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Comparison of Sectoral Performance of R&D Expenditures: Analysing Innovation Based Economic Growth

Ar-Ge Harcamalarının Sektörel Performansının Karşılaştırılması: İnovasyona Dayalı Ekonomik Büyüme Analizi

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Abstract: This study is testing the sectoral (for business enterprise sector, government sector, higher education sector and private non-profit sector) performance of Intramural R&D expenditures (as a proxy of innovation) for Europe-28 during 2000 and 2017 with VAR technique. Data is gathered from Eurostat science-technology and innovation database. Also the causality between economic growth (annual % GDP) and R&D expenditures (total all sectors) is examined with Hatemi-J et al. (2015) panel asymmetric causality test that takes into account structural breaks which cause positive or negative shocks (instabilities) and different reactions of agents to them. According to empirical results there is a two-way causality between innovation and economic growth; variance decompositions and the impulse-response functions indicate that business enterprise sector contributes the most to the innovation and economic growth and the most endogenous one is private non-profit sector. So it could be said that for Europe-28, the hypothesis of innovation based growth is accepted.

Keywords: Innovation, Economic Growth, Sectoral Performance of R&D, Panel Causality

Öz: Bu çalışma, 2000 ve 2017 yılları arasında Avrupa-28 ülkeleri için intramural Ar-Ge harcamalarının (inovasyon göstergesi olarak) sektörel (işletme sektörü, devlet sektörü, yükseköğretim sektörü ve özel kar amacı gütmeyen sektörler için) performansını VAR tekniği ile test etmektedir. Veriler Eurostat bilim-teknoloji ve yenilik veri tabanından indirilmiştir. Ayrıca, ekonomik büyüme (yıllık % GSYİH) ve Ar-Ge harcamaları (toplam tüm sektörler) arasındaki nedensellik ilişkisi, olumlu ya da olumsuz şoklara (dengesizlikler) neden olan yapısal kırılmaları ve birimlerin farklı reaksiyonlarını dikkate alan panel asimetrik nedensellik testi olan Hatemi-J ve diğerleri (2015) ile test edilmiştir. Ampirik sonuçlara göre, inovasyon ile ekonomik büyüme arasında iki yönlü bir nedensellik vardır. Varyans ayrıştırma ve etki-tepki fonksiyonları, ticari işletme sektörünün inovasyon ve ekonomik büyümeye en fazla katkıda bulunduğunu ve en içsel olanın özel kar amacı gütmeyen sektör olduğunu göstermektedir. Uygulamadan elde edilen bu sonuçlara göre, Avrupa-28 ülke grubu için, inovasyona dayalı büyüme hipotezinin kabul edildiğini söylenebilir.

Anahtar Kelimeler: Yenilik, Ekonomik Büyüme, Ar-Ge'nin Sektörel Performansı, Panel Nedensellik

1. Introduction

Economic growth is measured in terms of the change between Gross Domestic Product (GDP) of a country during a certain period. The change in the GDP depends on various factors. Currently, technological improvements are assumed to be one of the most important factors on the economic growth. Definition of economic growth is coming from the rising amount of good and services (output), which is possible in two different ways. Rising the number of inputs in production process or getting more outputs with same amount of inputs. Definition of innovation is much more complicated and mostly related with (invention, creativity and science) technology (but more than technology because), it refers cost reductions, increases in variety of good and services with a better quality, changing the variables of production function. Naturally, innovation is the key factor that fosters technological development. In addition, it is the main determinant of economic development and growth of a country. Countries that invest in innovation are expected to accelerate the growth in GDP and per capita income which will result in an increase in their development level in the long run.

The nature of innovation is mostly tested with the latest technology by the written literature and it represented by many indicators such as; number of patents, research and development expenditures, number of researchers or research and development centres, export volume of technology intensive goods and services, number of graduated population of higher education, consumer satisfaction, total factor productivity, human capital accumulation etc. But the importance of innovation for business sector means greater profit with new markets and with more recruitment opportunities. Therefore, the indicator of innovation needs revision because the level of the investment in research and development depends the allocation of resources in different sectors.

BERD-Business Enterprise expenditures on research and development is the measure of intramural research and development expenditures during a specific period and it comprises; including all resident corporations, the unincorporated branches of non-resident enterprises due to their contribution to the production process and NPIs-non-profit institutions (Frascati Manual, 2015: 366). The definition of intramural research and development expenditures as

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follow; ''all current expenditures plus gross fixed capital expenditures for R&D performed within a statistical unit during a specific reference period, whatever the source of funds. The aggregation of intramural R&D for all units within a sector is synonymous with the performance of R&D within a sector of the economy; the summation of intramural R&D for all sectors is synonymous with the performance of R&D for the entire economy'' (OECD, 2015: 112).

This is why in this paper innovation is considered as a major indicator of business sector performance and due to crucial components of intramural research and development expenditures, the sectoral (for business enterprise sector, government sector, higher education sector and private non-profit sector) performance of innovation is tested for Europe-28 from 2000 to 2017 are tested with VAR technique and causality test. This paper has two contributions to the existing literature. Firstly, to the best of authors' knowledge, Intramural R&D expenditures (as a proxy of innovation) are used to find out the relation between innovation and economic growth on a sectoral basis for the first time. Secondly, Hatemi-J et al. (2015) panel asymmetric causality test that takes into account structural breaks is implemented primarily for the empirical analysis to test the sectoral performance of business expenditures on economic growth. Also Frascati Manual (2002), GERD (Gross domestic expenditures on research and development) matrix shows that ''the total value of intramural research and development expenditures (R&D) of all organizations in performing sectors. As there are two dimensions to the reporting of R&D expenditures by performing sector and by funding sector. Science type, research and development (R&D) expenditures are spent by organizations performing in either the natural sciences and engineering or the social sciences and humanities.''. GERD data are based on the source of funds provided by the performing sector. The reason of working on EU-28 is ''the highlighted importance of innovation in EU Industrial Policy where 65 % private sector R&D comes from manufacturing and 79 % of companies introduced at least one innovation since 2011 (EU Commission)'' and the reason of chosen period is due to lack of previous year data.

The rest of the paper is organized as follows. Section 2, the related literature regarding the innovation and economic growth is discussed whereas Section 3 describes research methodology used for the empirical analysis. Sections 4 indicate the findings of the analysis and finally Section 5 provides conclusion, implication and recommendations of this paper for further research.

2. Literature Review

The importance of innovation and the relationship between innovation and economic growth have been widely studied following the studies of Schumpeter (1937). The paper has developed by Romer (1986; 1990), Grossman and Helpman (1991), Aghion and Howitt (1992) and Howitt (1999) and named after endogenous growth In addition, Schumpeter (1939) draw attention to the relationship between innovation and economic cycles because the firms have different innovation activities during recession and in other reverse cycles. According to Coad and Rao (2008), the importance of innovation depends on firm's size and Paunovic (2012); Cassia et al. (2009), innovation contributes more to the development of small size companies and mew entries to the market.

In addition to the theoretical papers, there are many papers regarding empirical studies among innovation and economic growth. Various innovation indicators are used in different papers. For instance, Samimi and Alerasoul (2009) use the share of government expenditures on research in GDFP whereas Aiginger and Falk (2005) use BERD intensity on GDP per capita as a proxy of innovation. Bilbao-Osorio and Rodríguez-Pose (2004) empirically analyse the innovation and economic growth relation in EU countries on private, public and higher education sectors. In the study where the number of patent applications per million population is taken as a proxy of innovation, the positive relationship among variables exist.

Petrariu et al. (2013) shows the link between innovation and economic growth for Central and Eastern European (CEE) countries. Different indicators of innovation is chosen such as; patenting, the number of researchers, R&D spending, firms characteristics etc. The yearly data is gathered from EUROSTAT for 15 countries and tested with panel fixed effect model. According to the results, growth not based on innovation but innovation depends on growth rate.

Cetin (2013) focuses on the innovation based growth of nine European countries from 1981 to 2008 and empirical findings show that innovation based growth is present on some countries whereas it is opposite on the others. Ozcan and Ari (2014) empirically analyses the relationship between R&D expenditures and economic growth on 15 OECD countries by using panel data. Findings reveal that R&D expenditures affect economic growth positively. Akcali and Sismanoglu (2015) search the relationship between R&D and economic growth in 19 developed and developing countries from 1990 to 2013. Empirical findings indicate the positive impact of R&D expenditures on economic growth.

Balli ve Güresci (2017), tested the effects of innovation on economic growth for high and upper middle income countries for the period between 1996 and 2014 with Dumetriscu and Hurlin (2012) panel causality test. Data is downloaded from World Bank and the rate of patenting to the population and the ratio of labour force with basic education to the population are chosen as a proxy of innovation. Empirical results indicate that innovation has positive and significant impact on economic growth for the chosen countries. Shukla (2017), tested the impact of innovation on economic growth for Indian economy with R&D expenditure, FDI, patents and unemployment during 1996-2011. The findings indicate there is a negative correlation between economic growth and innovation, so for a long term sustainable growth the role of innovation is crucial.

Broughel and Thierer (2019), make a conclusion to the literature with an extended discussion about the nature of innovation and they explain how policy makers foster innovation with their attitudes. The relationship between culture and technological changes is depend on the openness to experimentation and new ideas because innovation is allowing humankind to do more with less (productivity). Also they explain the concept of excludability; the quality of knowledge-blueprint is connected with research and development, needs to be protected such as patents due to requirement of monopoly power of new ideas such as business secrets. They also claim that total factor productivity which is estimated by Solow and Kendrick earlier leaves some uncertainty to measure technological change. Because the determinants of growth are beyond capital (human capital or learning by doing is included) and labour, remaining unexplained growth can be explained by GPT-general purpose of technology via revolutionary breakthroughs.

3. Methodology

Vector Auto Regression (VAR) is a system explains how interrelated (internal) variables move together and it defines dynamic relationships without any restrictions on the structural model and are frequently used for time series (Tari and Bozkurt, 2006). This technic is developed by Sims (1980), Litterman (1979) and Doan (1984) since macroeconomic variables interact with each other, it is difficult to distinguish between explanatory and dependent variables and to solve simultaneous equations under certain constraints.

Enders (1995), the stability of the variables analysed by VAR system is the subject of a discussion. Because the coefficient estimations made with non-stationary (trend / unit root) series are deviant and inconsistent, they will produce biased statistical results and will even cause fake regression problem between variables. However, Sims (1980) and Doan (1992) argue that the purpose of VAR analysis is not coefficient estimation Cooley and Leroy (1985), it is to determine the relationship between variables so that even if the individuals contain unit root, the variables should be run with their levels without taking the first differences.

VAR model is represented as follows (Karacor and Gerceker, 2012);

$$\Delta X_t = A_0 + \alpha_i \Delta X_{t-i} + \beta_0 A_t + \varepsilon_t \quad (1)$$

Equation 1 is the standard type od-f a VAR model; X_t and X_{t-i} are endogenous variables, A_t vector of exogenous variable. In this study variables ran with their first difference I(1), because of they have unit root in their level, I(0).

Variance decomposition helps to determine to the most effective variable on a macroeconomic indicator while through impulse-response functions we decide whether this variable can be used as a policy tool. Thus, variance decomposition provides information about the order and the degree of causal relationships between variables. The impulse-response functions express the dynamic response of each variable to a standard error in one of the variables, and the number of periods after which the effects of these shocks disappear and become uncertain (Saglam and Egeli, 2014: 4).

In this study, since the impulse-response functions obtained according to the ‘’Cholosky decomposition’’ method may vary depending on the order of the variables in the VAR model, the impulse-response functions obtained from the ‘’Generalized impulses’’ which are not dependent on the order of the variables are reported.

Hatemi-J et al. (2015) panel causality test helps researchers to increase the degree of freedom especially for developing and emerging market studies where time dimension (T) is shorter than number of observations (N) or taking into account spill-over effects between cross-sections. It also allows to take into account structural breaks, positive and negative shocks that causes for any instability The Granger causality approach is criticized for relying on whether the past values of a variable and neglect the effects of asymmetric causality (Hatemi-J et al., 2015: 3). Claiming that there is no asymmetry means being too restrictive in the assumptions of a study. For example; There is no market that is not characterized by symmetrical information. In practice, even though the decision-makers have the same attitude, they react very differently to negative shocks rather than positive shocks. This is why combining asymmetric causality with panel data analysis is much more efficient in a globalized era where all the economies are linked each other and crossed borders (Hatemi-J, 2011: 2-3). Also the empirical studies show that in general, a potential asymmetry in the causality testing has crucial indirect effects for the underlying causal inference between related variables (Saglam, 2019: 210).

The Hatemi- J test focuses on the relationship between w_1 *and* w_2. The interaction between the variables can be expressed as follows (Hatemi-J et al., 2015: 9);

$$w_{i1,t} = w_{i1,t} + e_{i1,t} = w_{i1,0} + \sum_{j=1}^{t} ei1, j \quad (2)$$

$$w_{i2,t} = w_{i2,t} + e_{i2,t} = w_{i2,0} + \sum_{j=1}^{t} ei2, j \quad (3)$$

N denotes the number of cross-sections. The error term (e) is white noisy, the mean is zero, and there is no correlation with the past values. For all $i = 1, \dots, N$, negative and positive shocks are defined as follows;

$$e_{i1,t}^{+} \coloneqq \max(e_{i1,t}, 0), e_{i2,t}^{+} \coloneqq \max(e_{i2,t}, 0) \; ve \; e_{i1,t}^{-} \coloneqq \min(e_{i1,t}, 0), e_{i2,t}^{-} \coloneqq \min(e_{i2,t}, 0) \quad (4)$$

Equation 4 is used to obtain the cumulative sum of shocks. Hatemi-J et al. (2015) use the asymmetric panel causality test VAR-SUR (p) - Vector Autoregressive Unrelated Regression (SUR) model. (p) represents the number of lags of the model and describes the trend in the time series.

The null hypothesis claims that H_0: $w_{i2,t}^{+}$ is not the reason of $w_{i1,t}^{+}$. The Wald test is based on the assumption of normality and shows the asymptotic chi-square χ^2 distribution (Hatemi-J and El-Khatib, 2016: 4036). When negative components are tested, the vector '' $(w_{i1,t}^{-}\ w_{i2,t}^{-})$'' can be used and etc. Cumulative shocks are calculated by an algorithm written by Hatemi-J in an econometric program called Gauss 10.0.

4. Empirical Results

The data is gathered from Eurostat science-technology and innovation database for the period between 2000 and 2017. VAR analysis is conducted to understand the performance of each sector on economic growth (GDP % annual) such as; business enterprise sector (BES), government sector (TGS), higher education sector (HES) and private non-profit sector (PNS) as a proxy of innovation (Intramural Research and Development expenditures-million euro, logarithmic form of the variables calculated on excel) for Europe-28 as a group. The stationary of the variables tested with CADF unit root test and their level has unit root so their difference is run with the E-views 8 program.

Right after the VAR analysis, to reject or accept ''innovation based economic growth hypothesis'', the asymmetric causality between economic growth and innovation (total all sectors) is examined via Hatemi-J et al. (2015). Some preliminary tests such as; Delta and $CDlm$ are conducted to figure out homogeneity and cross-sectional dependency of individual units. The countries included to the empirical model are in order; Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Spain, France, Italy, Cyprus, Latvia, Lithuania, Hungary, Netherland, Austria, Poland, Portugal, Romania, Slovenia, Slovakia. The rest of the countries and the previous years could not collect due to lack of data. The stationary of the variables conducted with Multifactor Error Structure unit root test developed by Pesaran et al. (2013), and the variables are integrated order one I(1).

VAR (2) model is estimated. Because, AR inverse roots and modules of VAR (1) model were not in the unit circle. Figure 1 shows that VAR (2) model has no stability or autocorrelation problem between the error terms and all inverse roots are inside of the unit circle.

Root	Modulus
-0.718085	0.718085
0.718085	0.718085
-0.230366 - 0.596823i	0.639740
-0.230366 + 0.596823i	0.639740
0.230366 - 0.596823i	0.639740
0.230366 + 0.596823i	0.639740
-4.16e-17 - 0.611574i	0.611574
-4.16e-17 + 0.611574i	0.611574
-0.310375	0.310375
0.310375	0.310375

Lags	LM-Stat	Prob
1	160.5951	0.0000
2	145.6566	0.0000
3	-	-

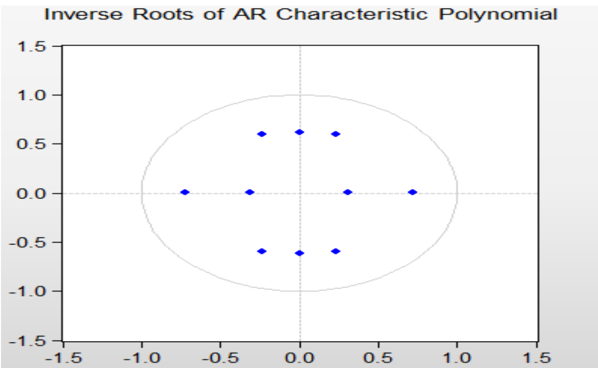

Figure 1. AR Roots graph and tables with LM statistics

$$GDP = -74.71HES - 45.22BES - 0.068GDP(-1) + 50.22TGS + 14.44PNS + 2.75 \quad (5)$$

Equation 5 shows that government sector and private non-profit sectors are contributing to the economic growth positively while the R&D expenditures of business enterprise sector and higher education sector have a negative impact on innovation based economic growth. According to the calculated coefficients Government Sector has the highest performance compare to the others.

Table 1. Variance Decompositions of GDP

T	S.E.	HES	BES	GDP	TGS	PNS
1	1.937599	0.558684	59.45888	39.98244	0.000000	0.000000
2	1.937599	0.558684	59.45888	39.98244	0.000000	0.000000
3	2.123804	2.689863	55.46734	33.49299	4.591432	3.758376
4	2.123804	2.689863	55.46734	33.49299	4.591432	3.758376
5	2.222615	3.060267	51.69979	31.75845	9.906107	3.575392
6	2.222615	3.060267	51.69979	31.75845	9.906107	3.575392
7	2.241387	3.159779	50.84338	31.59054	10.86441	3.541892
8	2.241387	3.159779	50.84338	31.59054	10.86441	3.541892
9	2.244407	3.163588	50.74423	31.50701	10.99114	3.594032
10	2.244407	3.163588	50.74423	31.50701	10.99114	3.594032

T represents periods (and number of the periods are selected by the program automatically) and S.E. indicates standard error. According to Table 1, we may list in order from most exogenous variable to endogenous one; business enterprise sector, government sector, private non-profit sectors and higher education sector. First two period government sector and private non-profit sector does not affect economic growth and the contribution of government sector is three times bigger then non-profit sector since the 3rd period. Economic growth also stimulates itself since period one and decreasing slightly till period ten.

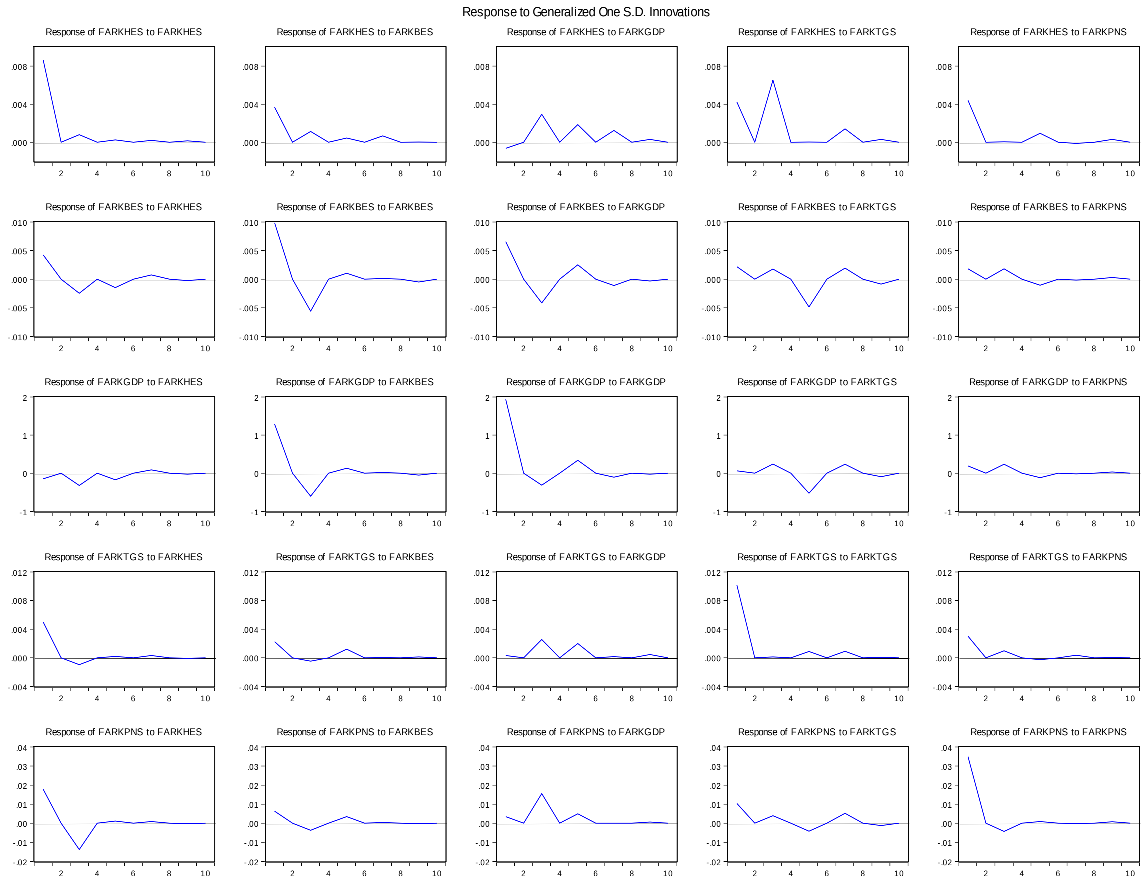

Figure 2. Impulse – Response Functions

Figure 2 shows the permanent or temporary effects (positive – negative) of structural changes on GDP and innovation indicators. It is obvious from the figure that responses of GDP to variables are temporary because eventually fluctuations are having a straight line form on the axis X.

This study has two different empirical model, VAR system examined the sectoral performance of innovation on economic growth for EU-28 as a group and second part is about to find out the direction of the causality between Intramural R&D expenditures (total all sectors) and economic growth with asymmetric panel causality technic for 21 members of EU-28.

Table 2 shows the results of homogeneity and cross-section dependence tests. Delta test is developed by Pesaran and Yamagata in 2004. CDlm test is initially developed by Breusch and Pagan (1980) after that it is adopted by Pesaran (2004).

Table 2. Preliminary test results

Tests	Statistics	Probability values
$\tilde{\Delta}$	2.930	0.002
$\tilde{\Delta}_{\mathbf{adj}}$	3.193	0.001
$\boldsymbol{CD_{LM1}}$ **(Breusch-Pagan)**	763.69	0.000
$\boldsymbol{CD_{LM2}}$	27.01	0.000
$\boldsymbol{CD_{LM}}$	2.90	0.002

$\tilde{\Delta}$ is for small sample and $\tilde{\Delta}_{adj}$ indicates Delta test statistics for big samples (augmented). Both of them are statistically significant (probability values are under 0.05), null hypothesis of Delta test is rejected and variables are heterogeneous. CD_{LM1}(Breusch-Pagan), CD_{LM2}, CD_{LM} are indicating cross-sectional dependent test statistics. According to probability values of table 2 there is cross-section dependency between individual units so null hypothesis is rejected.

Multifactor unit root test is developed by Pesaran et al. (2013) and it takes into account the cross-sectional dependency. Basically, the purpose of this unit root test is to eliminate the error structure of common factors (autocorrelation) for empirical studies in macroeconomic theory. There are two different test statistics estimated; $CIPS$ (cross-sectionaly augmented panel unit root test) and CSB (simple average of cross-sectional augmented Sargan-Bhargava) statistics.

Table 3. Multifactor Error Structure Unit Root Test Results

	Constant			**Constant and Trend**	
	Lags	**Stat.**	**Critical Value ($\boldsymbol{m^0}$=2)(%1)**	**Stat.**	**Critical Value ($\boldsymbol{m^0}$=2)(%1)**
<u>***GDP***</u>					
CIPSm	0	-27.08	-2.78	-25.785	-3.15
	1	-1.268	-2.68*	-1.239	-3.06*
	2	-1.489	-2.51*	-	-3.17*
	3	-	-	-	-
	4	-	-	-	-
CSBm	0	0.580	0.250*	0.024	0.092
	1	0.113	0.157	0.065	0.063*
	2	0.077	0.088	0.043	0.036*
	3	0.072	0.039*	0.012	0.014
	4	-	0.005	-	0.000
Factors		*INV*		*INV*	
<u>***INV***</u>					
CIPSm	0	-3.477	-2.78	-3.601	-3.15*
	1	-1.305	-2.68*	-1.345	-3.06*
	2	0.788	-2.51*	-	-3.17
	3	-	-	-	-
	4	-	-	-	-
CSBm	0	0.602	0.250*	0.042	0.092

1	0.103	0.157	0.068	0.063*
2	0.083	0.088	0.043	0.036*
3	-	0.039	0.013	0.014
4	-	0.005	-	0.000
Factors	*GDP*		*GDP*	

$CIPS$ and CSB statistic's critical values are taken from Pesaran et al.'s (2013) study. Check $CIPS$ values for constant model in page 108 at table B1; constant and trend model in page 110 at table B2. Check CSB values for constant model in page 112 at table B3; constant and trend model in page 114 at table B4. (*) indicates that calculated statistical value is greater than the table critical value. According to table 3, variables contain unit root at level I(0) and but their first difference I (1) is stationary.

Table 4. Results of Causality Test

Countries	Null Hypothesis	MWALD	Prob.	Null Hypothesis	MWALD	Prob.
Belgium	$GDP^- \neq> INV^+$	0.189	0.664	$INV^- \neq> GDP^+$	0.021	0.885
	$GDP^- \neq> INV^-$	5031	0.000*	$INV^- \neq> GDP^-$	0.094	0.759
	$GDP^+ \neq> INV^+$	0.227	0.000*	$INV^+ \neq> GDP^+$	6678	0.000*
	$GDP^+ \neq> INV^-$	0.093	0.761	$INV^+ \neq> GDP^-$	0.093	0.761
Bulgaria	$GDP^- \neq> INV^+$	0.032	0.857	$INV^- \neq> GDP^+$	0.338	0.561
	$GDP^- \neq> INV^-$	0.115	0.000*	$INV^- \neq> GDP^-$	3255	0.000*
	$GDP^+ \neq> INV^+$	1881	0.000*	$INV^+ \neq> GDP^+$	4714	0.000*
	$GDP^+ \neq> INV^-$	0.259	0.611	$INV^+ \neq> GDP^-$	0.259	0.611
Czech R.	$GDP^- \neq> INV^+$	0.116	0.733	$INV^- \neq> GDP^+$	0.024	0.877
	$GDP^- \neq> INV^-$	2731	0.000*	$INV^- \neq> GDP^-$	1.704	0.192
	$GDP^+ \neq> INV^+$	1.088	0.000*	$INV^+ \neq> GDP^+$	8011	0.000*
	$GDP^+ \neq> INV^-$	0.236	0.627	$INV^+ \neq> GDP^-$	0.236	0.627
Denmark	$GDP^- \neq> INV^+$	0.004	0.950	$INV^- \neq> GDP^+$	0.087	0.767
	$GDP^- \neq> INV^-$	2.020	0.000*	$INV^- \neq> GDP^-$	1234	0.000*
	$GDP^+ \neq> INV^+$	1853	0.000*	$INV^+ \neq> GDP^+$	0.886	0.000*
	$GDP^+ \neq> INV^-$	0.030	0.862	$INV^+ \neq> GDP^-$	0.030	0.862
Germany	$GDP^- \neq> INV^+$	0.034	0.853	$INV^- \neq> GDP^+$	0.000	1.000
	$GDP^- \neq> INV^-$	2213	0.000*	$INV^- \neq> GDP^-$	0.154	0.694
	$GDP^+ \neq> INV^+$	35.24	0.000*	$INV^+ \neq> GDP^+$	2946	0.000*
	$GDP^+ \neq> INV^-$	0.002	0.963	$INV^+ \neq> GDP^-$	0.002	0.963
Estonia	$GDP^- \neq> INV^+$	0.027	0.870	$INV^- \neq> GDP^+$	0.066	0.797
	$GDP^- \neq> INV^-$	0.009	0.000*	$INV^- \neq> GDP^-$	1335	0.000*
	$GDP^+ \neq> INV^+$	1600	0.000*	$INV^+ \neq> GDP^+$	0.580	0.000*
	$GDP^+ \neq> INV^-$	0.049	0.825	$INV^+ \neq> GDP^-$	0.049	0.825
Ireland	$GDP^- \neq> INV^+$	0.294	0.587	$INV^- \neq> GDP^+$	0.000	0.993
	$GDP^- \neq> INV^-$	3394	0.000*	$INV^- \neq> GDP^-$	0.804	0.359
	$GDP^+ \neq> INV^+$	0.476	0.000*	$INV^+ \neq> GDP^+$	6718	0.000*
	$GDP^+ \neq> INV^-$	0.053	0.818	$INV^+ \neq> GDP^-$	0.053	0.818
Spain	$GDP^- \neq> INV^+$	0.000	0.985	$INV^- \neq> GDP^+$	0.144	0.705
	$GDP^- \neq> INV^-$	1.070	0.000*	$INV^- \neq> GDP^-$	5171	0.000*
	$GDP^+ \neq> INV^+$	3594	0.000*	$INV^+ \neq> GDP^+$	1.761	0.000*
	$GDP^+ \neq> INV^-$	0.075	0.784	$INV^+ \neq> GDP^-$	0.075	0.784
France	$GDP^- \neq> INV^+$	0.090	0.764	$INV^- \neq> GDP^+$	0.091	0.762
	$GDP^- \neq> INV^-$	1384	0.000*	$INV^- \neq> GDP^-$	3.664	0.056*
	$GDP^+ \neq> INV^+$	1.866	0.000*	$INV^+ \neq> GDP^+$	1285	0.000*
	$GDP^+ \neq> INV^-$	0.024	0.876	$INV^+ \neq> GDP^-$	0.024	0.876
Italy	$GDP^- \neq> INV^+$	0.006	0.939	$INV^- \neq> GDP^+$	0.066	0.798
	$GDP^- \neq> INV^-$	5.638	0.000*	$INV^- \neq> GDP^-$	2273	0.000*
	$GDP^+ \neq> INV^+$	4593	0.000*	$INV^+ \neq> GDP^+$	23.34	0.000*
	$GDP^+ \neq> INV^-$	0.066	0.798	$INV^+ \neq> GDP^-$	0.066	0.798
Cyprus	$GDP^- \neq> INV^+$	0.015	0.903	$INV^- \neq> GDP^+$	0.001	0.979
	$GDP^- \neq> INV^-$	2209	0.000*	$INV^- \neq> GDP^-$	1.087	0.297
	$GDP^+ \neq> INV^+$	0.138	0.000*	$INV^+ \neq> GDP^+$	1244	0.000*
	$GDP^+ \neq> INV^-$	0.000	0.998	$INV^+ \neq> GDP^-$	0.000	0.998

Latvia	$GDP^- \neq> INV^+$	0.116	0.733	$INV^- \neq> GDP^+$	0.096	0.757
	$GDP^- \neq> INV^-$	13.40	0.000*	$INV^- \neq> GDP^-$	7707	0.000*
	$GDP^+ \neq> INV^+$	1274	0.000*	$INV^+ \neq> GDP^+$	4.841	0.000*
	$GDP^+ \neq> INV^-$	0.034	0.855	$INV^+ \neq> GDP^-$	0.034	0.855
Lithuania	$GDP^- \neq> INV^+$	0.001	0.969	$INV^- \neq> GDP^+$	0.000	0.992
	$GDP^- \neq> INV^-$	1844	0.000*	$INV^- \neq> GDP^-$	22.70	0.000*
	$GDP^+ \neq> INV^+$	3.292	0.000*	$INV^+ \neq> GDP^+$	5290	0.000*
	$GDP^+ \neq> INV^-$	0.009	0.926	$INV^+ \neq> GDP^-$	0.009	0.926
Hungary	$GDP^- \neq> INV^+$	0.077	0.781	$INV^- \neq> GDP^+$	0.148	0.701
	$GDP^- \neq> INV^-$	1.404	0.000*	$INV^- \neq> GDP^-$	9094	0.000*
	$GDP^+ \neq> INV^+$	1030	0.000*	$INV^+ \neq> GDP^+$	23.83	0.000*
	$GDP^+ \neq> INV^-$	0.316	0.574	$INV^+ \neq> GDP^-$	0.316	0.574
Netherland	$GDP^- \neq> INV^+$	0.254	0.614	$INV^- \neq> GDP^+$	0.003	0.960
	$GDP^- \neq> INV^-$	1627	0.000*	$INV^- \neq> GDP^-$	4.321	0.038*
	$GDP^+ \neq> INV^+$	0.024	0.000*	$INV^+ \neq> GDP^+$	6983	0.000*
	$GDP^+ \neq> INV^-$	0.062	0.803	$INV^+ \neq> GDP^-$	0.062	0.803
Austria	$GDP^- \neq> INV^+$	0.000	1.000	$INV^- \neq> GDP^+$	0.020	0.886
	$GDP^- \neq> INV^-$	0.323	0.000*	$INV^- \neq> GDP^-$	1309	0.000*
	$GDP^+ \neq> INV^+$	2545	0.000*	$INV^+ \neq> GDP^+$	14.31	0.000*
	$GDP^+ \neq> INV^-$	0.015	0.904	$INV^+ \neq> GDP^-$	0.015	0.904
Poland	$GDP^- \neq> INV^+$	0.164	0.686	$INV^- \neq> GDP^+$	0.002	0.960
	$GDP^- \neq> INV^-$	2243	0.000*	$INV^- \neq> GDP^-$	0.663	0.415
	$GDP^+ \neq> INV^+$	0.463	0.000*	$INV^+ \neq> GDP^+$	1310	0.000*
	$GDP^+ \neq> INV^-$	0.003	0.957	$INV^+ \neq> GDP^-$	0.003	0.957
Portugal	$GDP^- \neq> INV^+$	0.195	0.659	$INV^- \neq> GDP^+$	0.293	0.588
	$GDP^- \neq> INV^-$	3.360	0.000*	$INV^- \neq> GDP^-$	3554	0.000*
	$GDP^+ \neq> INV^+$	3651	0.000*	$INV^+ \neq> GDP^+$	2.996	0.000*
	$GDP^+ \neq> INV^-$	0.341	0.559	$INV^+ \neq> GDP^-$	0.341	0.559
Romania	$GDP^- \neq> INV^+$	0.000	0.993	$INV^- \neq> GDP^+$	0.088	0.767
	$GDP^- \neq> INV^-$	1019	0.000*	$INV^- \neq> GDP^-$	0.105	0.745
	$GDP^+ \neq> INV^+$	9552.3	0.000*	$INV^+ \neq> GDP^+$	4305	0.000*
	$GDP^+ \neq> INV^-$	0.204	0.652	$INV^+ \neq> GDP^-$	0.204	0.652
Slovenia	$GDP^- \neq> INV^+$	0.020	0.887	$INV^- \neq> GDP^+$	0.209	0.647
	$GDP^- \neq> INV^-$	333.3	0.000*	$INV^- \neq> GDP^-$	4103	0.000*
	$GDP^+ \neq> INV^+$	1111	0.000*	$INV^+ \neq> GDP^+$	23.05	0.000*
	$GDP^+ \neq> INV^-$	0.210	0.647	$INV^+ \neq> GDP^-$	0.210	0.647
Slovakia	$GDP^- \neq> INV^+$	0.263	0.608	$INV^- \neq> GDP^+$	0.029	0.866
	$GDP^- \neq> INV^-$	9920	0.000*	$INV^- \neq> GDP^-$	1.153	0.283
	$GDP^+ \neq> INV^+$	8.739	0.003*	$INV^+ \neq> GDP^+$	8269	0.000*
	$GDP^+ \neq> INV^-$	0.000	1.000	$INV^+ \neq> GDP^-$	0.000	1.000

The causality test has been repeated for four different modes. Also the causality from GDP to INV and INT to GDP is tested separately. $GDP^+ \neq> INV^+$indicates that economic growth is not the reason of innovation (intramural R&D expenditures-all sectors); $INV^+ \neq> GDP^+$ represents that innovation is not the reason of economic growth. (+) significates positive cumulative shocks and (-) significates negative cumulative shocks. (*) shows % 5 significant level.

According to table 4; the null hypotheses which claims that positive changes in economic growth will cause negative effects on innovation and negative cumulative changes in economic growth will cause positive effects on innovation are rejected for all the selected countries. So we may say that there is causality from GDP to INV and it is synchronistical.

The null hypothesis which claims that negative cumulative shocks in R&D expenditures will cause negative cumulative effects on economic growth is accepted only for Bulgaria, Denmark, Estonia, Spain, France, Italy, Latvia, Lithuania, Hungary, Netherland, Austria, Portugal, Slovenia. The null hypothesis which claims the opposite is accepted for all selected countries.

For both hypotheses first and third hypothesis are rejected. We may conclude that there is a two way confirmed causality from economic growth to innovation and agents give different reactions to negative shocks than positive ones, so there is an asymmetrical relationship between variables but synchronous. In general EU-28 is growing based on innovations.

5. Conclusion

The importance of innovation in this fast paced environment is inevitable. It is not a coincidence that the developed countries with high per capita income have already invested in innovation. In this paper, the sectoral (for business enterprise sector, government sector, higher education sector and private non-profit sector) performance of Intramural R&D expenditures (as a proxy of innovation) for Europe-28 during 2000 and 2017 is tested with VAR technique. Using the Intramural R&D expenditures for the sectoral analysis makes this paper differ from previous literature. Also the causality between intramural research and development expenditures and economic growth is tested for the first time with Hatemi-J et al. (2015) panel asymmetric causality for European countries.

Findings of the paper prove that that there is a two-way confirmed causality from economic growth to innovation and agents give different reactions to negative shocks than positive ones, so there is an asymmetrical relationship between variables but synchronous. In general EU-28 is growing based on innovations. The results of our study is similar to Cetin (2013) but oppose to Balli and Guresci (2017) and partially matching with Petrariu et al. (2013).

Innovation is very important to European competitiveness in the global economy. The EU is implementing policies and programmes that support the development of innovation to increase investment in innovation. European Horizon 2020 programme engages the latest innovation trends emerging in the European institutional, political, legal, and socio-economic context which identies the dynamics of good business practices of innovative companies. It helps collaboration between entrepreneurs, policy makers, innovation facilitators and researchers. So the empirical findings of this paper is supporting the EU Commission's innovative industrial policies.

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