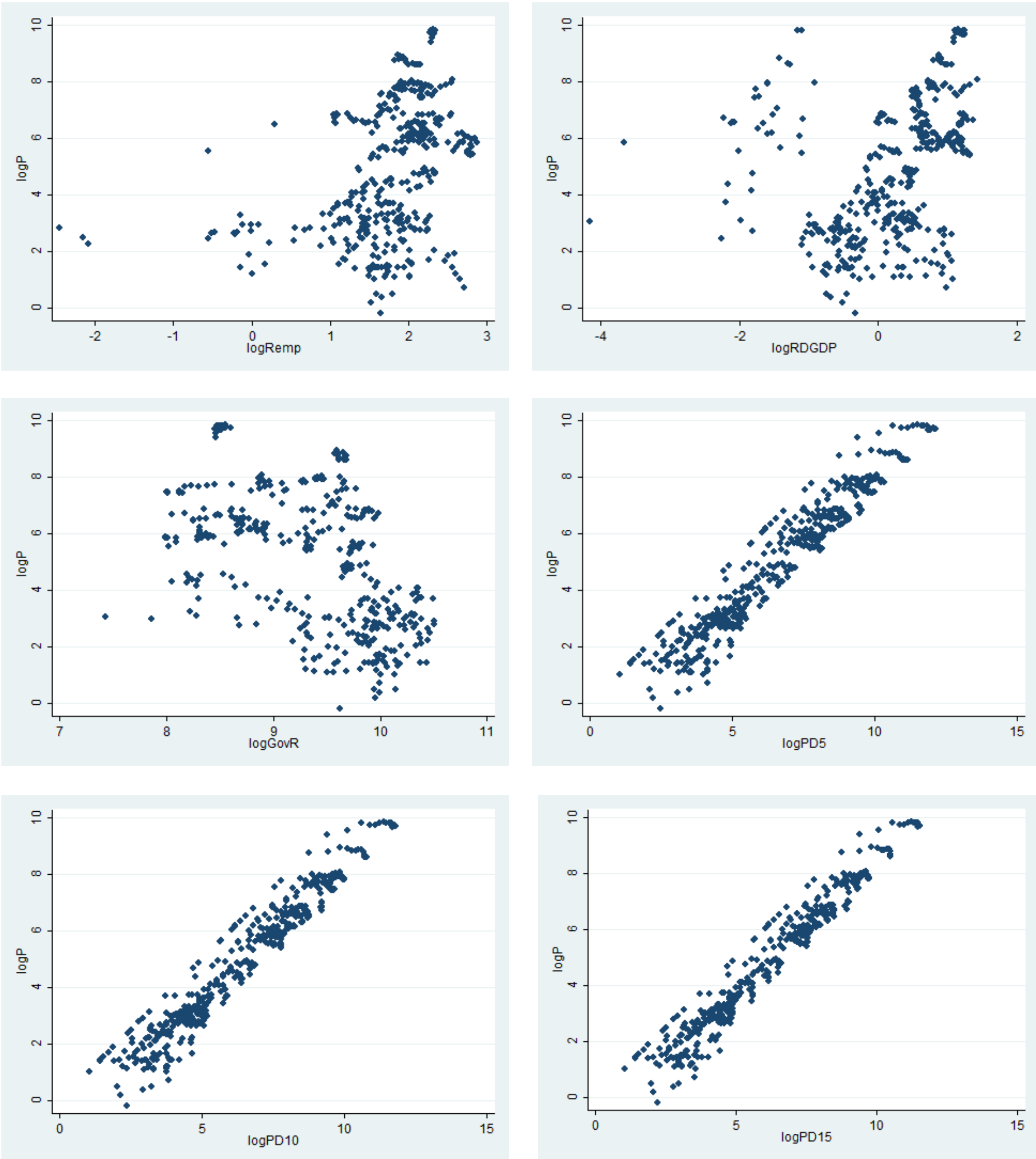

Fig. 1. The variation of triadic patent families through time and the variables for 28 OECD countries