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The Effect of Research and Development Spending on Economic Growth in OECD Countries

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Abstract
This paper investigates the effect of total research and development (R&D) spending and its sub-components (business and government R&D spending) on economic growth in 18 OECD countries over the period 1981-2012. The results of the empirical analysis indicate that total and business R&D spending do not have a statistically significant effect on economic growth. However, government R&D spending influences economic growth in both the short and long run. While R&D spending by government has a negative effect on economic growth in the short run this effect becomes positive in the long run. According to these results, it is suggested that instead of total and business R&D spending government R&D spending is efficient in terms of economic growth.
Keywords: *R&D spending, economic growth, Mean Group Estimator, Pooled Mean Group Estimator, OECD countries.*
Jel Codes: C23, E22, E62, O30, 040

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1. INTRODUCTION

The effect of research and development (henceforth R&D) activities on economic performance has been intensively examined both by reseracher s and policy makers. In the theoretical literature, economic growth models emphasize the importance of technical change and assert that technological development is the main driver of economic growth in the long run[1]. In line with this theoretical models, many empirical analyses demonstrate that R&D activities play a significant role in economic growth and development[2].

This study investigates the effect of R&D spending and its sub-components on economic growth in 18 OECD countries over the period 1981-2012. Although there are quite a few studies which examine the relationship between R&D spending and economic growth in OECD countries most of these studies cover 1990s and the first few years of 2000s. Moreover, the number of analyses which assess the effect of both total R&D spending and its sub-components (business and government R&D spending) is very low. This study tries to fill these gaps in the literature by using a data set which covers a long period of time (1981-2012) and by analyzing the relationship between R&D spending and economic growth in detail. The contribution of this study to the existing literature is threefold: First, the most comprehensive data set which is available for OECD countries is used and hence, the long run effects of R&D spending are investigated; second, not only the effect of total R&D spending but also the effects of business and government R&D spending are analyzed; and third, the new methodologies, i.e. Mean Group (MG) and Pooled Mean Group (PMG) estimators, developed by Pesaran and Smith[3] and Pesaran, Shin and Smith[4], are used in the empirical analysis.

The results of the empirical analysis indicate that total and business R&D spending do not have a statistically significant effect on economic

1 Robert M. Solow, "Technical Change and the Aggregate Production Function", The Review of Economics and Statistics, Volume: 39, No: 3, August 1957, p.312-320. Paul M. Romer, "Endogenous Technological Change", Journal of Political Economy, Part 2: The Problem of Development: A Conference of the Institute for the Study of Free Enterprise Systems, Volume: 98, No: 5, October 1990, p.S71-S102.

2 Argentino Pessoa, "R&D and Economic Growth. How Strong is the Link?", Economics Letters, Volume: 107, Issue: 2, May 2010, p.152-154.

3 M. Hashem Pesaran and Ron Smith, "Estimating Long-run Relationships from Dynamic Heterogenous Panels", Journal of Econometrics, Volume: 68, Issue: 1, July 1995, p.79-113.

4 M. Hashem Pesaran, Yongcheol Shin and Ron P. Smith, "Pooled Mean Group Estimation of Dynamic Heterogenous Panels", Journal of the American Statistical Assocation, Volume: 94, Issue: 446, June 1999, p.621-634.

growth in OECD countries. However, government R&D spending is statistically significant in both the short and long run. Whilst R&D spending by government negatively influences economic growth in the short run this effect turns out to be positive in the long run. As it is very well-known, the transformation of R&D spending into marketable products requires a long period of time. Thus, this result confirms the fact that in order to obtain the returns of government R&D spending a long time is necessary. Yet, after the required time period has passed government R&D spending has a positive effect on long run economic growth.

The structure of the paper is as follows: in section 2 recent empirical literature which analyzes the effect of R&D spending on productivity and economic growth by using macro aggregates is summarized. Section 3 presents the data and methodology. Section 4 presents the results of the empirical analysis and finally section 5 provides concluding remarks and discusses the policy implications of the empirical analysis.

2. LITERATURE REVIEW

In the existing literature, although a number of different approaches have been used to analyze the R&D spending-economic performance nexus most of the researchers have tried to find out the effect of R&D spending on productivity, output or economic growth[5]. While some of these studies use firm or industry level data other studies mainly focus on macroeconomic effects of R&D spending and hence, draw on aggregate data. Here, the results of the recent studies which mainly analyze the effect of R&D spending at the aggregate level are summarized[6].

One of the first analyses which investigate the effect of R&D spending on productivity at the national level is Lichtenberg's study[7]. Lichtenberg examines the impact of R&D investment on the level of productivity and the growth rate of productivity by using the Mankiw et al.'s data

5 Rajeev K. Goel, James E. Payne and Rati Ram, "R&D Expenditures and U.S. Economic Growth: A Disaggregated Approach", Journal of Policy Modelling, Volume: 30, Issue: 2, March-April 2008, p. 238.

6 For an extensive literature review see Bronwyn H. Hall, J. Mairesse and Pierre Mohnen, "Measuring the Returns to R&D", NBER Working Paper, No: 15622, December 2009, http://www.nber.org/papers/w15622 (accessed 01.11.2015).

7 Frank R. Lichtenberg, "R&D Investment and International Productivity Differences", NBER Working Papers, No: 4161, September 1992, http://www.nber.org/papers/w4161 (accessed 15.11.2015).

set[8] which is augmented with the data on R&D investment and its subcomponents[9]. According to the estimation results, Lichtenberg states that privately funded R&D investment has a strong positive effect on both the productivity level and its growth rate, however, the marginal product of government R&D is lower than the marginal product of private R&D[10].

Coe and Helpman assess the effects of domestic and foreign R&D capital stocks on total factor productivity in 21 OECD countries and Israel[11] between 1971 and 1990 by employing cointegration methodology[12]. The authors find that both domestic and foreign R&D capital stocks positively influence total factor productivity and the impact of foreign R&D capital stock is higher in more open economies[13]. Moreover, the results indicate that while foreign R&D capital stock is as significant as domestic R&D capital stock in smaller countries the impact of domestic R&D capital stock might be higher than that of foreign R&D capital stock in larger countries[14].

Engelbrecht[15] evaluates whether the results of Coe and Helpman's[16] study are robust when human capital variable added to their model by using the data set of Coe and Helpman[17] for domestic R&D capital stock, foreign R&D capital stock and imports and Barro and Lee's[18] measure of average years of education for human capital. Engelbrecht finds that although the coefficient estimates of domestic and foreign R&D capital stocks are reduced when the human capital variable is added to the regressions these variables are still significant[19].

8 N. Gregory Mankiw, David Romer and David N. Weil, "A Contribution to the Empirics of Economic Growth", Quarterly Journal of Economics, Volume: 107, Issue: 2, May 1992, p.407-437.

9 Lichtenberg, "R&D Investment and International Productivity Differences".

10 Lichtenberg, "R&D Investment and International Productivity Differences".

11 Israel was not a member of the OECD during the period that is covered in the Coe and Helpman's analysis.

12 David T. Coe and Elhanan Helpman, "International R&D Spillovers", European Economic Review, Volume: 39, Issue: 5, May 1995, p.859-887.

13 Coe and Helpman, "International R&D Spillovers", p.859-887.

14 Coe and Helpman, "International R&D Spillovers", p.859-887.

15 Hans-Jürgen Engelbrecht, "International R&D Spillovers, Human Capital and Productivity in OECD Economies: An Empirical Investigation", European Economic Review, Volume: 41, Issue: 8, August 1997, p.1479-1488.

16 Coe and Helpman, "International R&D Spillovers", p.859-887.

17 Coe and Helpman, "International R&D Spillovers", p.859-887.

18 Robert J. Barro and Jong-Wha Lee, "International Comparisons of Educational Attainment", Journal of Monetary Economics, Volume: 32, Issue: 3, December 1993, p.363-394.

19 Engelbrecht, "International R&D Spillovers, Human Capital and Productivity in OECD Economies: An Empirical Investigation", p.1479-1488.

Frantzen examines the impact of both domestic and foreign R&D on total factor productivity in 21 OECD countries for the period 1961-1991 by estimating the growth equations on a cross-section of average data and also by using cointegration techniques[20]. According to the results, it is asserted that both domestic and foreign R&D have an important effect on total factor productivity and in G7 countries domestic R&D is more significant than in the other countries[21].

Bassanini and Scarpetta[22] investigate the effect of macroeconomic and policy variables on economic growth in 21 OECD countries over the period 1971-1998 by employing the Pooled Mean Group (PMG) estimator developed by Pesaran and Smith and Pesaran, Shin and Smith[23] and come to the conclusion that business sector R&D leads to high social returns[24].

Fraumeni and Okubo estimate the contribution of R&D investment to economic growth in the US for the period 1961-2000 by drawing on National Income and Product Account framework and find that whilst the contribution of R&D investment to growth in adjusted GDP is around 4 percent the contribution of return on R&D capital to growth in adjusted GDP is around 11 percent[25].

Guellec and Van Pottelsberghe de la Potterie seek for the relationship between R&D and productivity growth in 16 OECD countries over the period 1980-1998 by taking into account business, foreign and public R&D capital stock separately and by estimating an error correction model[26]. The results of this study indicate that R&D is a significant factor for economic

20 Dirk Frantzen, "R&D, Human Capital and International Technology Spillovers: A Cross-Country Analysis", The Scandinavian Journal of Economics, Volume: 102, Issue: 1, March 2000, p.57-75.

21 Frantzen, "R&D, Human Capital and International Technology Spillovers: A Cross-Country Analysis", p.57-75.

22 Andrea Bassanini and Stefano Scarpetta, "Does Human Capital Matter for Growth in OECD Countries? A Pooled Mean Group Approach", Economics Letters, Volume: 74, Issue: 3, February 2002, p.399-405.

23 Pesaran and Smith, , "Estimating Long-run Relationships from Dynamic Heterogenous Panels" p.79-113. Pesaran, Shin and Smith, "Pooled Mean Group Estimation of Dynamic Heterogenous Panels", p.621-634.

24 Andrea Bassanini and Stefano Scarpetta, "Does Human Capital Matter for Growth in OECD Countries? A Pooled Mean Group Approach", p.399-405.

25 Barbara M. Fraumeni and Sumiye Okubo, "R&D in the National Income and Product Accounts A First Look at its Effect on GDP", in Carol Corrado, John Haltiwanger and Dan Sichel (Editors) Measuring Capital in the New Economy, University of Chicago Press, August 2005, http://www.nber.org/chapters/c10624.pdf, p.275-321, (accessed 01.12.2015).

26 Dominique Guellec and Bruno Van Pottelsberghe de la Potterie, "R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries", OECD Economic Studies, No: 33, 200I/II, http://www.oecd.org/eco/growth/1958639.pdf, p.103-126, (accessed 01.11.2015).

growth and productivity and the impact of R&D carried out by higher education is stronger than the R&D carried out by government laboratories[27]. In addition to these results, the authors suggest that the relationship between public and business R&D and openness to foreign technology have a significant influence on productivity and economic growth[28].

In a similar study, Guellec and Van Pottelsberghe de la Potterie analyze whether the origin of funding, socioeconomic aims and the sort of performing institutions has any effects on the effectiveness of business and public R&D[29]. According to the results of this analysis, while defence related public funding has a significant negative effect on business R&D the impact of civilian public funding on business R&D is positive[30]. Moreover, the results indicate that when the share of business in the funding of university research increases its impact on productivity lowers[31].

Ulku investigates the effect of R&D investment on economic growth in 20 OECD and 10 non-OECD countries over the period 1981-1997 by using several panel data models[32]. The results of this study show that there is a significant relationship between R&D investment and innovation and between innovation and GDP per capita in both OECD and non-OECD countries[33].

Falk[34] examines the impact of R&D expenditure on long term economic growth in OECD countries during 1970-2004 by drawing on Arellano-Bond's[35] Generalized Methods of Moments (GMM) estimator[36]. According to estimation results, Falk concludes that both the R&D expenditures of

27 Guellec and Van Pottelsberghe de la Potterie, "R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries", p.103-126.

28 Guellec and Van Pottelsberghe de la Potterie, "R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries", p.103-126.

29 Dominique Guellec and Bruno Van Pottelsberghe de la Potterie, "From R&D to Productivity Growth: Do Institutional Settings and the Source of Funds of R&D Matter?", Oxford Bulletin of Economics and Statistics, Volume: 66, Issue: 3, July 2004, p.353-378.

30 Guellec and Van Pottelsberghe de la Potterie, "From R&D to Productivity Growth: Do Institutional Settings and the Source of Funds of R&D Matter?", p.353-378.

31 Guellec and Van Pottelsberghe de la Potterie, "From R&D to Productivity Growth: Do Institutional Settings and the Source of Funds of R&D Matter?", p.353-378.

32 Hulya Ulku, "R&D, Innovation, and Economic Growth: An Empirical Analysis", IMF Working Papers, No: 04/185, September 2004, https://www.imf.org/external/pubs/ft/wp/2004/wp04185.pdf, (accessed 15.09.2015).

33 Ulku, "R&D, Innovation, and Economic Growth: An Empirical Analysis".

34 Martin Falk, "R&D Spending in the High-tech Sector and Economic Growth", Resarch in Economics, Volume: 61, Issue: 3, September 2007, p.140-147.

35 Manuel Arellano and Stephen Bond, "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations", The Review of Economic Studies, Volume: 58, No: 2, April 1991, p.277-297.

36 Falk, "R&D Spending in the High-tech Sector and Economic Growth", p.140-147.

business enterprises and R&D investment in high technology sectors positively influence GDP per capita and GDP per hour worked[37].

Goel, Payne and Ram investigate the effects of federal, non-federal and (federal) defense R&D spending on economic growth in the US over the period 1953-2000[38]. The authors use the ARDL Model developed by Pesaran, Shin and Smith[39] and find that federal and defense R&D spending have higher positive effects on economic growth than non-fedaral and non-defense R&D spending[40].

Guloglu and Tekin assess the causal relationships between R&D expenditures, innovation and economic growth in 13 high income OECD countries over the period 1991-2007 by estimating a panel vector autoregressive (VAR) model and find that R&D intensity leads to innovation and both R&D investment and innovation causes economic growth[41]. Moreover, the results indicate that not only R&D investments but also economic growth induces innovation[42].

Silaghi et al. analyze the effects of private and public R&D spending on economic growth in Central and Eastern European countries between 1998 and 2008[43]. The authors employ Arellano and Bond's[44] GMM estimator in the empirical analysis and find that private R&D expenditure has a positive effect on economic growth[45]. Furthermore, the results of this study

37 Falk, "R&D Spending in the High-tech Sector and Economic Growth", p.140-147.

38 Goel, Payne and Ram, "R&D Expenditures and U.S. Economic Growth: A Disaggregated Approach", p.237-250.

39 M. Hashem Pesaran, Yongcheol Shin and Richard J. Smith, "Bounds Testing Approaches to the Analysis of Level Relationships", Journal of Applied Econometrics Special Issue: In Memory of John Denis Sargan 1924-1996: Studies in Empirical Macroeconometrics, Volume: 16, Issue: 3, May/June 2001, p.289-326.

40 Goel, Payne and Ram, "R&D Expenditures and U.S. Economic Growth: A Disaggregated Approach", p.237-250.

41 Bulent Guloglu and R. Barıs Tekin, "A Panel Causality Analysis of the Relationship among Research and Development, Innovation, and Economic Growth in High-Income OECD Countries", Eurasian Economic Review, Volume: 2, Issue: 1, June 2012, p.32-47.

42 Guloglu and Tekin, "A Panel Causality Analysis of the Relationship among Research and Development, Innovation, and Economic Growth in High-Income OECD Countries", p.32-47.

43 Pop Silaghi, et al., "Do Business and Public Sector Research and Development Expenditures Contribute to Economic Growth in Central and Eastern European Countries? A Dynamic Panel Estimation", Economic Modelling, Volume: 36, January 2014, p.108-119.

44 Arellano and Bond, "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations", p.277-297.

45 Silaghi et al., "Do Business and Public Sector Research and Development Expenditures Contribute to Economic Growth in Central and Eastern European Countries? A DynamicPanel Estimation", p.108-119.

show that public R&D expenditure does not negatively influence the positive effect of private R&D expenditure[46].

In a recent study, Kokko, Tingvall and Videnord examine the effect of R&D spending on economic growth in the European Union (EU) by using Meta-Analysis[47]. They take into consideration 49 studies in the empirical estimations and come to the conclusion that the positive effect of R&D spending on economic growth in EU15 countries does not differentiate from that in other countries[48]. However, when EU15 countries are compared with the US it is found that the effect of R&D spending on economic growth is stronger in the US than in the EU15 countries[49].

In summary, although there are many studies which focus on the relationship between R&D spending and productivity or economic growth in OECD countries and they generally come to the conclusion that R&D spending has a positive impact on economic growth almost none of these studies analyzes this relationship by taking into account a long time period which covers recent years. However, as it is well-known the relationship between R&D spending and economic growth is a long term phenomenon. Moreover, to the best of our knowledge, except the study of Bassanini and Scarpetta[50] none of the studies uses Pooled Mean Group (PMG) estimator developed by Pesaran and Smith and Pesaran, Shin and Smith[51] in their empirical analyses and Bassanini and Scarpetta's study covers the period between 1971 and 1998[52]. So, in this study it is tried to fill these gaps in the existing literature by taking into account the most comprehensive data set available for OECD countries and by using Mean Group (MG) and Pooled Mean Group (PMG) estimators developed by Pesaran and Smith[53] and Pesaran, Shin and Smith[54].

46 Silaghi et al., "Do Business and Public Sector Research and Development Expenditures Contribute to Economic Growth in Central and Eastern European Countries? A DynamicPanel Estimation", p.108-119.

47 Ari Kokko, Patrik Gustavsson Tingvall and Josefin Videnord, "The Growth Effects of R&D Spending in the EU: A Meta Analysis", Economics The Open-Access, Open Assessment E-Journal, Discussion Paper No: 2015-29, http://www.economics-ejournal.org/economics/discussionpapers/2015-29, (accessed 01.10.2015).

48 Kokko, Tingvall and Videnord, "The Growth Effects of R&D Spending in the EU: A Meta Analysis".

49 Kokko, Tingvall and Videnord, "The Growth Effects of R&D Spending in the EU: A Meta Analysis".

50 Bassanini and Scarpetta, "Does Human Capital Matter for Growth in OECD Countries? A Pooled Mean Group Approach", p.399-405.

51 Pesaran and Smith, , "Estimating Long-run Relationships from Dynamic Heterogenous Panels" p.79-113. Pesaran, Shin and Smith, "Pooled Mean Group Estimation of Dynamic Heterogenous Panels", p.621-634.

52 Bassanini and Scarpetta, "Does Human Capital Matter for Growth in OECD Countries? A Pooled Mean Group Approach", p.399-405.

53 Pesaran and Smith, , "Estimating Long-run Relationships from Dynamic Heterogenous Panels" p.79-113.

54 Pesaran, Shin and Smith, "Pooled Mean Group Estimation of Dynamic Heterogenous Panels", p.621-634.

3. METHODOLOGY AND DATA

In this study, the effect of R&D spending on economic growth is analyzed by estimating a growth equation in which standard determinants of growth (i.e. gross fixed capital formation and population growth) and a number of control variables are used as explanatory variables. Most of the existing empirical analyses use standard GMM-difference estimator developed by Arellano and Bond[55] or GMM system estimator proposed by Arellano and Bover[56] to estimate growth equations. However, these methodologies assume all slope parameters are homogenous and allow only the constant parameters to differ across groups in panel data context[57]. Pesaran and Smith state that when the slope parameters are heterogenous across groups the methods which assume parameter homogeneity give inconsistent and misleading results[58].

In contrast, the MG estimator proposed by Pesaran and Smith[59] and the PMG estimator developed by Pesaran, Shin and Smith[60] provide more reliable results by allowing coefficients to differ across groups. In the following subsection the characteristics of these estimators are briefly explained.

3.1. The MG and PMG Estimators

Suppose the dynamic panel specification form of an ARDL[61] (p, q_1, q_2, ..., q_k) model is as follows[62]:

$$y_{it} = \sum_{j=1}^{p} \alpha_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta'_{ij}\, x_{i,t-j} + \mu_i + \varepsilon_{i,t} \qquad (1)$$

55 Arellano and Bond, "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations", p.277-297.

56 Manuel Arellano and Olympia Bover, "Another Look at the Instrumental Variable Estimation of Error-Components Model", Journal of Econometrics, Volume: 68, Issue: 1, July 1995, p.29-51.

57 Edward F. Blackburne and Mark W. Frank, "Estimation of Nonstationary Heterogenous Panels", The Stata Journal, Volume: 7, No: 2, 2007, http://www.stata-journal.com/sjpdf.html?articlenum=st0125, p.197, (accessed 01.10.2015).

58 Pesaran and Smith, "Estimating Long-run Relationships from Dynamic Heterogenous Panels", p.79-113.

59 Pesaran and Smith, "Estimating Long-run Relationships from Dynamic Heterogenous Panels", p.79-113.

60 Pesaran, Shin and Smith, "Pooled Mean Group Estimation of Dynamic Heterogenous Panels", p.621-634.

61 Autoregressive Distributed Lag

62 Blackburne and Frank, "Estimation of Nonstationary Heterogenous Panels", p.198

where x_{it} is a k x 1 vector of explanatory variables, δ_{ij} are k x 1 coefficient vectors, α_{ij} are scalars and μ_i is the group-specific effect. This equation can be reparameterized as an error correction equation[63]:

$$\Delta y_{it} = \varphi_i\left(y_{i,t-1} - \rho_i' x_{it}\right) + \sum_{j=1}^{p-1} \alpha_{ij}^* \Delta y_{i,t-1} + \sum_{j=0}^{q-1} \delta_{ij}'^* \Delta x_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (2)$$

where $\varphi_i = -(1 - \sum_{j=1}^{p} \alpha_{ij})$, $\rho_i = \sum_{j=0}^{q} \delta_{ij} / (1 - \sum_k \alpha_{ik})$,

$\alpha_{ij}^* = -\sum_{m=j+1}^{p} \alpha_{im}$, j= 1, 2, ..., p-1 and

$\delta_{ij}^* = -\sum_{m=j+1}^{q} \delta_{im}$, j=1, 2, ..., q-1.

In this equation, two parameters are particularly important. The first one is φ_i which is called as the speed of adjustment term. In order to have a long run equilibrium relationship between the variables this parameter should be significantly negative[64]. The second parameter is ρ_i' which represents the long run relationship between the variables[65].

Recently, MG and PMG estimators proposed by Pesaran and Smith[66] and Pesaran, Shin and Smith[67] respectively are typically used to estimate this error correction model. While MG estimates regressions for each group separately and then calculate the means of coefficients over groups[68] PMG allows the intercepts, short run coefficients and error variances to be different but, assumes that long run coefficents are equal across groups[69]. Pesaran, Shin and Smith suggest a maximum likelihood method in order to estimate the coefficients of equation 2[70] since this equation is nonlinear with regard to coefficients[71].

In this empirical analysis, both MG and PMG estimators are used to estimate the growth equation and then in order to decide which results are more consistent the Hausman's specification test[72] is calculated.

63 Blackburne and Frank, "Estimation of Nonstationary Heterogenous Panels", p.198, 199.

64 Blackburne and Frank, "Estimation of Nonstationary Heterogenous Panels", p.198, 199.

65 Blackburne and Frank, "Estimation of Nonstationary Heterogenous Panels", p.199.

66 Pesaran and Smith, "Estimating Long-run Relationships from Dynamic Heterogenous Panels", p.79-113.

67 Pesaran, Shin and Smith, "Pooled Mean Group Estimation of Dynamic Heterogenous Panels", p.621-634.

68 Pesaran and Smith, "Estimating Long-run Relationships from Dynamic Heterogenous Panels", p.79-113.

69 Pesaran, Shin and Smith, "Pooled Mean Group Estimation of Dynamic Heterogenous Panels", p.621-634.

70 Pesaran, Shin and Smith, "Pooled Mean Group Estimation of Dynamic Heterogenous Panels", p.621-634.

71 Blackburne and Frank, "Estimation of Nonstationary Heterogenous Panels", p.199.

72 J. A. Hausman, "Specification Tests in Econometrics", Econometrica, Volume: 46, No: 6 , November 1978, p.1251-1271.

3.2. Model Specification and Data

The growth equation which is estimated in the empirical analysis is as follows:

$$g_{i,t} = -\varphi_i\left(g_{i,t-1} - \beta_1 s_{i,t} - \beta_2 pg_{i,t} - \beta_3 hc_{i,t} - \beta_4 open_{i,t} - \beta_5 randd_{i,t} + \beta_6 crisis_t - \beta_{0,i}\right) + \theta_{1,i}\Delta s_{i,t} + \theta_{2,i}\Delta pg_{i,t} + \theta_{3,i}\Delta hc_{i,t} + \theta_{4,i}\Delta open_{i,t} + \theta_{5,i} randd_{i,t} + \theta_{6,i} crisis_t + \varepsilon_{i,t} \qquad (3)$$

where g is real GDP growth rate, s is gross fixed capital formation as a percentage of GDP, pg is population growth rate, hc is human capital represented by secondary school enrollment rate, open is the openness of the country and represented by the sum of exports and imports as a percentage of GDP, randd is research and development expenditure (total, business and government) as a percentage of GDP, crisis is the dummy variable which stands for the 2008 Global Economic Crisis, ε is the error term and i and t are the country and time subscripts respectively. Whilst the GDP, GDP growth rate, gross fixed capital formation, population growth, secondary school enrollment rate, exports and imports data is taken from the World Bank-World Development Indicators Database[73] the total, business and government R&D spending data is taken from the Organization for Economic Co-operation and Development (OECD)-Science, Technology and R&D Statistics database[74].

Equation 3 is estimated by using an annual unbalanced panel data set which covers 18 OECD countries[75] over the period 1981-2012. In the empirical estimations, total, business and government R&D spending are taken into account separately. Hence, the effects of total R&D spending and its sub-components (business and government R&D spending) are assessed according to the results of the three models estimated.

73 World Bank, World Development Indicators Database, http://data.worldbank.org/data-catalog/world-development-indicators, (accessed 01.09.2015).

74 Organization for Economic Co-operation and Development (OECD), OECD Science, Technology and R&D Statistics Database, 2015.

75 These countries are Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hungary, Ireland, Israel, Italy, Japan, the Netherlands, Portugal, Spain, Turkey, the United Kingdom and the United States. The countries are chosen according to data availability.

4. RESULTS

In the empirical analysis, at first Im-Pesaran and Shin[76] and Fisher type unit root tests (Fisher-ADF)[77] are applied in order to determine the order of integration of the variables. Although the unit root properties of the variables are not important for the MG[78] and PMG models[79] as long as the order of integration is either I(0) or I(1) unit root tests are calculated to ensure that the variables are either stationary or are integrated in the first order. Table 1 presents the results of the Im-Pesaran-Shin and Fisher-ADF unit root tests. As it is clearly seen in this table, all of the variables is either I(0) or I(1). Hence, MG and PMG estimators can be used in order to estimate the models.

Table 1: *Unit Root Test Results*

	Level			First-Difference		
Variables	**Im-Pesaran-Shin**	**ADF-Fisher Chi-Square**	**ADF-Choi-Z-Stat**	**Im-Pesaran-Shin**	**ADF-Fisher Chi-Square**	**ADF-Choi-Z-Stat**
g	-9.2444***	165.994***	-8.6985***	-14.0110***	249.919***	-12.5838***
s	-2.5980***	58.0896**	-2.7152***	-9.3528***	156.583***	-8.8144***
pg	-2.3657***	73.1472***	-1.9365***	-9.7807***	178.761***	-8.8190***
hc	-1.1939	40.3557	-1.0320	-11.9939***	204.174***	-10.6915***
open	4.9708	9.7835	5.2754	-14.4852***	262.196***	-12.7471***
randd	3.6096	23.4528	3.5393	-10.1506***	185.042***	-9.1848***
bus. randd	1.3371	30.8240	1.4674	-8.6287***	162.111***	-7.8314***
gov. randd	-0.5100	49.9340*	-0.3331	-13.0850***	224.618***	-10.8318***

Note: *, **, *** indicate 10%, 5% and 1% significance levels respectively. For both the Im-Pesaran-Shin and Fisher-ADF tests H_0 hypothesis states that all panels contain unit roots. All test statistics are estimated by adding an intercept to the models. Lag lenght is chosen according to Akaike Information criterion.

Source: Author's estimations.

76 Kyung So Im, M. Hashem Pesaran and Yongcheol Shin, "Testing for Unit Roots in Heterogenous Panels", Journal of Econometrics, Volume: 115, Issue: 1, July 2003, p.53-74.

77 In Choi, "Unit Root Tests for Panel Data", Journal of International Money and Finance, Volume: 20, Issue: 2, April 2001, p.249-272.

78 Pesaran and Smith, "Estimating Long-run Relationships from Dynamic Heterogenous Panels", p.79-113.

79 Pesaran, Shin and Smith, "Pooled Mean Group Estimation of Dynamic Heterogenous Panels", p.621-634.

Before estimating the models by employing MG and PMG estimators it is important to decide the lag length of the variables. Since the time dimension of the data set used in this empirical analysis does not cover a long period of time a common lag structure which is ARDL (1, 1, 1, 1, 1, 1) is imposed as suggested by the literature[80].

Table 2, table 3 and table 4 show the results of MG and PMG estimations together with the Hausman test statistic[81]. While table 1 and table 2 present the results of regressions in which total R&D spending and business R&D spending variables are used as the key explanatory variable respectively table 3 presents the results of the regression in which government R&D spending is the key explanatory variable.

In order to evaluate regression results at first we should decide which estimator is more efficient. As it is seen in table 2, table 3 and table 4 PMG estimator is more efficient than MG estimator for all of the regressions according to the Hausman test statistic. So, the results of the regressions which is estimated by PMG estimator is taken into account when the results are interpreted.

According to the coefficient estimates in table 2 (column 1 and 2), while gross fixed capital formation, and opennes are statistically significant in both the short and long run at conventional significance levels crisis variable has a statistically significant effect on economic growth only in the long run. As expected gross fixed capital formation positively influence economic growth. However, whilst openness has a positive effect on economic growth in the short run it has a negative impact on economic growth in the long run. This may stem from the unfavorable effects of trade openness on economic growth and development in the long run. Considering the key variable with regard to the R&D spending the results show that total R&D spending does not have a statistically significant effect on economic growth in both the short and long run.

80 Norman V. Loayza and Romain Rancière, "Financial Development, Financial Fragility, and Growth", Journal of Money, Credit and Banking, Volume: 38, No: 4, June 2006, p.1051-1076. Panicos Demetriades and Siong Hook Law, "Finance, Institutions and Economic Growth", International Journal of Finance & Economics, Volume: 11, Issue: 3, July 2006, p.245-260.

81 The models are also estimated by using dynamic FE estimator. However, this estimator assumes coefficients of the cointegrating vector, speed of adjustment coefficient and short run coefficients are equall across all groups (See Edward F. Blackburne and Mark W. Frank, "Estimation of Nonstationary Heterogenous Panels", The Stata Journal, Volume: 7, No: 2, 2007, p.197-208. for the explanation of the dynamic FE estimator.). Since this assumption is not realistic because of the different country characteristics the results of the models which are estimated by using dynamic FE estimator are not presented.

Table 2: Regression Results with the Total R&D Spending

	PMG		MG	
Explanatory Var.	**Long Run**	**Short Run**	**Long Run**	**Short Run**
s	0.0966**		0.2711	
	(0.0426)		(0.1771)	
pg	-0.2091		-28.9836	
	(0.2853)		(29.3993)	
hc	-0.0056		-1.0834	
	(0.0064)		(1.0538)	
open	-0.0213***		0.0723	
	(0.0063)		(0.0620)	
randd	0.4118		11.3259	
	(0.2915)		(11.9817)	
Crisis	-0.9738***		-3.9641	
	(0.2151)		(3.0391)	
ec		-0.8323***		-1.1328***
		(0.0379)		(0.2213)
Δs		0.9724***		0.9641**
		(0.1539)		(0.3819)
Δpg		0.3042		-4.2881
		(1.0538)		(3.9705)
Δhc		0.0149		-0.3333
		(0.0417)		(0.2202)
Δopen		0.3567***		0.2821***
		(0.0514)		(0.0953)
Δcrisis		0.1159		1.5124
		(0.2801)		(1.4087)
Δrandd		-3.1409*		0.9494
		(1.8408)		(3.6964)
cons		1.0749***		17.4125
		(0.2702)		(32.4746)
Hausman Test		1.28 (0.9729)		

Note: *, **, *** indicate 10%, 5% and 1% significance levels respectively.Standard errors are in paranthesis. While the first and third columns show long run coefficient estimates the second and fourth columns show both short run coefficient estimates and the speed of adjustment (ec) parameter. The chosen lag structure is ARDL(1, 1, 1, 1, 1, 1). The models are estimated by using xtpmg routine in Stata. Hausman test indicates that PMG estimator is more consistent and efficient than MG estimator.

Source: Author's estimations.

The results in table 3 are similar to the results in table 2. Once again, openness is statistically significant in both the short and long run. While it has a positive effect on economic growth in the short run this effect turns out to be negative in the long run. Moreover, gross fixed capital formation has a positive effect on economic growth. However, this time it is statistically significant only in the short run. As in the previous results, crisis has a statistically significant and negative impact on economic growth in the long run. When it comes to the R&D spending it is seen that business R&D spending does not have a statistically significant effect on economic growth in both the short and long run.

Table 3: Regression Results with the Business R&D Spending

	PMG		MG	
Explanatory Var.	**Long Run**	**Short Run**	**Long Run**	**Short Run**
s	0.0677		0.8104	
	(0.0493)		(0.5971)	
pg	0.0993		92.2679	
	(0.3292)		(98.2576)	
hc	-0.0019		3.0021	
	(0.0072)		(2.9419)	
open	-0.0218**		0.1965	
	(0.0087)		(0.5363)	
business randd	-0.0030		-33.9602	
	(0.5923)		(27.4199)	
crisis	-0.8192***		19.4371	
	(0.2530)		(19.8445)	
ec		-0.8505***		-0.6968***
		(0.0465)		(0.2362)
Δs		1.0869***		0.3417
		(0.1541)		(0.3980)
Δpg		0.9479		-51.0660
		(1.1281)		(51.0811)
Δhc		0.0191		-0.0031
		(0.0464)		(0.1396)
Δopen		0.3486***		0.4882***
		(0.0475)		(0.1065)
Δcrisis		-0.1721		3.1255
		(0.3311)		(3.2047)
Δbusiness randd		-1.0080		-10.0169
		(2.4084)		(11.1146)
cons		1.7627***		-18.1783
		(0.2749)		(13.2166)
Hausman Test		1.49 (0.9602)		

Note: *, **, *** indicate 10%, 5% and 1% significance levels respectively. Standard errors are in paranthesis. While the first and third columns show long run coefficient estimates the second and fourth columns show both short run coefficient estimates and speed of adjustment (ec) parameter. The chosen lag structure is ARDL(1, 1, 1, 1, 1, 1). The models are estimated by using xtpmg routine in Stata. Hausman test indicates that PMG estimator is more consistent and efficient than MG estimator.

Source: Author's estimations.

Finally, when the results of the regression in which government R&D spending is used as the key explanatory variable are investigated it is clearly seen that the significance and sign of the variables except the key variable (R&D spending) are the same with the results in table 1. However, unlike previous results, government R&D spending has a statistically significant effect on economic growth in both the short and long run. While it negatively influence economic growth in the short run its effect becomes positive in the long run. As it is very well-known, occurence of the positive effects of R&D investment takes a long time since transforming this investment into innovation and then commercializing it requires a long process. Thus, these results suggest that although R&D spending by government has a negative effect on economic growth in the short run this effect turns out to be positive if the time necessary for transforming R&D spending into a marketable product is passed.

Table 4: *Regression Results with the Government R&D Spending*

	PMG		MG	
Explanatory Var.	**Long Run**	**Short Run**	**Long Run**	**Short Run**
s	0.1550***		0.4418	
	(0.0471)		(0.3329)	
pg	-0.1662		10.6915	
	(0.3457)		(7.8703)	
hc	0.0005		0.2242	
	(0.0071)		(0.3092)	
open	-0.0221***		0.0121	
	(0.0073)		(0.0751)	
government randd	1.7340***		-1.6315	
	(0.6188)		(8.8508)	
crisis	-0.7717***		-2.2957	
	(0.2248)		(1.5513)	
ec		-0.8552***		-1.0417***
		(0.0491)		(0.1115)
Δs		0.9739***		0.4365
		(0.1494)		(0.4159)
Δpg		-0.7987		-3.6419
		(1.5348)		(3.1067)
Δhc		-0.0312		-0.0365
		(0.0469)		(0.1328)
Δopen		0.3348***		0.2749***
		(0.0493)		(0.0868)
Δcrisis		-0.2352		1.0473
		(0.2271)		(0.6941)
Δgovernment randd		-6.5304**		-9.8404
		(3.3146)		(6.6935)
cons		-0.7012**		-9.4818
		(0.2777)		(22.4383)
Hausman Test		2.93 (0.8178)		

Note: *, **, *** indicate 10%, 5% and 1% significance levels respectively. Standard errors are in paranthesis.

While the first and third columns show long run coefficient estimates the second and fourth columns show both short run coefficient estimates and speed of adjustment (ec) parameter. The chosen lag structure is ARDL(1, 1, 1, 1, 1, 1). The models are estimated by using xtpmg routine in Stata. Hausman test indicates that PMG estimator is more consistent and efficient than MG estimator.

Source: Author's estimations.

In a nutshell, according to all of the results it is suggested that although total and business R&D spending do not have any significant effects on economic growth in both the short and long run government R&D spending has a positive effect on economic growth in the long run.

5. CONCLUSION

In recent years, countries which have become technology leaders in the world have also achieved high and sustainable economic growth rates. Hence, nowadays investment on research and development is generally accepted as one of the main drivers of economic growth and development.

This study investigates the effect of R&D spending and its main sub-components (business and government R&D spending) on economic growth in 18 OECD countries over the period 1981-2012. Although there are many studies which examine the relationship between R&D spending and economic growth in the existing literature most of the analyses cover 1990s and the begining of 2000s and very few of them takes into account the sub-components of R&D spending.

Unlike previous studies, in this study the effect of R&D spending and its sub-components in OECD countries is assessed by drawing on the most comprehensive data set available. Moreover, the new methodologies which are Mean Group (MG) and Pooled Mean Group (PMG) estimators are used in the empirical estimations.

According to the estimation results, though total R&D spending and business R&D spending do not have a statistically significant effect on economic growth government R&D spending has a statistically significant impact on economic growth in both the short and long run. Whilst R&D spending by government negatively affects economic growth in the short run this effect becomes positive in the long run. This result is consistent with the fact that in order to transform R&D investment into marketable products and hence attain the possible returns a long time is necessary.

These findings have important policy implications. Since the results indicate that instead of business R&D spending government R&D spending is efficient governments of the OECD countries should continue to support R&D activities in government institutions. Furthermore, necessary policy changes should be implemented in order to increase the efficiency of business R&D spending.

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