THE HYPOTHESIS OF INNOVATION-BASED ECONOMIC GROWTH: A CAUSAL RELATIONSHIP

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ABSTRACT

Theoretically, the innovation-based growth hypothesis suggests that there is a positive linkage between innovation and economic growth. R&D plays a major role in innovation, raising productivity and increasing economic growth. In this study, this hypothesis is tested empiricially. The paper examines the causal relationship between R&D expenditures and economic growth. We apply our methodology, based on the standart Granger and Toda-Yamamoto tests for causality, to time-series data covering the period 1981-2008 for nine European countries. In consideration of standart Granger causality test, our empirical findings clearly exhibit that R&D expenditures cause GDP in the cases of Finland, France and Spain. The results also indicate that GDP causes R&D expenditures in Denmark and there is no causality between variables in other countries. On the other hand, the results of Toda-Yamamoto test imply that there is no causality between R&D expenditures and GDP in Holland, Ireland and Italy. However, there is bi-directional causality in Finland and France. Empirical results also indicate that there is a causal relationship between variables running from R&D expenditures to GDP for Austria, while the direction of causality is from GDP to R&D expenditures for Denmark, Spain and Portugal. Consequently, this study provides further evidence supporting the hypothesis for some European countries.

Keywords: Innovation, R&D expenditures, Economic growth, Causality.

JEL Classifications: O30, O40, O52.

YENİLİK ODAKLI EKONOMİK BÜYÜME HİPOTEZİ: BİR NEDENSELLİK İLİŞKİSİ

ÖZ

Teorik olarak yenilik odaklı büyüme hipotezi, yenilik ile ekonomik büyüme arasında pozitif bir ilişkinin olduğunu kabul eder. AR-GE yeniliklerde, verimlilik ve ekonomik büyümenin artırılmasında temel bir rol oynar. Çalışmada bu hipotez ampirik olarak test edilmektedir. Bu makale, AR-GE harcamaları ile ekonomik büyüme arasındaki nedensellik ilişkisini inceler. Metodoloji, standart Granger ve Toda-Yamamoto nedensellik testlerine dayanır ve 1981-2009 periyoduna yönelik dokuz AB ükesini içerir. Standart Granger nedensellik testleri dikkate alındığında, ampirik bulgular Finlandiya, Fransa ve İspanya örneğinde AR-GE harcamalarının GSYİH'ya neden olduğunu göstermektedir. Danimarka ekonomisinde GSYİH AR-GE harcamalarına neden olurken, diğer ülkelerde nedensellik ilişkisi söz konusu değildir. Diğer taraftan Toda-Yamamoto test sonuçları ise Hollanda, İrlanda ve İtalya'da AR-GE harcamaları ile GSYİH arasında bir nedensellik ilişkisinin olmadığını göstermektedir. Bununla birlikte Finlandiya ve Fransa'da çift yönlü nedenselliğe rastlanmıştır. Ampirik sonuçlar Avusturya için AR-GE harcamalarından GSYİH'ya doğru, Danimarka, İspanya ve Portekiz için GSYİH'dan AR-GE harcamalarına doğru bir nedensellik ilişkisini ortaya koymaktadır. Sonuç olarak bu çalışma, bazı AB ülkeleri için hipotezi destekleyici kanıtlar sunmaktadır.

Anahtar Kelimeler: Yenilik, AR-GE harcamaları, Ekonomik büyüme, Nedensellik

JEL Sınıflandırması: O30, O40, O52.

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1. Introduction

Economic growth is most commonly measured using changes in the total value of goods and services produced by a country's economy or what is known as Gross Domestic Product (GDP). Economic growth depends on a variety of factors. These factors are a country's rate of savings, increases in the stock of productive inputs, and technological change.

Innovation[1] gives rise to technological change. Thus it is a major determinant of economic growth and development. Creating economic value by introducing new products to the market, redesigning production processes, or reconfiguring organizational practices is essential for firms, industries and countries. According to OECD (2003; 2005a) long run economic growth is based on the creating and fostering of an environment that stimulates innovation and application of new technologies. Generating innovation, creating new technologies, and encouraging adoption of these new technologies cause higher economic growth rate.

Lisbon Strategy aims at encouraging knowledge and innovation by supporting more investment in research and development (R&D)[2], by facilitating innovation. In 2006, the European Council adopted four priority areas of the renewed Lisbon Strategy. At the 2008 spring summit, the Council reiterated those priorities and kept the integrated planning guidelines pertaining to the method of the Member Sates achieving the objectives of the Lisbon Strategy essentially unchanged (Grosse, 2008: 4). In recent years, national policy makers search for policies to strengthen innovative performance in European Union. Therefore, innovation policies play crucial role in reformulation of economy policies.

Theoretically, the innovation-based growth hypothesis suggests that there is a positive linkage between innovation and economic growth. According to this hypothesis, R&D plays a major role in innovation, raising productivity and accelerating economic growth.

In this study, this hypothesis is examined empiricially for nine European Countries. It gives chance to compare these countries and provides policy implications focused on R&D. We apply our methodology, based on the standart Granger causality and Lag-augmented Granger causality test developed by Toda-

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[1] The Oslo Manual defines innovation comprising product, process, marketing and organizational innovations (OECD, 2005b: 3). According to the neoclassical approach, innovation is a linear process in the market. Whereas, evolutionary economists claim that innovation is a cumulative, interactive and learning process with complex feed back mechanisms (Asheim, 2001: 41).

[2] HSE (2007) defines R&D as the commitment of resources to research and the refinement of ideas aimed at the development of commercially viable products and processes. According to Feldman (2004) R&D is the systematic augmentation or deepening of knowledge by applying it to some practical problem or new context with the idea of generating a commercial return. R&D is typically conducted by private firms.

Yamamoto, to time-series data covering the period 1981-2008. By doing so, this study presents an analysis of causality.

The remainder of the paper is organized as follows: Second section explains the theoretical and empirical literature. In the third section, the econometric methodology is presented. The study examines the causal relationship between innovation and economic growth. The fourth section explains the main findings and last section concludes.

2. Literature Rewiev

First theoretical suggestions about linkage between innovation and economic growth belongs to Adam Smith, Karl Marx and Allyn Young. According to Smith (1776) the extent of the market determines the division of labor. All increases in the extent of the market can lead to an increase in the division of labor and hence in specialization. Specialization is the essential for dedicated learning and the eventual introduction of innovations. Innovations enhance the efficiency of labor and hence the extent of the market. In fact, Smith deal with the foundations for the analysis of technological change as an endogenous process (Antonelli, 2009: 615).

Some decades later, Marx (1867) developed the importance of technological progress in a broader historical perspective by stressing its strong heterogeneity over time and space and the direct relationship between technological progress and the emergence of capitalistic institutions. Moreover, Marx replaced the concept of stationary state with an alternative historical vision of the economic system characterised by a continuous technology-oriented evolution (Conte, 2006: 5).

Young (1928) mentions the critical role of technological change, as both the product and the cause of increasing functional differentiation and complementarity within the economic system, in economic growth. He discusses economic growth in a dynamic approach. According to Young, economic systems are viewed as complex and dynamic adaptive organizations composed by autonomous and yet interrelated and interdependent units that change over time (Antonelli, 2009: 617).

Early neo-classical growth models emphasised the importance of capital accumulation. In the Solow (1956)-Swan (1956) model[1], output is produced by capital and labour. Economic growth gets along well with labouraugmenting technical progress, which acts as if it were increasing the available amount of labour. In the long-run, output per capita and labour productivity grow at an exogenously according to development in technical progress. Technical progress is

[1] *Both Solow and Swan established mathematically and diagrammatically how the economy finds the steady-state growth path in a one-commodity world. Instead of a general constant-returns production function, Swan worked out the mathematics of growth under the assumption of a Cobb-Douglas function. What is more, it is the capital-output ratio rather than Solow's capital-labor ratio that takes pride of place in Swan's diagram.*

entirely exogenous to these models so that in reality economic growth is left unexplained. Conversely, Arrow (1962) endogenized technology by assuming learning by doing. He states that technical progress grows at a constant rate and finds that long-run economic growth increases due to increase in population.

The theoretical relationship between innovation and economic growth is started to be intensively discussed in academic society following Schumpeter's studies. According to Schumpeter (1937; 1942) economic growth is generated by the endogenous introduction of product and/or process innovations. In other words, the essential characteristic of this growth model is the incorporation of technological progress which is a result of the endogenous introduction of product and/or process innovations. The term "endogenous" adverts to innovations that result from rational bahaviors undertaken by economic individuals to maximize their objective function (Dinopoulos and Şener, 2007: 2).

The re-birth of Schumpeterian growth theory has started in the late 1980's and early 1990s. The studies that developed the foundations of Schumpeterian growth theory are Romer (1986; 1990), Grossman and Helpman (1991), Aghion and Howitt (1992) and Howitt (1999). These so-called endogenous growth models were pioneered by Romer firstly. He took attention to endogenous technological change while explaining the growth patterns of world economies.

There are three suggestions in Romer (1990)'s model. First of them is that technological change drives growth. Secondly, people who respond to market incentives take intentional actions and this causes technological change. Last one ise designs for producing new products are nonrival, i.e. they can be replicated with no additional cost. There are three sectors in this model: R&D sector, intermediate goods sector and final output sector. technological innovation is created by R&D sector and this sector uses human capital and the existing knowledge stock. The product of R&D sector is used in the production of final goods and then growth rate of output increases permanently.

In the Grossman-Helpman (1991) product innovation model, innovation is at the heart of the model. Innovation has the creation of new processes and products in its train. The model assumes that growth rate of economy is equal to the aggregate rate of innovation. According to model successful innovators earn monopoly profits for a while, because their new products are superior to old product. There are many goods in this economy and so the model can be seen as a model of 'patent races'.

Two other economists who made important contributions on the link between innovation and economic growth are Philippe Aghion and Peter Howitt. Aghion-Howitt (1992) develop an endogenous growth model in the context of creative destruction. R&D oriented activities can lead to innovations. As a result of protection by patent law, firm can behave monopolistic to market a new product. The prospect of monopoly profits encourages firms to produce new and better products, so that the innovating firm can enter the market and the incumbent

monopolist is replaced. The speed of the innovation process is the main determinant of economic growth.

Recently, Howitt (1999) has come to the defense of innovation-oriented endogenous growth theory. In his model, firms can engage in both horizontal and vertical R&D activities. Howitt doesn't play the scale effect property in the model: the long-run economic growth rate is an increasing function of the population growth rate. However, all of the other forces determining the long-run economic growth rate are similar to the early innovation- based endogenous growth models. R&D activities subsidize long-run economic growth.

On the empirical side, there is a vast literature analyzing the link between innovation and economic growth. However the formel definition of innovation is broader, the impact of innovation is generally estimated by using R&D spending as a proxy in the economic literature. In most of the studies, it is found that there is a strong positive link between R&D capital and output.

Fabricant (1954) estimates that technical progress causes about 90% of the increase in output per capita in the US between 1871 and 1951. Solow (1957)[1] suggests that technical change is responsible for the most (87.5%) of economic growth. Mansfield (1972) who examines the relationship between R&D expenditures and output growth, implies that R&D expenditures assist substantially to output growth in different types of industries in the USA and Japan. Griliches (1992) denotes that R&D expenditures account for the majority of the change in the Solow residual in the United States.

Birdsall and Rhee (1993) employ cross-country regressions of data from both OECD and developing countries in their study. They find that there is a positive correlation between R&D expenditures and economic growth in the OECD countries. They also find that there is no significant relationship between variables in developing countries. Even for OECD countries, the study finds no evidence that R&D expenditure causes growth. These findings imply that R&D expenditures support to productivity only once a country attains a threshold level of economic prosperity.

Goel and Ram (1994) use the data from a cross-section of 52 countries in the late 1970s and early 1980s to identify the effect of R&D on economic growth. The model consists of labor, capital and R&D expenditures. Results show that the estimated impact of R&D outlays on economic growth is positive and large, but its statistical significance is low.

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[1] *In 1957, Solow made a basic and important calculation that is still instructive for scholars today. He examined U.S. economic data from 1909 to 1949 and asked what they tell us about the sources of U.S. economic growth over that period of time. Solow demonstrated that technical progress- not just factor inputs of capital and labour -account for economic growth. Total factor productivity, also known as the growth residual and which includes innovation and technology application, represents output growth not accounted by the growth in factor inputs.*

Eaton and Kortum (1996) find that more than 50 per cent of the productivity growth in each of the 19 OECD countries comes from innovations from just excluded three countries (US, Germany and Japan). These three countries, together with France and the United Kingdom, collect more than 10 per cent of their growth from domestic research.

Griffith et al. (2000) show that R&D intensities at the industry level in 12 OECD nations are positively and significantly correlated with growth of Solow residuals at the industry level between 1974-1994. Zachariadis (2003) compares the effect of R&D on aggregate and manufacturing output. The study finds that the effect of R&D is much higher for aggregate economy than the manufacturing sector.

Fraumeni and Okubo (2004) use USA time-series data from 1960 to 2000 imply that the contribution of R&D investment to GDP growth average between 2% to 7% under alternative scenarios. In all cases, the assistance of R&D to economic growth is found to be significant.

Aiginger and Falk (2005) investigate the determinants of GDP growth per capita by employing panel data methodology. They use data belonging OECD countries for the period 1970-1999. The study finds a large and statistically significant impact of business R&D (BERD) intensity on GDP per capita with an elasticity of 0.22. In addition, there is a significant and positive correlation between the share of hightechnology exports and GDP per capita. However, the results seems that BERD is more important than technological specialization in explaining the level of GDP per capita.

By employing USA data including for the 48-year-period 1953-2000, Rajeev at al. (2008) makes a contribution on the R&D and growth relation. The relatively new bounds-testing and ARDL procedures of Pesaran et al. (2001) are used in this study. Contrary to the recent results, the study gives a larger role of federal R&D relative to non-federal R&D in growth, and also a stronger role of defense R&D than of non-defense (federal) R&D.

Lebel (2008) uses a panel regression model and analyses data on a sample of 103 countries in different geographic regions for the 1980-2005 period. He develops a nested panel model which is applied to the global sample as well as to six geographic sub-samples. The findings show an empirical evidence of the positive role of creative innovation in economic growth.

Ahmad and Seyede (2009) investigate the impact of R&D on economic growth for developing countries. The study includes 30 developing countries and the data are available for the period 2000-2006. Contrary the other studies, they use different proxies for R&D. These are the share of government expenditures on research in GDP; the number of researchers in each one million population; and the scientific output of the countries. The findings based on panel data regression

models imply that there is no significant relationship in the countries under consideration.

Yuen at al. (2009) estimate empirically the impact of R&D on the economic growth of a Newly Industrialised Economy, Singapore. R&D intensity has been low initially, but rising rapidly for Singapore in recent years. The Cobb-Douglas based analysis shows that R&D investment in Singapore has a significant impact on its total factor productivity performance in the last 20 years. Compared to the OECD nations, the impact of R&D investment on economic growth in Singapore is not as strong as evidenced by lower estimated elasticity values.

Yanrui (2010) uses regional data to examine the impact of R&D efforts on innovation and hence economic growth in China. As a result of this paper, innovation activities affects China's economic growth positively while R&D intensity impacts regional innovation positively.

3. Econometric Methodology

There are several methods which is used in analyzing the causality relationship between time series[1]. This study have employed the standart Granger (1969) and Toda-Yamamato (1995) tests to determine the causality relationship between innovation and economic growth. As a measure of innovation criteria, R&D expenditures are handled in the analyses.

3.1. Model and Data

In investigating the causality links between R&D expenditures and GDP, the empirical anlyses take into account linear regression models below:

$$GDP_t = \alpha_0 + \alpha_1 R\&D_t + e_t \quad (1)$$

$$R\&D_t = \beta_0 + \beta_1 GDP_t + u_t \quad (2)$$

The data set consists of gross domestic product (GDP) and R&D expenditures obtained from The United Nations Statistics and EUROSTAT. The data set is annually and covers the period 1981 to 2008 for nine European countries namely Austria, Denmark, Finland, France, Holland, Ireland, Spain, Italy, Portugal. This time period is largely dictated by the availability of data on R&D. The number of countries analysed in this study is limited due to the absence of data belonging some European Countries. Besides in some of European Countries don't have sufficient and healty data in order to employ time series methodology. The variables are presented in Table 1.

[1] *Granger (1969), Hsiao (1981), Toda-Yamamoto (1995) and Dolado-Lütkepohl (1996) take part in causality methods.*

Tablo 1: Descriptions of The Data

Variables	Descriptions
GDP	Gross Domestic Product (1990=100; €)
R&D	Resarch and Development Expenditures (1990=100; €)
DGDP	First Differenced GDP
DR&D	First Differenced R&D
DDGDP	Second Differenced GDP
DDR&D	Second Differenced R&D

3.2. Estimation Methodology

One major assumption of the causality analysis, especially Granger (1969) test, is that the time-series variables are stationary. The study employs the Augmented Dickey-Fuller (ADF) (1981) and Phillips-Perron (PP) tests for stationarity properties of the variables. The ADF and PP tests are based on the regression equations below:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t + \sum_{i=1}^{n} \beta_i \Delta Y_{t-i} + u_t \quad (3)$$

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t + u_t \quad (4)$$

where Y_t and X_t represents GDP and R&D expenditures. *t* is the time trend, u_t is the white noise error term. The ADF and PP tests are essentially the tests of significance of the coefficient α_1 in the above equation. In these tests, the null hypothesis of non-stationarity (presence of unit root) for ADF are given by $\alpha_1 = 0$. Rejection of the null hypothesis implies stationarity of the series.

The empirical methodology in the study is based on the standart Granger (1969) and Toda-Yamamoto (1995) causality tests to investigate the relationship between R&D expenditures and GDP. According to Granger (1969), a variable (in this case R&D expenditures) is said to Granger cause another variable (GDP) if past and present values of R&D expenditures help to predict GDP.

The Vector Auto Regression (VAR) framework allows to test for Granger causality and explicitly includes the possibility of a feedback causality. For X_t and Y_t two stationary time series, a bivariate VAR model of order k is given by

$$Y_t = \alpha_0 + \beta_{1i}\sum_{i=1}^{k} Y_{t-i} + \beta_{2j}\sum_{j=1}^{k} X_{t-j} + \varepsilon_{1t} \quad (5)$$

$$X_t = \alpha_1 + \lambda_{1i}\sum_{i=1}^{k} X_{t-i} + \lambda_{2j}\sum_{j=1}^{k} Y_{t-j} + \varepsilon_{2t} \quad (6)$$

where the error terms ε_{1t} and ε_{2t} are assumed to be Gaussian white noise with zero mean and a constant covariance matrix. After estimating equations (5) and (6), several tests for Granger causality can be conducted. The traditional Granger causality test uses the simple F-test statistics. The series X_t Granger causes Y_t if the β_{2j} are jointly significant, while Y_t Granger causes X_t if the λ_{2j} are jointly significant. If both the β_{2j} and the λ_{2j} are jointly significant, there is evidence for bi-directional causality between X_t and Y_t.

Meanwhile, the results of Granger's test of causality are too sensitive to the selection of the length of lag. If the length of the selected lag is shorter than the actual length of the real lag, extra lags in VAR model will make the estimations inefficient. Therefore, the principal problem of Granger's standard test of causality is so sensitive to the selection of the length of lag, so that different lengths of lag will bring about different results.

At the other hand, Toda and Yamamoto (1995) proposed a simple approach based on estimating a modified VAR model in order to investigate Granger's test of causality. This approach uses a modified Wald (MWALD) test to test restrictions on the parameters of the VAR(k) model.

This test has an asymptotic chi-squared distribution with k degrees of freedom in the limit when a VAR[k+d_{max}] is estimated (where d_{max} is the maximal order of integration for the series in the system). Two steps are involved with implementing the procedure. The first step includes determination of the lag length (k) and the maximum order of integration (d) of the variables in the system. Measures such as the Akaike Information Criterion (AIC) and Hannan-Quinn (HQ) Information Criterion can be used to determine the appropriate lag structure of the VAR. Given the VAR(k) selected, and the order of integration d_{max} is determined, a levels VAR can then be estimated with a total of p=[k+ d_{max}] lags. The second step is to apply standard Wald tests to the first k VAR coefficient matrix (but not all lagged coefficients) to conduct inference on Granger causality. Toda-Yamamoto causality test involving two variables, R&D expenditures and GDP is written as:

$$Y_t = \alpha_0 + \beta_{1i}\sum_{i=1}^{k} Y_{t-i} + \beta_{2j}\sum_{j=k+1}^{d_{\max}} Y_{t-j} + \gamma_{1i}\sum_{i=1}^{k} X_{t-i} + \gamma_{2j}\sum_{j=k+1}^{d_{\max}} X_{t-j} + \varepsilon_{1t} \quad (7)$$

$$X_t = \alpha_1 + \lambda_{1i}\sum_{i=1}^{k} X_{t-i} + \lambda_{2j}\sum_{j=k+1}^{d_{\max}} X_{t-j} + \delta_{1i}\sum_{i=1}^{k} Y_{t-i} + \delta_{2j}\sum_{j=k+1}^{d_{\max}} Y_{t-j} + \varepsilon_{2t} \quad (8)$$

where the error terms ε_{1t} and ε_{2t} are assumed to be white noise with zero mean, constant variance and no autocorrelation. The series X_t Granger causes Y_t if the γ_{1i} are jointly significant, while Y_t Granger causes X_t if the δ_{1i} are jointly significant. If both the γ_{1i} and the δ_{1i} are jointly significant, there is evidence for bi-directional causality between X_t and Y_t.

4. Main Findings

The results of ADF test are reported in Table 2. The lag length for the ADF test is selected to ensure that the residuals are white noise. As seen in this table, each series is not stationary on level in Austria, Denmark, Finland, France, Holland, Ireland, Spain and Italy. But they become stationary when their first difference or second differrence is taken. Only, GDP is stationary on level for Portugal.

Tablo 2: The Results of ADF Unit Root Test

Countries	GDP	DGDP	DDGDP	Result	R&D	DR&D	DDR&D	Result
Austria	-3,454(4)	-3,853(6)**	-	I(1)	-0,197(5)	-2,111 (4)	-6,926(3)*	I(2)
Denmark	-2,581(1)	-3,414(6)	-4,301(0)*	I(2)	-2,827(1)	-2,779(5)	-4,240(2)*	I(2)
Finland	-0,964(2)	-3,058(1)	-3,875(0)**	I(2)	-1,891(1)	-3,163(0)	-6,758(0)*	I(2)
France	-2,909(1)	-3,696(6)**	-	I(1)	-2,021(5)	-3,401(6)	-4,054(3)**	I(2)
Holland	-2,581(1)	-3,414(6)	-4,301(0)**	I(2)	-1,338(0)	-5,325(0)*	-	I(1)
Ireland	-1,524(1)	-2,159(6)	-3,664(5)**	I(2)	-1,194(0)	-3,095(4)	-6,364(0)*	I(2)
Spain	-1,124(1)	-3,260(3)	-4,120(0)**	I(2)	-1,959(1)	-3,119(0)	-6,182(0)*	I(2)
Italy	-2,395(1)	-3,675(0)**	-	I(1)	-3,509(5)	-3,078(2)	-3,601(2)**	I(2)
Portugal	-3,969(0)**	-	-	I(0)	-3,571(1)	-3,138(1)	-5,154(0)*	I(2)

Note: The lag order is presented in the parenthesis after the test statistics for each variable. The superscripts * and ** denote significance at 1 and 5 % respectively.

The findings of PP test are seen from Table 3. Each series is not stationary on level in all countries. But they become stationary when their first difference or second differrence is taken.

Tablo 3: The Results of PP Unit Root Test

Countries	GDP	DGDP	DDGDP	Result	R&D	DR&D	DDR&D	Result
Austria	-3,454(4)	-3,329(1)	-6,621(1)*	I(2)	-1,197(2)	-18,473 (4)*	-	I(1)
Denmark	-2,773(2)	-2,987(1)	-4,295(1)*	I(2)	-1,823(2)	-2,672(0)	-4,867(2)*	I(2)
Finland	-0,847(2)	-2,192(0)	-3,768(3)**	I(2)	-1,419(2)	-3,668(0)**	-	I(1)
France	-2,053(2)	-3,057(0)	-5,756(2)*	I(2)	-2,049(1)	-3,767(5)**	-	I(1)
Holland	-2,773(2)	-2,987(1)	-4,295(1)**	I(2)	-1,239(2)	-5,704(4)*	-	I(1)
Ireland	-1,114(2)	-2,845(1)	-6,791(5)*	I(2)	-1,206(1)	-4,048(0)**	-	I(1)
Spain	-0,686(2)	-2,314(1)	-4,095(2)**	I(2)	-1,179(2)	-3,173(1)	-6,169(1)*	I(2)
Italy	-1,559(1)	-3,613(3)**	-	I(1)	-1,940(3)	-2,741(2)	-5,792(1)*	I(2)
Portugal	-2,197(2)	-2,251(0)	-4,227(2)**	I(2)	-2,911(1)	-2,847(2)	-6,003(5)*	I(2)

Note: The lag order is presented in the parenthesis after the test statistics for each variable. The superscripts * and ** denote significance at 1 and 5 % respectively.

Here, classical VAR model is prefered to test Granger causality relationship. Optimal lag is determined according to the measures such as FPE, AIC and HQ criteries. Also, the issues of autocorrelation, constant variance and normal distribution of each model are considered for the optimal lag.

The results of Granger causality test are presented in Table 4. Our empirical findings clearly exhibit that R&D expenditures cause GDP in the cases of Finland, France and Spain. The results also indicate that GDP causes R&D expenditures in Denmark and there is no causality between variables in other countries. The findings support the innovation- oriented growth hypothesis for Finland, France and Spain economies.

Tablo 4: The Results of Granger Causality Test

Countries	Hypotheses	Optimal Lag (k)	F-Statistic	P-Value	Direction of Causality
Austria	DDR&D=f(DGDP)	4	0,563	0,693	No
	DGDP=f(DDR&D)		0,506	0,732	No
Denmark	DDR&D=f(DDGDP)	1	0,007	0,931	No
	DDGDP=f(DDR&D)		9,798	0,005	GDP → R&D
Finland	DDR&D=f(DDGDP)	3	7,705	0,002	R&D → GDP
	DDGDP=f(DDR&D)		2,291	0,119	No
France	DDR&D=f(DGDP)	2	4,343	0,028	R&D → GDP
	DGDP=f(DDR&D)		1,173	0,331	No
Holland	DR&D=f(DDGDP)	2	0,087	0,916	No
	DDGDP=f(DR&D)		0,014	0,985	No
Ireland	DDR&D=f(DDGDP)	2	0,286	0,754	No
	DDGDP=f(DDR&D)		2,436	0,115	No
Spain	DDR&D=f(DDGDP)	1	7,357	0,013	R&D → GDP
	DDGDP=f(DDR&D)		0,630	0,436	No
Italy	DDR&D=f(DGDP)	3	1,493	0,259	No
	DGDP=f(DDR&D)		0,092	0,962	No
Portugal	DDR&D=f(GDP)	3	1,361	0,292	No
	GDP=f(DDR&D)		0,619	0,613	No

The results of Toda-Yamamoto test which is a developed form of standart Granger causality test are summarized in Table 5. Empirical results imply that there is no causality between R&D expenditures and GDP in Holland, Ireland and Italy. However, there is bi-directional causality in Finland and France. Empirical findings also indicate that there is a causal relationship between variables running from R&D expenditures to GDP for Austria, while the direction of causality is from GDP to R&D expenditures for Denmark, Spain and Portugal. Consequently, the results of Toda-Yamamoto test present further evidince in favour of the innovation-based growth hypothesis for Austria, Finland and France.

Tablo 5: The Results of Toda-Yamamoto Causality Test

Countries	Hypotheses	$k+d_{max}$	X^2-Statistic	P-Value	Direction of Causality
Austria	R&D=f(GDP)	4+2=6	11,904	0,018	R&D → GDP
	GDP=f(R&D)		2,033	0,729	No
Denmark	R&D=f(GDP)	1+2=3	0,157	0,691	No
	GDP=f(R&D)		9,862	0,001	GDP → R&D
Finland	R&D=f(GDP)	3+2=5	7,779	0,050	R&D → GDP
	GDP=f(R&D)		18,917	0,000	GDP → R&D
France	R&D=f(GDP)	2+2=4	6,669	0,035	R&D → GDP
	GDP=f(R&D)		8,329	0,015	GDP → R&D
Holland	R&D=f(GDP)	2+2=4	0,630	0,729	No
	GDP=f(R&D)		0,535	0,765	No
Ireland	R&D=f(GDP)	2+2=4	1,029	0,597	No
	GDP=f(R&D)		3,078	0,214	No
Spain	R&D=f(GDP)	1+2=3	0,022	0,879	No
	GDP=f(R&D)		4,489	0,034	GDP → R&D
Italy	R&D=f(GDP)	3+2=5	0,766	0,857	No
	GDP=f(R&D)		3,071	0,380	No
Portugal	R&D=f(GDP)	3+2=5	4,406	0,220	No
	GDP=f(R&D)		19,946	0,000	GDP → R&D

5. Concluding Remarks

The importance of innovation for economic growth is well-known, as indicated by the numerous studies in the last two decades, especially Romer (1986; 1990), Aghion and Howitt (1992), and Howitt (1999). According to these growth models, innovation is created in the R&D sectors and R&D significantly enhances growth and increases productivity, and the ongoing stream of new innovations is a critical element in the positive growth in the long run. On the other hand, the majority of empirical literature assessing the link between R&D and economic growth by using the new growth theories found a strong positive relationship.

In this study, the relationship between innovation and economic growth is investigated theoretically and empiricially. In economic literature the impact of innovation is typically estimated by using R&D spending as a proxy. Hence, we handle R&D expenditures as a measure of innovation criteria. We also employe Granger (1969) and Toda-Yamamato (1995) tests to analyze the causality link

between R&D expenditures and economic growth. The period between years 1981-2008 is taken into account for nine European Countries.

Since in standart Granger and Toda-Yamamoto methods, we need to know about the degree of integration of the variables, ADF (1981) and PP (1988) tests are used to test the variables' staionarity. The results of ADF and PP tests show that each series is not stationary on level in Austria, Denmark, Finland, France, Holland, Ireland, Spain and Italy. In some of countries, the series belonging the variables become stationary when their first difference while in the other countries, they become stationary in second differrence.

The results of standart Granger causality test exhibit that R&D expenditures cause GDP for Finland, France and Spain. The results also indicate that GDP causes R&D expenditures in Denmark and there is no causality between variables in other countries. The findings support the innovation-oriented growth hypothesis for Finland, France and Spain. The results of Toda-Yamamoto test imply that there is no causality between R&D expenditures and GDP in Holland, Ireland and Italy. However, there is bi-directional causality in Finland and France. Empirical findings also indicate that there is a causal relationship between variables running from R&D expenditures to GDP for Austria, while the direction of causality is from GDP to R&D expenditures for Denmark, Spain and Portugal. The results support the innovation based growth hypothesis for Austria, Finland and France.

In conclusion, this study provides further evidence supporting the innovation-based growth hypothesis for some European countries and importance of Lisbon Strategy's priorities. The direction of causality in Austria, Finland and France running from R&D expenditures to GDP and the data of R&D intensity for the same countries overlap. Furthermore, the empirical findings exhibit that R&D investments are one of the important companent of economic growth. Findings of this study support evidence of Mansfield (1972), Goel and Ram (1994), Fraumeni and Okubo (2004), Aiginger and Falk (2005), Lebel (2008), Yanrui (2010). On the other hand, we find results contrary to Ahmad and Seyede (2009).

These findings have important policy implications. Not only has innovation moved to centre-stage in economic policy making, but there is a realisation that a co-ordinated, coherent, "whole-of-government" approach is required. The national strategic roadmaps should have been sustained to foster innovation and enhance its economic impact. In this context, governments should support sector in institutions, industries and universities. Governments should also increase R&D intensity and apply effective R&D policies.

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