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INVESTIGATING THE RELATION BETWEEN TECHNOLOGY AND ECONOMIC GROWTH WITH AK MODEL: AN APPLICATION SWAMY'S RANDOM COEFFICIENT MODEL (RCM)

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Abstract:

This study aims to investigate effect of technology on economic growth and 2008 crises on this relation in thirty-OECD countries using static panel data model and random coefficient model (RCM) with AK model. We applied cross-sectional dependence test, panel unit-root test and cointegration test. As a result of static panel regression model with different OECD sub-sample for both pre and post-2008 period, there is negative significant effect of Business Enterprise Expenditure on R&D (BERD) on economic growth in OECD countries which has high R&D expenditure to GDP EU countries for the post-2008. As a result of RCM, in Denmark, France, and Germany, it was observed decreasing technology effect on economic growth after 2008 crisis.

Keywords:

Technology, R&D expenditure, economic growth, panel regression model, random coefficient model.

JEL Classification: C33, O32, O47

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Introduction

Research and development (R&D) expenditure is a key indicator of innovative activities for countries. In 2015, total world R&D expenditures were 1.750 trillion dollars, which was a 8.15% (1.618 trillion dollars) on the year before. The 10 largest R&D spending countries of 2015 accounted for 1.480 trillion dollars in R&D expenditures, about 84.6% of the global total. World research and development expenditure (% of GDP) decreased 0.16 point from 1996 to 2007. After 2008 crisis, total world research and development expenditure (% of GDP) raised 0.22 point from 2008 to 2015.

In 2015, total OECD R&D spending increased in 2.32% from 1.12 trillion dollars to 1.14 trillion dollars. The ratio of gross domestic expenditure on R&D (GERD) to GDP realized 2.38% in 2014 and remained in 2015. In OECD countries, expenditure on R&D as a percentage of Gross Domestic Product (GDP) remained stable at 2.4% in 2015.

Gross domestic expenditure on R&D (GERD) stood at 299 billion euro in the EU-28 in 2015, which was a 4.4% increase on the year before. The ratio of GERD to GDP, is also known as R&D intensity, increased slightly to 2.03 % in 2013 and remained in 2014 and 2015. In 2015, among the EU member states, the highest R&D intensities were recorded in Sweden (3.26 %), Austria (3.07 %) and Denmark (3.03 %). One of the five key targets of the Europe 2020 strategy is 3% of gross domestic product (GDP) to R&D activities.

This study aims to investigate effect of technology on economic growth and 2008 crises on this relation in thirthty-OECD countries using random coefficient model (RCM) with AK model. We applied cross-sectional dependence test, panel unit-root test and co-integration test. As a result of static panel regression model with EU-dummy variables, in OECD countries (excluded EU countries) for both pre and post-2008 period, there is no significant effect of business enterprise expenditure on R&D (BERD) on economic growth. In OECD countries which is only EU members, for pre-2008, there is no significant effect of BERD on economic growth. But, for post-2008 period there is significant effect of BERD on economic growth.

Literature Reviews

Endogenous growth model investigated the relation between innovation behaviour and economik growth. (AK types of model of Romer, 1990; Rebelo (1991), Grossman and Helpman, 1991; Aghion and Howitt, 1992) Romer (1990) has revealed the importance of technological capital on economic growth. Raising research and development expenditures will result a permanently higher growth rates.

Lichtenberg (1993) investigated the relationship between R&D expenditures and economic growth in both the private and public sectors of 74 countries period for 1964-1989. They found that there is no relationship between R&D expenditures and economic growth in the public sector. Otherwise, R&D expenditures positively affected on economic growth in the private sector. Birdsall and Rhee (1993) used cross-country growth regression and found that there was a positive correlation between R&D expenditure and economic growth for only OECD countries. Gittleman and Wolff (1995) proved the relationship between R&D activities (R&D expenditures, the number of scientists per R&D, and the number of engineers per R&D) and economic growth (real GDP per capita) using panel data period of 1960-1988. Their study showed that R&D activities has significant for economic growth in developed countries. Ayres (1996) showed that technological progress can negatively impact economic growth, and especially in the field of information technology. The falling price of manufacturing goods will lower the economic growth rate. Nadiri and Kim (1996) examined the effect of R&D spillover on TFP growth in seven largest economies (1965-1991). They found that the effect of R&D spillover differ across countries.

Braconier (2000) investigated the relation between per capita income and R&D expenditures in ten OECD member countries fort he period 1973- 1992. The study showed that per capita income level has positive effect on R&D expenditures. Bialbao-Osorio and Rodriguez-Pose (2004) showed that the coefficient for the initial number of patents reports a negative effect in terms of growth rates. This finding suggests the existence of a catch up process, in line with the neoclassical growth theory, since those regions with lower levels of initial patents grow faster. Samimi and Alerasoul (2009) argued that the impact of R&D expenditures on economic growth using panel data analysis in thirty developing countries including Turkey. They found that R&D expenditures did not contribute to growth in developing countries. Mehran and Reza (2011) proved the effect of R&D expenditures on economic growth in underdeveloped countries and OECD countries using the fixed effects panel data model. They found that R&D expenditures has positive impact on economic growth in both country groups. Gyekye et al. (2012) examined the impact of R&D investments on socio-economic development in Sub-Saharan African countries with the Cobb-Douglas production function. As a results of fixed-effects panel regression estimation R&D investments has positive effect on economic growth. Güloğlu and Tekin (2012) investigated the relationship among R&D expenditures, innovation, and economic growth for OECD countries with higher income levels using a panel causality analysis. They showed that there is a significant and positive relationship between R&D and innovation, R&D and economic growth, and economic growth and innovation. Petrariu et al. (2013) investigated link between innovation and economic growth in the Central and Eastern European countries (CEE) for the period of 1996-2010 by using pooled data regression. They show that R&D spending level and the number of patents are significant but have a negative coefficient. This suggests the existence of a catch-up process, which is typical for the neoclassical growth theory. Wang (2013) found that the role of innovation in US, UK and Germany has decreased to a large extent in the second period (the post-World War II period), when a non-positive relationship between innovations and economic growth was found. Whereas, positive and statistically significant coefficient estimates were obtained in the first period (pre-World War II period). For these three countries in the second (post-World War II) period: the evidence shows a dramatic decrease in the effectiveness of the innovation's role in enhancing economic growth a negative relationship between innovations and economic growth was consistently obtained for the UK and Germany.

Huňady and Orviska (2014) based their research on panel data regression for 26 selected EU countries in the period of 1999–2011. Results of their research suggested a positive impact of R&D expenditures on the economic growth when considering a two-year lag, at the same time the effect was negative for the current year. Ozcan and Arı (2014) analysed the relationship between R&D expenditures and economic growth in 15 selected OECD countries for the period of 1990-2011. As a results of the study R&D expenditures positively effect on economic growth in 7 OECD countries. However, R&D expenditures negatively effect on economic growth in Germany, Netherland, Spain, and England. Kokko et al. (2015) showed that the effect of R&D expenditures on economic growth are negative and significant for both EU high R&D and EU low R&D countries. It is not determined by whether their R&D expenditures are above or below the EU average. Tuna et al. (2015) examined the relation between R&D expenditures and economic growth in Turkey for the period of 1990 to 2013. It is found that there is no causality relationship between R&D expenditures and economic growth.

Data and Methodology

Data

This study covered 30-OECD countries for the period of 2000-2015. 30 OECD countries includes Avustria, Belgium, Canada, Czechia, France Denmark, Estonia, Finland, Hungary, Germany, Greece, Iceland, Irland, Italy, Japan, Korea, Luxemburg, Mexico, Netherland, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Turkey, United Kingdom, and United States.

Gross domestic expenditure on R&D (GERD), business enterprise expenditure (BERD) and researchers variables was reduced only one variable by using factor analysis method. All variables located factor 1. Business enterprise expenditure (BERD) which has the biggest factor loading with 0.999 was selected as a technology proxy. Business enterprise expenditure (BERD) is here expressed in constant 2005 dollars (adjusted for purchasing power parity) and as a share of GDP. In the study, it was used BERD to GDP as proxy for technology, gross capital formation (%, GDP) as a proxy for capital formation, gross domestic product growth (annual, %) as a proxy for economic growth. Data collected from World Bank. In this study, it has been prefered panel data model, baceuse of it provides high freedom degree and reduce multicolinearity.

Studies used R&D expenditure as a proxy for technology are as follows:

Hoskisson Hitt (1988) have used R&D expenditure as a proxy for technological capabilities. Deprez and Harvey (1999) used patents or R&D expenditures as a proxy for technology. Archibugi and Pianta (1996), Smith (2005), Hanel and Zorgati (2001) use the R&D

expenditure as a proxy for technology. Elmslie and Vieira (1999) use patents and R&D expenditure for proxy for technology to investigate the effect of technology on trade flow.

In the data analysis we introduced an additional dummy variables pre-2008, post-2008, EU and HIGHRDEU which has high R&D spending to GDP EU countries, OECD membered.

OECD average R&D spending to GDP ratio, named R&D intensity, is 2.33% in 2016. Avustria, Belgium, Denmark Finland, France, Germany, Luxemburg, Slovenia, Sweden and United Kingdom has R&D intensity above OECD average. Random coefficient model was estimated for these countries which has high R&D intensity.

Methodology

We follow AK type production function is a special case of the Cobb-Douglas function.

$$Y = AK^{\alpha} + L^{1-\alpha}$$

In Cobb–Douglas function, Y, represent total production, A, represent total factor productivity, K, represent capital, L, labor force, α, output elasticity of capital. If $\alpha = 1$, production function is linear. AK endogenous growth model demonstrated by Rebelo (1991);

$$Y = AK$$

is in the form; Y represent economic output, A, represent technology level, K, represent capital.

Static panel regression model was constructed as follows

$$GDP_{it} = \alpha_{it} + \beta_{0it}GCF_{it} + \beta_{1it}BERDTOGDP_{it} + \varepsilon_{it} \quad (1)$$

where t=1,…16 time period; i=1,…,30 OECD countries, GDP, GDP Growth (%); GCF, Gross Fixed Capital Formation as a proxy for capital; BERDTOGDP, Business Enterprise Expenditure (BERD) to GDP (%) as a proxy for technology.

Swamy's random-coefficients was formed as follows

$$GDP_{i} = \alpha_{i} + \beta_{0i}GCF_{i} + \beta_{1i}BERDTOGDP_{i} + \varepsilon_{i} \quad (2)$$

where i=1....,10 OECD countries which highly R&D EU membered countries.

Results

The main problem of panel approach is cross-sectional dependence (CSD). Firstly, determine whether the CSD or not. If there is CSD, panel unit-root tests are used allowed CSD. When T<N, the LM test statistics, developed by Breusgh and Pagan (1980), exhibits substantial size distortion.[1] Pesaran's (2004) cross-sectional dependence (CD) test, Friedman's (1937) statistic, and the test statistic proposed by Free's (1995) designed to test for cross-sectional dependence in large-N, small-T panels (Hoyos and Sarafidis, 2006). In the study, because T<N, we use Pesaran's (2004) cross-sectional dependence (CD) test, Friedman's (1937) statistic, and the test statistic proposed by Free's (1995).

Pesaran (2004) cross-sectional dependence (CD) test has proposed the following,[2]

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\rho_{ij}\right)$$

and showed that under the null hypothesis of no cross-sectional dependence CD $\overset{d}{\rightarrow}$ N (0,1) for N $\rightarrow\infty$ and T sufficiently large.

For unbalanced panels, Pesaran (2004) proposes a slightly modified version of (3), which is given by

$$CD = \sqrt{\frac{2}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\sqrt{T_{ij}}\rho_{ij}\right)$$

Friedman (1937) proposed a nonparametric test based on Spearman's rank correlation coefficient. Friedman's statistic is based on the Spearman's correlation and is given by

$$R_{average} = \frac{2}{N(N-1)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} r_{ij}$$

where r_{ij} is the sample estimate of rank correlation coefficient of the residuals. Large values of $R_{average}$ show the presence of nonzero cross-sectional correlations. Friedman indicated that $(\mathrm{T}-1)\{(\mathrm{N}-1)\mathrm{R}_{\mathrm{average}}+1\}$ is asimptotically χ^2 distributed with T-1 degrees of freedom, for fixed T as N gets large.

Frees (1995, 2004) statistic is based on the sum of squared rank correlation coefficients and is given by

[1] See Pesaran (2004) or Sarafadis, Yamagata and Robertson (2006).
[2] The CD test are performed using the STATA routine "xtcsd" proposed by De Hoyos and Sarafidis (2006)

$$R^2_{average} = \frac{2}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} r^2_{ij}$$

Frees shows that $N\{R^2_{average} - (T-1)^{-1}\}$ is asimptotically Q distributed with T-1 and T(T-3)/2 degrees of freedom, respectively.

Firstly, cross-sectional dependence tests was applied. Table 1. present the results obtained for three different cross-sectional dependence test statistics: CD (Pesaran 2004), Frees' and Friedman's tests. The results show that there is enough evidence to reject the null hypothesis of cross-sectional independence. The results indicate that for the OECD countries at significance level p=0.01 we rejected the null hypothesis indicating cross-sectional independence. This finding necessitates taking into account cross-section dependence when applying panel unit-root tests.

Table 1: Cross-sectional Dependence Tests

	CD (Pesaran, 2004)	Friedman (1937)	Frees Test
FE Model	41.215*** (0.000)	166.718*** (0.000)	3.672* (0.000)
RE Model	42.302*** (0.000)	170.926*** (0.000)	3.763* (0.000)

Note: The p-values are in parentheses. *** indicate the statistical significance $\alpha = 0.01$.

We use of Pesaran (2003, 2005) CADF, the second-generation panel unit-root test, that take into account the dependence between countries. Table 2 shows the results of CADF test. As a result of test, the null hypothesis of unit root is rejected.[1] The result of test indicate that all variables are integrated of order 1.

Table 2: Pesaran CADF Panel Unit Root Test

Variables	t-bar	Z
<u>Level</u>		
GDP	-2.023	-1.518 (0.065)
GCF	-1.175	3.033 (0.999)
BERDTOGDP	-2.031	1.406 (0.920)
<u>First Difference</u>		
DGDP	-2.473*	-3.748 (0.000)
DGCF	-2.247*	-2.625 (0.004)
DBERDTOGDP	-2.277*	-2.774 (0.003)

Note: Critical values for the t-bar statistics with trend at 1%, 5% and 10% significance levels are -2.070, -2.170 and -2.340 respectively.

[1] See Pesaran (2007) for critic value.

We used Westerlund (2007) to test whether variables are cointegrated. Westerlund (2007) panel cointegration test showed that the null hypothesis is no cointegration. Table 3 represents the Westerlund (2007) results. The null hypothesis of no cointegration is rejected by all test statistics (except G_α and P_α - may be because the sample size is smaller).

Table 3: Westerlund (2007) Panel Cointegration Test

Statistics	Value	Z-value
G_τ	-3.334*	-7.724* (0.000)
G_α	-6.764	2.062 (0.980)
P_τ	-13.276*	-3.770* (0.000)
P_α	-6.311	-0.437 (0.331)

Note: The cointegration tests take no cointegration as the null. G_τ and G_α are Group mean tests P_τ and P_α Panel tests. The Ga statistic may reject the null hypothesis of no cointegration in small panel data (Westerlund, 2007).

Table 4: Static Regression Model (Random Effect Estimator)

N=30, T=16	OECD COUNTRIES	OECD (EU COUNTRIES-HIGH R&D)	OECD (EU COUNTRIES-LOW R&D)	OECD (EU COUNTRIES)	OECD (NON-EU COUNTRIES)
Full Sample					
DGFC	0.672*** (0.000)	0.036 (0.882)	0.690 (0.000)	0.682*** (0.000)	0.700*** (0.001)
DBERDTOGDP	-3.629 (0.068)	-6.641*** (0.003)	1.357 (0.720)	-1.845 (0.386)	-8.651 (0.059)
C	0.125 (0.493)	-0.012 (0.957)	0.147 (0.635)	0.200 (0.325)	-0.003 (0.994)
R	0.0825	0.11	0.04	0.0938	0.2868
Wald	30.41*** (0.000)	8.85*** (0.0120)	19.71*** (0.000)	31.09*** (0.000)	12.30*** (0.000)
Pre-2008 Sample					
DGFC	0.744*** (0.000)	-0.431 (0.144)	0.967 (0.000)	0.802*** (0.000)	0.655*** (0.009)
DBERDTOGDP	-5.080 (0.051)	-4.407 (0.093)	-9.800 (0.100)	-5.339 (0.052)	-4.569 (0.430)
C	-0.455*** (0.018)	-0.353 (0.130)	-0.605*** (0.040)	-0.514*** (0.009)	-0.316 (0.487)
R	0.1760	0.1454	0.2938	0.1921	0.2333
Wald	38.03*** (0.000)	5.23 (0.073)	33.05*** (0.000)	32.01*** (0.000)	7.04*** (0.029)
Post-2008 Sample					
DGFC	0.733*** (0.000)	0.466 (0.235)	0.669*** (0.010)	0.790*** (0.000)	0.783*** (0.040)
DBERDTOGDP	-3.159 (0.271)	-7.092*** (0.048)	2.938 (0.571)	-0.564 (0.855)	-12.240 (0.089)
C	0.827*** (0.012)	0.544 (0.205)	1.076 (0.066)	1.106*** (0.003)	0.364 (0.587)
R	0.0945	0.1223	0.0976	0.1125	0.2509
Wald	17.53*** (0.000)	6.46*** (0.039)	7.52*** (0.023)	12.21*** (0.000)	6.09*** (0.047)

Note: The p-values are in parentheses. *** indicate the statistical significance $\alpha = 0.01$.

As a result of Equation (1), in OECD countries, which has high R&D expenditure to GDP ratio and EU countries, BERD to GDP ratio has a negative and significant effect on economic growth after 2008 crisis. In OECD countries, which has low R&D expenditure to GDP ratio and EU countries, BERD to GDP ratio has a positive and insignificant effect on economic growth after 2008 crisis. We estimated random coefficient regression model (RCM) for OECD countries which has high R&D intensity membered EU countries for the post-2008.

Table 5: Random Coefficient Model (RCM) for OECD Countries (High R&D EU) for Post-2008

N=10, T=11	DGCF	DBERDTOGDP	C
Austria	0.017 (0.986)	-4.890 (0.605)	0.438 (0.584)
Belgium	-0.062 (0.914)	-9.674(0.109)	1.035 (0.057)
Denmark	-0.700 (0.155)	-33.359*** (0.000)	-0.324 (0.573)
Finland	0.218 (0.804)	-11.082 (0.284)	0.392 (0.574)
France	0.938 (0.280)	-23.629*** (0.015)	1.027 (0.138)
Germany	1.939*** (0.040)	-29.618*** (0.005)	1.467 (0.054)
Luxemburg	-0.759 (0.413)	-9.028 (0.324)	-0.186 (0.806)
Slovenia	0.833 (0.278)	-2.819 (0.724)	1.102 (0.135)
Sweden	0.861 (0.377)	-14.542 (0.149)	0.803 (0.330)
United Kingdom	0.944 (0.312)	-18.853 (0.060)	0.945 (0.225)
Wald Statistics	9.88 (0.004)		

Note: The p-values are in parentheses. *** indicate the statistical significance $\alpha = 0.01$.

As a result of Equation (2), it was observed decreasing technology effect on economic growth after 2008 crisis. The evidence shows a dramatic decrease in the effectiveness of the technology's role in enhancing economic growth. A negative relationship between technology and economic growth was obtained for the Denmark, France, and Germany. The findings also show evidence of decline in the role of technology in the period after the 2008 crisis break date. Findings, technology has a negative coefficient on economic growth, is supported by Ayres (1996), Bialbao-Osorio and Rodriguez-Pose (2004), Petrariu et al. (2013), Kokko et al. (2015) and Wang (2013) studies. Griliches (1988) proved that the fluctuation of macroeconomic conditions are probably responsible for the decline of innovation's role. Lichtenberg and Frank (1993) found that government R&D expenditure showed a negative impact on economic growth. Eckbo (2007) presented that a country's high R&D intensity is not guarantee for future growth.

Conclusion

We analyzed that the impact of technology on economic growth in thirthty-OECD countries using static panel data model and random coefficient model (RCM) with AK model for the period 2000-2015. Cross-sectional dependence test, panel unit-root test and cointegration test was used. As a result of estimation with all of OECD countries, high R&D EU OECD countries, low R&D EU OECD countries, EU-OECD countries, and OECD (excluded EU countries) for both pre and post-2008 period, there is significant effect of business enterprise expenditure on R&D (BERD) on economic growth for high R&D EU OECD. In high R&D EU OECD countries there is negative and significant effect of BERD on economic growth for post-2008.

As a result of RCM, in Denmark, France, and Germany, it was observed decreasing technology effect on economic growth after 2008 crisis. Findings, supported by Ayres (1996), Kiley (1999), Bialbao-Osorio and Rodriguez-Pose (2004), Petrariu et al. (2013), Kokko et al. (2015) and Wang (2013) studies. EU countries with higher R&D spending shows lower economic growth. Negative coefficient on BERD, in high R&D EU OECD countries, suggests the existence of opportunity cost of BERD.

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