Theoretical and Applied Economics
Volume XXIII (2016), No. 4(609), Winter, pp. 153-164

Effects of R&D and innovation on income in EU countries: new generation panel cointegration and causality analysis

Ismet GOCER
Adnan Menderes University, Turkey
ismetgocer@gmail.com
Sedat ALATAS
Adnan Menderes University, Turkey
sedat.alatas@adu.edu.tr
Osman PEKER
Adnan Menderes University, Turkey
ottopeker@gmail.com

Abstract. *The purpose of this study is to examine the effects of research-development expenditures and innovation on income using new generation panel data analysis for 11 EU countries. We found that that if research-development expenditures and innovation goes up by 1%, income, on average, raises by 0.19% and 4.05%, respectively.*

Keywords: R&D, Innovation, Panel Cointegration, Panel Causality.

JEL Classification: O31, O32, O47.

1. Introduction

Economic growth differences across countries occur for several reasons. They may be associated with large differences in literacy, infant mortality or life expectancy conditions. In addition to those, social standards, geography, culture and luck may also be fundamental causes of differences in economic performance across countries (Acemoglu, 2012). However, the key factor determining the differences in income across countries is related to the technological level in the contemporary world (Breznitz, 2007). Labor-based economic growth and natural resources-based economic growth are no longer valid in today’s world. Advanced technology and productivity took the place of labor and natural resources-based growth (Potters, Ortega-Argilés and Vivarelli, 2011). At this point, the question of how developing countries can obtain advanced technology and arise their productivity.

The main objective of this study is to examine the effects of research and development (henceforth R&D) expenditures and innovation activities on income by new generation panel data analysis for the period of 1990-2011 for 11 Europe Union (EU) countries; Germany, Austria, Belgium, Denmark, Finland, France, Netherlands, UK, Spain, Sweden and Portugal. The findings show that if R&D expenditures and innovation goes up by 1%, income, on average, raises by 0.19% and 4.05%, respectively. The findings from this study are considered to be a guide for developing economies and countries that wait to join EU soon.

The remainder of the paper is organized as follows: The next section presents theoretical framework. Section 3 contains summary of the literature. The main empirical results are presented in section 4. Section 5 concludes.

2. Theoretical framework

In the existing literature, a number of explanations directly connected to this issue are developed. Krugman (1986) developed the technology gap model. This model suggests that a large part of the trade between industrialized countries is based on new goods. Filipovic, Devjak and Putnik (2012) states that innovative companies improving these production processes and patents and technical knowledge assured by intellectual property rights will accelerate the economic growth and monopoly profits of companies. In addition, the product life cycle hypothesis shows that industrialized countries owning a high degree of human capital and investing in R&D produce more technical innovations and new goods (Maksimovic and Phillips, 2008).

Besides that, according to the endogenous growth model developed by Romer (1986) and Lucas (1988), knowledge, R&D activities, human capital and technological progress are endogenous and significant contributors explaining growth and increased productivity. Additionally, Lucas (1988) includes technological progress and investment in the same model and focuses on the effects of R&D expenditures and human capital on technology. He finds that R&D and innovation activities play a substantial role in decreasing the technological gap and accelerating economic growth.

In recent years, labour force with knowledge and skill, experience and information, infrastructure of R&D, modern communication network, the effective use of information technology, productivity without sacrificing quality and wealth of product range are the main determinants of competitive capacity. This is because high value-added product competition has shifted to a competition of scientific and technology in developed countries. To do this, substantial funds are allocated for R&D and innovation in developed countries. For instance, in 2004, the public sector in the OECD countries spent approximately $190 billion on R&D (OECD, 2007).

The number of patents which is an indicator of inventions carried out and demonstrates the capacity of country's R&D and number of R&D-based output are enormously crucial and shows the innovation potential of the country. This is because a design produced by R&D activities and the use of this design in production process decreases production costs and provides a competitive advantage for exporter companies in foreign trade (Amaghouss and Ibourk, 2013).

Investments in knowledge and innovation also provide a basis for technological progress (OECD, 2007). The invention achieved through technological development and R&D activities can be considered as capital accumulation and innovation. In this way, available resources can be used more efficiently and countries can eventually have higher levels of production, consumption and standard of living (Kiper, 2004; Miroslav, Boris, Ivanova and Mitja, 2011). Thus, countries are required to allocate a higher proportion of national income for R&D and innovation in these countries. This is because sustainable economic growth in the long-run depends on technological progress and innovation (Bourgeois and LeBlanc, 2002: 33).

Legislative regulations protecting patent and intellectual property rights in countries have importance owing to the fact that these regulations can make a positive impact on companies' R&D expenditures (Wangwe, 2007). The reason is that knowledge produced by R&D and innovation activities is often also non-excludable. Due to the non-excludability of new knowledge, companies on free market may invest too little in R&D (Svensson, 2008).

Recently, R&D activities have become an element of productivity, economic growth and competitive advantage. Especially, the product life cycle has shortened in technology-intensive industries. This condition has forced companies to develop new products and innovation existing products. Companies not allocating sufficient resources for R&D and innovation have to pull out of the market. More than half of the economic growth in advanced economies in recent years is originated from R&D and innovation (OECD, 2007).

3. Literature

There are many studies in the literature which investigate the empirical aspects of the relationship between R&D, innovation and income. This section presents a selected empirical literature review on the impacts of R&D expenditures and innovation activities on economic performance. Sylwester (2001) examine the association between R&D and the growth rate of output per capita. He found that there is weak positive relationship between R&D expenditures and the growth rate of output per capita for OECD economies. Osorio and Pose (2004) examine the relationship between R&D investment and innovation for the peripheral regions of Europe by cross-section OLS regression. The results indicate that R&D investment and higher education R&D investment is positively associated with innovation in these peripheral regions. Ulku (2004) investigate relationship between per capita GDP and R&D, innovation for 20 OECD economies and 10 non-OECD economies in 1981-1997 periods by panel data analysis. It is found that innovation and per capita GDP had strong and positive linkage in OECD and non-OECD countries. He also noted that innovations in OECD countries are supported by R&D investments. Torun and Cicekci (2007) examine the link between innovation and economic growth. They found that innovation makes a significant impact on growth and there are significant spillover between countries. Besides that, Estrada and Estrada (2009) develop the theoretical endogenous model for analyzing the impact of R&D investment on long term growth. They found that R&D shocks have a positive impact on economic activity. Yinsheng, Baomin and Die (2010) investigate the relationship between R&D investment and economic growth for the period 2000-2008. The results show that R&D investment has a positive impact on economic growth, although this impact decreases gradually. Kilic, Savrul and Ustaoglu (2011) examine the effects of technology and innovation on economic growth for Turkey. They found that there is a positive relationship between R&D expenditures and economic growth. Guloglu and Tekin (2012) investigate OECD countries for the period 1991-2007 by using GMM and Panel VAR methods. They suggest that technological change increases economic growth and technological change is the cause of R&D investment. Akinci and Sevinc (2013) examine the link between R&D expenditures and economic growth for Turkey for the period 1990-2011 by using the Granger Causality method. They found that there is a unidirectional causality from R&D investment and higher education R&D investment to economic growth. Bayarcelik and Tasel (2013) investigate the relationship between innovation and economic growth in Turkey by using the endogenous growth theory for the period 1998-2010. The results suggest that there is a positive and significant effect of R&D expenditures and the number of R&D employees on economic growth. Westmore (2013) examine effects of innovation specific policies across 19 OECD countries. The results suggest that innovation specific policies such as R&D tax incentives, direct government support of business R&D and patent rights encourages private sector innovative activity. Conversely, there is no direct effect of such policies on aggregate productivity growth.

4. Empirical analysis

4.1. Data and model specification

In this study, the effects of R&D expenditures and innovation activities on income are analyzed by new generation panel data analysis based on annual data for the period of 1990-2011 for 11 EU countries. The variables are: Gross National Product (2005=100)

(Y); R&D expenditures (2005=100) (R&D) and innovation (IN). Innovation is represented by the total number of patent applications previously used by Ulku (2004), Kilic et al. (2011), Guloglu and Tekin (2012).

Consider the following model used by Ho, Wong and Toh (2009)

$$Y_t = A\, RD_t^{\beta_1}\, K_t^{\alpha_1} L_t^{\alpha_2} e^{\mu t} \tag{1}$$

We begin by adding innovation as a variable to Eq. (1)

$$Y_t = A\, RD_t^{\beta_1} IN_t^{\beta_2} K_t^{\alpha_1} L_t^{\alpha_2} e^{\mu t} \tag{2}$$

Where *Y* equals real GDP, *RD* is the R&D capital stock, *IN* is the number of patents, *L* is labour input, *K* is capital input, *A* is a constant and μ is a time trend which captures other trended influences. When we take the logarithm of both sides, we obtain

$$LogY_t = LogA + \beta_1 LogRD_t + \beta_2 LogIN_t + \alpha_1 LogK_t + \alpha_2 LogL_t + \mu t \tag{3}$$

If the effect of labour and capital on income is represented by β_0

$$\beta_0 = LogA + \alpha_1 LogK_t + \alpha_2 LogL_t + \mu t \tag{4}$$

This econometric model obtained in this study

$$LogY_{it} = \beta_{i0} + \beta_1 LogRD_{it} + \beta_2 LogIN_{it} + \varepsilon_{it} \tag{5}$$

4.2. Cross-sectional dependence tests

Taking into consideration cross-sectional dependence between countries makes a significant impact on the results of panel data analysis. For this reason, before we apply the analysis, the presence of cross-sectional dependence of model and variable needs to be tested. This is because unit root and cointegration tests should be chosen with respect to cross-sectional dependence results (Breusch and Pagan, 1980; Pesaran, 2004).

In this study, the presence of cross-sectional dependence is examined by the Adjusted Cross-Sectional Dependence Lagrange Multiplier *($CDLM_{adj}$)* developed by Pesaran, Ullah and Yamagata (2008). Test statistic is expressed as

$$CDLM_{adj} = \left(\frac{2}{N(N-1)}\right)^{1/2} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2 \frac{(T-K-1)\hat{\rho}_{ij} - \hat{\mu}_{Tij}}{\upsilon_{Tij}} \sim N(0,1) \tag{6}$$

where $\hat{\mu}_{Tij}$ is mean and υ_{Tij} is variance. When we reject the null hypothesis, we say that there is a cross-sectional dependence between countries. The test statistic obtained from Equation (6) is normally distributed asymptotically (Pesaran et al. 2008). The results were presented in Table 1.

Table 1. *$CDLM_{adj}$ The Results of Cross-Sectional Dependence Test*

Variables	*t-statistics*	*p-value*
GDP	84.332	0.007
R&D	5.909	0.000
IN	12.739	0.000
Model	101.844	0.000

According to results presented in Table 1, there is a strong cross-sectional dependence among these countries. It means that when R&D, innovation or income shocks occur in a country, these shocks affect the others. Thus, while countries determine their economic policy, they should take into consideration policies implemented by other countries and the shocks affecting these countries.

4.3. Panel unit root tests

In this study, stationarity of variables is examined by Hadri and Kuruzomi (2012) panel unit root test. These test takes into consideration not only cross-sectional dependence, but also unit root arising from common factors forming series. In order to remedy autocorrelation problem, it uses SPC (Sul-Phillips-Choi) method developed by Sul, Phillips and Choi (2005) and is based on the *SUR* (Seemingly Unrelated Regression) method using *AR (p)* process. In this study, *p* optimal lag length was determined by Cross-Sectional Dependency Augmented Dickey Fuller *(CADF)* test. Consider the following model

$$y_{it} = z_t^{'}\delta_i + f_t\gamma_i + \varepsilon_{it} \quad (7)$$

$$\varepsilon_{it} = \phi_1\varepsilon_{it-1} + v_{it} \quad (8)$$

where f_t is common factor. To expand Eq. (7) in SPC method by AR (*p*), we proceed as follows

$$y_{it} = z_t^{'}\hat{\delta}_i + \hat{\phi}_{i1}y_{it-1} + \cdots + \hat{\phi}_{ip}y_{it-p} + \hat{\psi}_{i0}\bar{y}_t + \cdots + \hat{\psi}_{ip}\bar{y}_{t-p} + \hat{v}_{it} \quad (9)$$

By calculating variance in the long term ($\hat{\sigma}_{vi}^2 = \frac{1}{T}\sum_{t=1}^{T}\hat{v}_{it}^2$) and SPC variance

($\hat{\sigma}_{iSPC}^2 = \frac{\hat{\sigma}_{vi}^2}{(1-\hat{\phi}_i)^2}$) of estimation of Eq. (9) we can obtain the Z_A^{SPC} statistic

$$\mathrm{Z_A^{SPC}} = \frac{1}{\hat{\sigma}_{iSPC}^2 T^2}\sum_{t=1}^{T}(S_{it}^{w})^2 \quad (10)$$

To expand Equation (7) in *LA* method by *AR (p+1*), we proceed as follows:

$$y_{it} = z_t^{'}\tilde{\delta}_i + \tilde{\phi}_{i1}y_{it-1} + \cdots + \tilde{\phi}_{ip}y_{it-p} + \tilde{\phi}_{ip+1}y_{it-p-1} + \tilde{\psi}_{i0}\bar{y}_t + \cdots + \tilde{\psi}_{ip}\bar{y}_{t-p} + \tilde{v}_{it} \quad (11)$$

By calculating variance in the long term ($\hat{\sigma}_{vi}^2 = \frac{1}{T}\sum_{t=1}^{T}\hat{v}_{it}^2$) and *LA* variance ($\hat{\sigma}_{iLA}^2 = \frac{\hat{\sigma}_{vi}^2}{(1-\tilde{\phi}_{i1}-\ldots-\tilde{\phi}_{ip})^2}$) of estimation of Equation (10) we can obtain Z_A^{LA} statistic is:

$$Z_A^{LA} = \frac{1}{\hat{\sigma}_{iLA}^2 T^2}\sum_{t=1}^{T}(S_{it}^{w})^2 \quad (12)$$

The hypotheses are as follows

H₀: $\phi_i(1) \neq 0 \quad for\ all\ i$, there is no unit root.

H_1: $\phi_i(1) = 0 \quad for\ some\ i$, there is unit root.

The results were presented in Table 2.

Table 2. *The Results of Hadri and Kuruzomi (2012) Panel Unit Root Test*

Variables	*Levels*		*First Difference*	
	Z_A^{SPC}	Z_A^{LA}	Z_A^{SPC}	Z_A^{LA}
GDP	-2.2998	-2.6055	0.4574*	1.5767*
R&D	-2.3565	-2.6016	0.6036*	0.1238*
IN	3.0451	16.5601	-0.0365*	-0.4328*

Notes: * denotes statistical significance at the 1% level of significance.

The results show that the level values of all series are non-stationary. Hence, all we have to do is to take the first difference of series. The first-differenced series are stationary; that is *I (1)*. Namely, series were non-stationary in level and they became stationary in the first difference.

4.4. Homogeneity test for cointegration coefficients

The first studies to determine homogeneity of slope coefficients in cointegration equations were developed by Swamy (1970) and improved by Pesaran and Yamagata (2008). A cointegration equation is as follows:

$$Y_{it} = \alpha + \beta_i X_{it} + \varepsilon_{it} \qquad (13)$$

where ε_{it} is an error term and where β_i is a slope coefficient. In this homogeneity test, we examine whether slope coefficients differ across cross-section units. The hypotheses are as follows

H_0: $\beta_i = \beta$ Slope coefficients have homogeneity

H_1: $\beta_i \neq \beta$ Slope coefficients have homogeneity

To test this, Pesaran and Yamagata (2008) developed two different test statistics:

Large Samples: $\hat{\Delta} = \sqrt{N}\left(\frac{N^{-1}\tilde{S}-k}{2k}\right) \sim \chi_k^2$

Small Samples: $\hat{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\tilde{S}-k}{v(T,k)}\right) \sim N(0,1)$

where N is number of cross-section units, S is Swamy test statistics; k is number of explanatory variable and $\upsilon(T, k)$ standard error. The results of slope homogeneity test are presented in Table 3.

Table 3. *The Results Slope Homogeneity Test*

	t-statistics	*p-value*
$\tilde{\Delta}$	0.127	0.450
$\tilde{\Delta}_{adj}$	0.139	0.445

The result shows that slope coefficient have homogeneity. In this case, we can interpret the panel cointegration coefficient.

4.5. Panel cointegration test

The presence of a cointegration relationship between series is examined by the LM bootstrap panel cointegration test developed by Westerlund and Edgerton (2007). The main advantages of this method are: *(i)* it takes into consideration cross-sectional dependence, *(ii)* allows autocorrelation and heteroscedasticity in cointegration equation, *(iii)* produces effective results in small samples and *(iv)* prevents endogeneity problems by using Fully Modified Ordinary Least Square (FMOLS) method as an estimator (Westerlund and Edgerton, 2007). To understand this test, consider the following equation

$$y_{it} = \alpha_i + x_{it}^{'}\beta_i + z_{it} \qquad (14)$$

where $z_{it} = u_{it} + \sum_{j=1}^{t} \eta_{ij}$ and η_{ij}; is an independent and identically distributed process with zero mean and variance $\text{var}(\eta_{ij}) = \sigma_i^2$. The hypotheses are as follows

H_0: $\sigma_i^2 = 0 \quad for\ \forall i$, there is a cointegration relationship between series

H_1: $\sigma_i^2 > 0 \quad for\ \exists i$,there is no cointegration relationship between series

To test these hypotheses, Westerlund and Edgerton (2007) developed LM test statistic

$$LM_N^+ = \frac{1}{NT^2}\sum_{i=1}^{N}\sum_{t=1}^{T} \widehat{w}_i^{-2} S_{it}^2 \qquad (15)$$

where $w_{it} = (u_{it}, \Delta x_{it}^{'})^{'}$ and S_{it} are sub-total values of error terms $(\widehat{z}_{it})$ of model estimated by *FMOLS*. LM test statistic and p-values are calculated by Bootstrap in the Westerlund and Edgerton (2007) Panel Cointegration Test.

Table 4. *The results of Westerlund and Edgerton (2007) Panel Cointegration Test*

Test statistic	*p- value*
1.586	0.685

Notes: Bootstrap critical values are obtained from 1000 replications

The findings show that there is a cointegration relationship between series. In other words, series tend to move together in the long run. Hence, the analysis with level values of series will not fall suspicious regression problem.

4.6. Estimation of cointegration coefficients

Cointegration coefficients were estimated bias adjusted OLS estimator developed by Westerlund (2007). This method does not only take into consideration cross-sectional dependence between countries, but also considers endogeneity and common factors. In this respect, this method is considered superior to other estimators. The results of cointegration coefficients are presented in Table 5.

Table 5. *Cointegration Coefficients*

	Coefficient	*t-statistics*
R&D	0.19**	1.55
IN	4.05*	2.25

Notes: Autocorrelation and heteroscedasticity problems are fixed Newey-West method. * and ** denote statistical significance at the 1% and 10% level of significance, respectively.

The results show that if R&D expenditures and innovation goes up by 1 percent, on average, economic growth goes up by approximately 0.19 percent and 4.05 percent, respectively.

4.7. Panel Causality Tests

The causality relationship between series is analyzed by Panel Fisher test developed by Emirmahmutoglu and Kose (2011). This test employs level values of series and provides more knowledge about them. In addition to this, it includes *I(0)* and *I(1)* series in the model together. The test essentially involves two stages. The first stage determines the optimal lag length (p) and the maximum order of integration (d_{max}) of the variables in the system. The lag length, p is obtained in the process of the Vector Auto Regression (VAR) in levels among the variables in the system. We can express the level VAR model with ($p+ d_{max}$) as

$$X_{i,t} = \mu_i^x + \sum_{j=1}^{p_i+d_{max}} \alpha_{1ij} X_{i,t-j} + \sum_{j=1}^{p_i+d_{max}} \alpha_{2ij} Y_{i,t-j} + u_{i,t}^x \quad (16)$$

$$Y_{i,t} = \mu_i^y + \sum_{j=1}^{p_i+d_{max}} \beta_{1ij} Y_{i,t-j} + \sum_{j=1}^{p_i+d_{max}} \beta_{2ij} X_{i,t-j} + u_{i,t}^y \quad (17)$$

The second stage uses the modified Wald procedure to test the VAR ($p+d_{max}$) model for causality. H_0 hypothesis for Equation (16) indicates that there is no causality from Y to X. In this study, we applied Emirmahmutoglu and Kose (2011) Panel Fisher test and the results are presented in Table 6.

Table 6. *The Results of Emirmahmutoglu and Kose (2011) Panel Fisher Causality Test*

Causality	*t-statistic*	*Decision*
R&D=>GDP	37.77(0.019)**	There is bidirectional causality between R&D and GDP
GDP=>R&D	45.36(0.002)*	
IN=>GDP	50.72(0.00)*	There is bidirectional causality between IN and GDP
GDP=>IN	32.46(0.06)***	
R&D=>IN	44.95(0.002)*	There is unidirectional causality from R&D to innovation
IN=>R&D	29.10(0.14)	

Notes: Akaike Information Criteria was used to determine optimum lag lengths. The figures in the parentheses indicate p-values. *, ** and *** denote statistical significance at the 1%, 5% and 10% level of significance, respectively.

According to the results, while there is bidirectional causality between R&D expenditures, innovation and income, there is unidirectional causality from R&D to innovation. This result is consistent with the theoretical expectations. Because an increase in R&D expenditures and innovation enhances product range and quality, competitiveness of country in the international arena by reducing costs and makes positive impact on income by affecting export. Conversely, increased income allows more resources to be transferred to R&D.

5. Conclusion

In this study, the effects of R&D expenditures and innovation activities on income were analyzed by new generation panel data analysis based on data for the period of 1990-2011 for 11 EU countries. First, the presence of cross-sectional dependence was tested by $CDLM_{adj}$ developed by Pesaran (2008) and it is seen that there is cross-sectional dependence between countries. Secondly, stationarity of series was examined by the Hadri and Kuruzomi (2012) panel unit root test. The results show that while level values of all series is non-stationary, the first-differenced series is stationary. Thirdly, homogeneity of cointegration coefficients is analyzed by slope homogeneity test developed by Pesaran and Yamagata (2008). This finding suggests that cointegration coefficients were homogeneous between cross sections. Next, the presence of cointegration between series was analysed *LM* Bootstrap panel cointegration test developed by Westerlund and Edgerton (2007) and it is found that series is cointegrated. Then, cointegration coefficients were estimated by bias adjusted OLS estimator developed by Westerlund (2007). According to these results, if R&D expenditures and innovation rises by 1%, on average, income rises by 0.19% and when innovation rises by 1%, income rises by 4.05%. Consequently, the Panel Fisher causality test developed by Emirmahmutoglu and Köse (2011) was applied. These findings also show that there is bidirectional causality between R&D expenditures, innovation and income.

As a result, we can suggest that R&D expenditures and innovation have a positive and statistically significant impact on income. In this case, developing and least developed countries can have the opportunity to accelerate their income by investing R&D and innovation activities. For this reason, education system training of highly qualified labour force and collaboration of universities and industries are required in order to use resources efficiently in these countries. The incentives should be project-based and application-oriented.

References

Acemoglu, D., 2012. Institution, Political Economy and Growth. *MIT* <http://www-2.iies.su.se/Nobel2012/Presentations/Acemoglu.pdf>

Akbas, Y.E., Senturk, M. and Sancar, C., 2013. Testing for Causality between the Foreign Direct Investment, Current Account Deficit, GDP and Total Credit: Evidence from G7. *Panoeconomicus*, 6, pp. 791-812.

Akinci, M. and Sevinc, H., 2013. The Relationship between R&D Expenditures and Economic Growth: The Case of Turkey, 1990-2011. *The Journal of International Social Research*, 6(27), pp. 7-17.

Amaghouss, J. and Ibourk, A., 2013. Entrepreneurial Activities, Innovation and Economic Growth: The Role of Cyclical Factors Evidence from OECD Countries for the Period 2001-2009. *International Business Research,* 6(1), pp. 153-165.

Bayarcelik, E.B. and Taşel, F., 2012. Research and Development: Source of Economic Growth. *Procedia Social and Behavioral Sciences.* 8th International Strategic Management Conference, 58, pp. 744-753.

Bourgeois, Y. and LeBlanc, S., 2002. Innovation in Atlantic Canada. *The Canadian Institute for Research on Regional Development. Maritime Series*. Canada.

Breusch, T. and Adrian, P., 1980. The Lagrange Multiplier Test and Its Applications to Model Specification Tests in Econometrics. *Review of Economic Studies*, 47, pp. 239-53.

Breznitz, D., 2007. Innovation and the State: Political Choice and Strategies for Growth in Israel, Taiwan, and Ireland. *Yale University Press.* USA.

Choi, I., 1993. Asymptotic Normality of the Least-Squares Estimates for Higher Order Autoregressive Integrated Processes with Some Applications. *Econometric Theory,* 9, pp. 263-282.

David, P., Hall, B. and Toole, A., 2000. Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence. *Research Policy*, 29(4-5), pp. 497-529.

Emirmahmutoglu, F. and Kose, N., 2011. Testing for Granger Causality in Heterogeneous Mixed Panels. *Economic Modelling*, 28, pp. 870-876.

Estrada, Á. and Montero, J.M., 2009. R&D Investment and Endogenous Growth: A SVAR Approach. *Documentos de Trabajo,* N. 0925, pp. 1-40.

Filipovic, J., Devjak, S. and Putnik, G., 2012. Knowledge Based Economy: The Role of Expert Diaspora. *Panoeconomıcus*, 3, pp. 369-386.

Guellec, D. and Pottelsberghe, B.V., 2004. From R&D to Productivity Growth: Do the Institutional Settings and Source of Funds of R&D Matter?. *Oxford Bulletin of Economics and Statistics,* 66, pp. 353-78.

Guloglu, B. and Tekin, R.B., 2012. A Panel Causality Analysis of the Relationship among Research and Development, Innovation and Economic Growth in High-Income OECD Countries. *Eurasian Economic Review*, 2(1), pp. 32-47.

Hadri, K. and Kurozumi, E., 2012. A Simple Panel Stationarity Test in the Presence of Serial Correlation and a Common Factor. *Economics Letters,* 115, pp. 31-34.

Hall, B.H., 2011. Innovation and Productivity. *NBER Working Paper,* 17178, pp. 1-25.

Ho, Y.P., Wong, P.K. and Toh, M.H., 2009. The Impact of R&D on the Singapore Economy: An Empirical Evaluation. *The Singapore Economic Review (SER).* World Scientific Publishing Co. Pte. Ltd., Vol. 54(01). pp. 1-20.

Kilic, C., Kilinc Savrul, B. and Ustaoglu, M., 2011. Impacts of Technology and Innovation on Economic Growth: Reflections on Turkey. *The Entrepreneurship Innovation and Economic Development, Third International Istanbul Economic Conference.* October10-12. Proceeding Book III: 223-237, Istanbul.

Kiper, M., 2004. Technology Transfer Mechanisms and University-Industry Collaboration. *MMOB*, No. 59-122, Ankara.

Krugman, P.R., 1986. Industrial Organization and International Trade. *NBER Working Papers,* No. 1957.

Lucas, R.E., 1988. On The Mechanics of Economic Development. *Journal of Monetary Economics*, 22, pp. 25-50.

Maksimovic, V. and Phillips, G., 2008. The Industry Life Cycle, Acquisitions and Investment: Does Firm Organization Matter?. *The Journal of Finance,* 63(2), pp. 673-708.

Miroslav, V., Boris, M., Ivanova, O. and Mitja, M., 2011. R&D and Economic Growth in Slovenia: A Dynamic General Equilibrium Approach with Endogenous Growth. *Panoeconomicus*, 1, pp. 67-89.

OECD, 2007. *Science, Technology and Industry: Scoreboard* <http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2007_sti_scoreboard-2007-en>

Osorio, B.B. and Pose, A.R., 2004. From R&D to Innovation and Economic Growth. *Gatton College of Business and Economics, University of Kentucky in its Journal Growth and Change,* 35(4), pp. 434-455.

Pesaran, M.H., 2004. General Diagnostic Tests for Cross Section Dependence in Panels. *Cambridge Working Papers in Economics*, 435.

Pesaran, M.H. and Yamagata, T., 2008. Testing Slope Homogeneity in Large Panels. *Journal of Econometrics*, 142(1), pp. 50-93.

Pesaran, M.H., Ullah, A. and Yamagata, T., 2008. A Bias-Adjusted LM Test of Error Cross-Section Independence. *Econometrics Journal*, 11, pp. 105-127.

Poole, E. and Bernard, J.T., 1992. Defence Innovation Stock and Total Factor Productivity Growth. *Canadian Journal of Economics,* 25, pp. 438-52.

Potters, L., Ortega-Argilés, R. and Vivarelli, M., 2011. R&D and Productivity: Testing Sectoral Peculiarities Using Micro Data. *Empirical Economics*, 41(3), pp. 817-839.

Romer, P.M., 1986. Increasing Returns and Long Run Growth. *Journal of Political Economy,* 94(5), pp. 1002-1037.

Sul D., Phillips, P.C.B. and Choi, C., 2005. Prewhitening Bias in HAC Estimation. *Oxford Bulletin of Economics and Statistics, Department of Economics*, University of Oxford, 67(4), pp. 517-546.

Swamy, P.A.V.B., 1970. Efficient Inference in a Random Coefficient Regression Model. *Econometrica*, 38(2), pp. 311-323.

Svensson, R., 2008. Growth Through Research and Development- What Does the Research Literature Say?. *VINNOVA Swedish Governmental Agency for Innovation System*, 19, pp. 1-68.

Sylwester, K., 2001. R&D and Economic Growth. *Knowledge, Technology, & Policy,* 13(4), pp. 71-84.

Toda, H.Y. and Yamamoto, T., 1995. Statistical inference in Vector Autoregressions with possibly integrated processes. *Journal of Econometrics*, 66, pp. 225-250.

Torun, H. and Cicekci, C., 2007. Innovation: Is The Engine for Economic Growth. *Ege University the Faculty of Economics and Administrative Sciences,* 1-54.

Ulku, H., 2004. R&D, Innovation, and Economic Growth: An Empirical Analysis. *IMF Working Paper,* No. 04/185. Washington, DC.

Wangwe, S., 2007. A Review of Methodology for Assessing ICT Impact on Development and Economic Transformation. *African Economic Research Consortium Working Papers*, No. ICTWP-02, 1-31.

Westerlund, J. and Edgerton, D.L., 2007. A Panel Bootstrap Cointegration Test. *Economic Letters*, 97(3), pp. 185-190.

Westerlund, J., 2007. Estimating Cointegrated Panels with Common Factors and the Forward Rate Unbiasedness Hypothesis. *Journal of Financial Econometrics*, 5(3), pp. 491-522.

Westmore, B., 2013. R&D, Pantenting and Growth the Role of Public Policy. *OECD Economics Department Working Papers,* No. 1047, pp. 1-48.

Yinsheng, L., Baomin, H. and Die, Z., 2010. An Empirical Research on R&D Investment and Economic Growth. *International Conference on Information Science and Engineering-ICISE.*