Is Innovation Conducive to Economic Growth? The Case of Central and Eastern European Countries

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Introduction

In economics literature, the effects of technological progress and innovation on economic growth and development have been investigated since the 1980s both theoretically and empirically. In particular, along with the development of Endogenous Economic Growth Models which were put forward by Romer (1986, 1990) and Lucas (1988), the number of empirical studies that focus on this issue has increased dramatically.

Although the number of empirical analyses that examine the effect of technological progress and innovation on the level of economic growth and development is quite high, there are very few studies examining this issue in Central and Eastern European countries. Furthermore, most of the existing studies do not take into account the quality aspect of

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innovation. Unlike most of the previous studies, this chapter makes two contributions to the existing literature: first, the effect of innovation is investigated in the Central and Eastern European countries; and second, both the quantity and quality aspects of innovation are taken into consideration in the empirical analysis.

The results of the empirical estimations indicate that research and development (R&D) expenditures do not have any effects on economic growth both in the short- and long-run. Moreover, while patent applications to the European Patent Office (EPO) and patents granted by the United States Patent and Trademark Office (USPTO) have a negative effect on economic growth in the short-run, this effect becomes positive in the long-run. The negative effect of patents in the short-run may result from the fact that obtaining a patent requires a long invention process carried out by spending a huge amount of money on R&D activities. However, once a patent is obtained and new goods and services are introduced to the market, the profits of the firm that owns the patent increase and this also leads to an increase in the economic growth rate. Hence, we suggest that innovation activities, especially patents, positively influence the economic growth rates of Central and Eastern European countries in the long-run.

In this chapter we first briefly summarise the theoretical literature and the recent empirical analyses that investigate the effect of innovation on economic growth (section "Literature Review"), followed by an explanation of the dataset and methodology used in the empirical analysis in section "Data and Methodology". Section "Results" discusses the results of the empirical analysis in detail and, finally, section "Conclusion" draws conclusions.

Literature Review

The determinants of economic growth have been one of the mostly debated issues in the economics literature since the beginning of the 1900s. In the theoretical field, different economic growth models have been put forward in order to explain the process of economic growth. According to the Neoclassical Economic Growth Models developed by Ramsey (1928), Solow (1956) and Swan (1956), economic growth is determined by the developments in capital and labour. However, although technological progress plays a significant role in maintaining long-run economic growth by eliminating diminishing returns to capital in these models, technological progress is taken as an exogenous determinant of economic growth together with the population growth rate (Guloglu and Tekin 2012).

In contrast to the Neoclassical Economic Growth Models, the Endogenous Economic Growth Models developed by Romer (1986, 1990), Lucas (1988), Grossman and Helpman (1990, 1991), and Aghion and Howitt (1992) argue that technological progress is an endogenous determinant of long-run economic growth. According to these models, technological progress, or more precisely innovation, is generated in R&D industries by drawing on human capital and knowledge stock and it is then used to produce goods and services, causing a lasting rise in economic growth (Ulku 2004).

Together with the development of Endogenous Economic Growth Models, the number of empirical studies that examine the effect of innovation activities on economic growth has increased dramatically. Here, we present the results of recent empirical studies that focus on the economic growth–innovation nexus.[1]

Crosby (2000) has analysed the influence of innovation on economic growth in Australia between 1901 and 1997. In this empirical analysis, Crosby (2000) used patent data as the key independent variable that represents innovation and found that rising patent activities increase labour productivity and economic growth.

Ulku (2004) investigated whether innovation lead to sustainable economic growth in 20 OECD (Organization for Economic Co-operation and Development) and 10 non-OECD countries during the period 1981–1997 by employing patent and R&D expenditure data. In the empirical analysis, the author used a number of panel data techniques and found that whilst innovation positively affects economic growth both in the OECD and non-OECD countries, R&D stock influences innovation only in the OECD countries with large markets (Ulku 2004).

Bilbao-Osorio and Rodriguez-Pose (2004) examined the relationship between R&D investments and innovation and between innovation and economic growth in the peripheral and non-peripheral regions of the European Union (EU). Using a dataset covering the 1990s, they found that while privately funded R&D activities are the main determinants of innovation in the non-peripheral regions of the EU, it is the private research together with the research in the higher education institutions that lead to innovation in the peripheral regions of the EU (Bilbao-Osorio and Rodriguez-Pose 2004). With regard to the effect of innovation on economic growth, Bilbao-Osorio and Rodriguez-Pose (2004) argue that although innovation has a positive effect on economic growth in the peripheral European regions, there is no relationship between innovation and economic growth in the non-peripheral European regions.

Goel et al. (2008) investigated the relationship between federal, non-federal, defence R&D expenditures and economic growth in the USA for the period 1953–2000. The Bounds Testing approach and Autoregressive Distributed Lag (ARDL) methodology developed by Pesaran et al. (2001) were employed in the empirical estimations (Goel et al. 2008). The empirical results of this study indicate that federal R&D expenditures in comparison with non-federal R&D expenditures and defence R&D expenditures relative to non-defence R&D expenditures have a stronger effect on the economic growth rates in the USA over the period under investigation (Goel et al. 2008).

Similar to the study by Bilbao-Osorio and Rodriguez-Pose (2004), Capello and Lenzi (2014) analysed the impact of knowledge and innovation on the economic growth performance of 262 regions in 27 EU countries. In the empirical analysis, the authors used R&D expenditures and the share of firms introducing product and/or process innovations as the indicators of knowledge and innovation activities, respectively, and found that the positive effects of innovation on economic growth are more diffusive than knowledge in the regions under investigation (Capello and Lenzi 2014).

Falk (2007) assessed the impact of R&D investment on economic growth for OECD countries over the period 1970–2004. In the empirical analysis, Falk (2007) uses 5-year averages of the variables and estimates the models by using the system Generalized Method of Moments (GMM) estimator in order to remove the endogeneity problem.

According to the results of the estimations, Falk (2007) concludes that R&D investments in high-tech sectors have a positive effect on economic growth rates in the OECD countries.

Wang (2007) examined the efficiency of R&D activities in 23 OECD and 7 non-OECD countries by constructing a cross-country production model. In the empirical analysis, stochastic frontier methods were employed and the models were estimated using a dataset covering the period between 1998 and 2002 (Wang 2007). According to the estimation results, Wang (2007) asserts that there is a positive correlation between R&D activities and income level in the 30 countries under investigation.

Pessoa (2010) investigated the relationship between R&D expenditures and economic growth in the OECD countries by proposing a method to obtain the growth rate of technology. The results of the estimations indicate that the relationship between R&D expenditures and economic growth changes according to the specific characteristics of the countries (Pessoa 2010).

Hasan and Tucci (2010) investigated the effect of both the quality and quantity of innovation on economic growth in 58 countries over the period 1980–2003. The authors used two different quality indicators of innovation and found that higher-quality patents led to higher economic growth (Hasan and Tucci 2010). Moreover, the results of this empirical analysis show that an increase in the number of patents results in an increase in the level of economic growth for the countries under investigation (Hasan and Tucci 2010).

The casual relationship among R&D expenditures, innovation and economic growth in 13 high-income OECD countries was analysed by Guloglu and Tekin (2012) for the period 1991–2007. The authors estimated panel Granger Causality tests by employing panel fixed effects and GMM methods (Guloglu and Tekin 2012). According to the results of empirical estimations, Guloglu and Tekin (2012) suggest that R&D expenditures lead to technological change and technological change results in economic growth in high-income OECD countries.

Petrariu et al. (2013) assessed the influence of innovation on economic growth in the Central and Eastern European countries between 1996 and 2010. The authors used a number of different indicators of innovation such as R&D spending, patents and the number of researchers (Petrariu et al. 2013). The empirical results of this analysis show that R&D spending and the number of patents have a statistically significant but negative effect on economic growth in the Central and Eastern European countries (Petrariu et al. 2013). Hence, Petrariu et al. (2013) suggest that this result indicates the existence of a catch-up process.

Galindo and Mendez (2014) analysed the interaction between entrepreneurship, innovation and economic growth in 13 developed countries using panel data for the period 2002–2011. According to the empirical results, they conclude that innovation and entrepreneurship have a positive effect on economic growth and that increasing rates of economic growth causes increasing innovation and entrepreneurship activities (Galindo and Mendez 2014).

Pece et al. (2015) examined the relationship between innovation and economic growth in Poland, the Czech Republic and Hungary over the period 2000–2013. In the empirical analysis, the authors employed the number of patents, the number of trademarks and R&D expenditures per capita as the indicators of innovation and concluded that innovation activities positively influence economic growth rates in these countries (Pece et al. 2015).

In summary, as can be seen from the literature reviewed here, there are many studies that mainly focus on the relationship between R&D activities and economic growth in the existing literature. However, the majority of these studies only take into account the quantity aspect of R&D activities and innovation and do not deal with the quality aspect of these factors. In this study, we investigate the effect of innovation on economic growth by considering both the quantity and quality dimensions of innovation and hence contribute to the literature by providing new evidence with regard to the relationship between innovation and economic growth.

Data and Methodology

In this empirical analysis, we use an unbalanced panel dataset covering the period between 1993 and 2014 in order to investigate the effect of innovation on economic growth in the Central and Eastern European countries that are also the members of the EU. We used the OECD's definition of the Central and Eastern European countries (OECD 2016) to select the countries for inclusion in the empirical analysis. According to this definition, Central and Eastern European countries are Albania, Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, the Slovak Republic, Slovenia, Estonia, Latvia and Lithuania. Since Albania is not a member of the EU and the R&D expenditure data for Croatia starts in 2002 we excluded these countries from our dataset. The variables used in the empirical analysis are the real gross domestic product (GDP) growth rate, gross fixed capital formation as a percentage of GDP, population growth rate, total R&D expenditures as a percentage of GDP, patent applications to the EPO as a percentage of total R&D expenditures, and patents granted by the USPTO as a percentage of total R&D expenditures. While real GDP growth rate, gross fixed capital formation and population data are taken from the annual macroeconomic database of the European Commission (AMECO) (European Commission Economic and Financial Affairs–AMECO 2016) data on total R&D expenditures, patent applications to the EPO and patents granted by the USPTO are obtained from the Eurostat (European Commission–Eurostat 2016).

As stated earlier, we take into account both the quantity and quality aspects of innovation and examine whether these different aspects have a diverse impact on the GDP growth rate. Similar to the study by Hasan and Tucci (2010), total R&D expenditures and patent applications to the EPO represent the quantity aspect of innovation whilst patents granted by the USPTO represent the significance and the quality of innovation.

We have estimated a standard Solow Model, which asserts that economic growth is determined by capital and population growth. In order to ascertain the influence of innovation on economic growth we added variables representing the quantity and quality aspects of innovation to the model. The estimated empirical model is stated as follows (Eq. 1):

$$\Delta y_{it} = \alpha_{1t} cap_{it} + \alpha_{2t}(g_{it} + n_{it} + \varphi_{it}) + \alpha_{3t} randd_{it} + \alpha_{4t} crisis + \sigma_i + \varepsilon_{it} \quad (1)$$

In this equation, y is real GDP (Δy is the real GDP growth rate), *cap* is gross fixed capital formation as a percentage of GDP, η is population growth, g and φ are technological progress and technological depreciation, respectively (since we do not have a reliable measure of these two terms in the countries under investigation, we substitute the sum of them with a constant term which is equal to 0.06), *rand* represents innovation (total R&D expenditures as a percentage of GDP, patent applications to the EPO as a percentage of total R&D expenditures, patents granted by the USPTO as a percentage of total R&D expenditures), *crisis* is a dummy variable that takes the value of 1 after 2007 and represents the 2008 Global Economic Crisis, σ represents country dummies, ε is the error term, and i and t are the country and time subscripts, respectively. We take the logarithms of all of the variables and estimate this model for each innovation indicator separately.

In order to estimate this model we employ Mean Group (MG) and Pooled Mean Group (PMG) estimators, new techniques developed by Pesaran and Smith (1995) and Pesaran et al. (1997, 1999). These estimators are used to estimate non-stationary dynamic panels in which the parameters are heterogeneous across groups (Blackburne and Frank 2007).

The dynamic heterogeneous panel regression can be stated as an error–correction model by drawing on ARDL (p,q)[2] model (Pesaran et al. 1999; Blackburne and Frank 2007) (Eq. 2):

$$\Delta y_{it} = \vartheta_i\left(y_{i,t-1} - \sigma_i^{'} X_{it}\right) + \sum_{j=1}^{p-1} \tau_{ij}^{*} \Delta y_{i,t-1} + \sum_{j=0}^{q-1} \gamma_{ij}^{'*} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (2)$$

In this equation, y is the real GDP growth rate, X represents the independent variables, τ and γ are the short-run coefficients of the dependent and independent variables, respectively, σ is the long-run coefficient, ϑ is the speed of adjustment term (error correction coefficient), and i and t are country and time subscripts, respectively. Here, the speed of adjustment term (error correction coefficient) is particularly important as this variable should be statistically significant and negative in order to have a long-run relationship between the variables (Blackburne and Frank 2007). This equation can be estimated by employing MG and PMG estimators (Pesaran and Smith 1995; Pesaran et al. 1997, 1999). While the intercepts, slope coefficients and error variances are allowed to change across groups with the MG estimator developed by Pesaran and Smith (1995), the PMG estimator developed by Pesaran et al. (1997, 1999) allows the intercept, short-run coefficients and error variances to change but restricts long-run coefficients to be equal across groups (Blackburne and Frank 2007).

We estimate our model by drawing on both MG and PMG estimators and then use the Hausman test (Hausman 1978) to decide which estimator is more efficient and thus should be preferred.

Results

In order to estimate our model using MG and PMG estimators we need to decide the lag length of the variables before the estimations.[3] In the literature it is suggested that when the time period is short, ARDL (1, 1), a common lag structure, can be used in the model (Loayza and Ranciere 2006; Demetriades and Law 2006). Since our dataset covers only 22 years, we applied ARDL (1, 1) while estimating our regressions.

Table 1 shows the results of regressions in which R&D expenditures as a percentage of GDP is used as the innovation variable. In order to evaluate the coefficient estimations, we should first decide which estimator is more efficient and thus gives more reliable results than the other estimator. According to the result of the Hausman Test, the PMG estimator is more efficient than the MG estimator. Hence, we take into account the results of regressions obtained using the PMG estimator. These results are shown in column 2 of Table 1.

According to the coefficient estimations, gross fixed capital formation has a statistically significant and positive effect on economic growth both in the short- and long-run. Moreover, the crisis variable which represents the 2008 Global Economic Crisis has a significant and negative impact on economic growth in the long-run. However, neither the sum of population growth, technological progress and technological depreciation nor R&D expenditures has a statistically significant influence on economic growth. Hence, these results suggest that R&D expenditures do not affect economic growth rates in the Central and Eastern European countries over the period under investigation.

Table 1 Estimation results (innovation variable: research and development expenditures)

Long-run coefficients	Pooled mean group	Mean group
Gross fixed capital formation	0.036967*** (0.0114)	0.002941 (0.0347)
Pop. growth + tech. progress + tech. depreciation	0.005742 (0.0284)	−0.03452 (0.0798)
Research and development expenditure	−0.01254 (0.0095)	0.005844 (0.0117)
Crisis	−0.01706*** (0.0050)	−0.03699*** (0.0098)
Error correction coefficient	−0.94685*** (0.0474)	−1.02136*** (0.0721)
ΔGross fixed capital formation	0.20085*** (0.0472)	0.190939*** (0.0483)
ΔPopulation growth	0.079282 (0.0497)	0.098125 (0.0787)
ΔResearch and development expenditure	0.005263 (0.0186)	−0.01459 (0.0244)
Intercept	0.047859*** (0.0050)	−0.035 (0.2608)
Hausman Test	7.1	
P value	0.1306	
Observation	203	203

Standard errors are in parentheses. The chosen lag structure is Autoregressive Distributed Lag (1, 1, 1, 1). The models are estimated using the xtpmg routine (Blackburne and Frank 2007) in STATA®. The Hausman Test indicates that the Pooled Mean Group estimator is more consistent and efficient than the Mean Group estimator

$^{***}p \leq 0.01$

Source Authors' estimations

Table 2 represents the results of regressions in which patent applications to the EPO as a percentage of total R&D expenditures are used as the innovation variable. According to the Hausman Test result, the PMG estimator is more efficient than the MG estimator. Thus, we take into consideration the results of regression, which is estimated using the PMG estimator while assessing the effect of patent applications to the EPO on economic growth. These results are shown in column 2 of Table 2.

Table 2 Estimation Results (Innovation Variable: Patents—Europe)

Long-run coefficients	Pooled mean group	Mean group
Gross fixed cap. for.	0.02957*** (0.0103)	0.014935 (0.0233)
Population growth	0.009102 (0.0274)	–0.00475 (0.0955)
Patents—Europe	0.011885*** (0.0035)	0.014286 (0.0104)
Crisis	−0.02666*** (0.0036)	–0.03562*** (0.0053)
Error correction coef.	−0.9607*** (0.0428)	–1.06584*** (0.0711)
ΔGross fixed cap. for.	0.207856*** (0.0440)	0.222799*** (0.0581)
ΔPopulation growth	0.077908 (0.0496)	0.096364 (0.0962)
ΔPatents—Europe	−0.01162*** (0.0031)	–0.00402 (0.0057)
Intercept	0.056129*** (0.0052)	–0.0134 (0.2970)
Hausman Test	5.86	
P value	0.2098	
Observation	197	197

Standard errors are in parenthesis. The chosen lag structure is ARDL (1, 1, 1, 1). The models are estimated by using xtpmg routine (Blackburne and Frank 2007) in STATA®. Hausman Test indicates that PMG estimator is more consistent and efficient than MG estimator.
$^{***}p \leq 0.01$
Source Authors' estimations

Similar to the previous results, gross fixed capital formation has a statistically significant and positive impact on economic growth both in the short- and long-run. Furthermore, while crisis negatively affects economic growth in the long-run, the sum of population growth, technological progress and technological depreciation does not influence economic growth in either the short- or long-run. However, unlike previous results, patent applications to the EPO has a statistically significant effect on economic growth. Whilst this variable has a negative impact on economic growth in the short-run, this impact turns out to be positive in the long-run. This may stem from the fact that in order to obtain a patent, considerable R&D investments are made and these investments do not come to fruition in the short-run. However, in the long-run the patents increase the profitability of firms and positively influence economic growth. Thus, according to these results, we argue that instead of innovation inputs (R&D expenditures), innovation outputs (patents) have a positive effect on economic growth in the Central and Eastern European countries.

Table 3 shows our final estimations, in which our innovation variable is the patents granted by the USPTO as a percentage of total R&D expenditures. Consistent with the previous results, the Hausman Test indicates that the PMG estimator is more efficient than the MG estimator. According to the results of regression, which is estimated using the PMG estimator, gross fixed capital formation has a positive influence on economic growth both in the short- and long-run. In addition to this, the sum of population growth, technological progress and technological depreciation is statistically significant in neither the short-run nor the long-run and crisis has a statistically significant negative impact on economic growth in the long-run. These results are in keeping with our previous results. With regard to the effect of patents granted by the USPTO, we conclude that this variable positively affects economic growth in the long-run. So, according to this result, we assert that the quality of innovation has a positive impact on economic growth in the long-run.

To summarise, our results show that gross fixed capital formation positively influences economic growth both in the short- and long-run. Furthermore, crisis has a negative impact on economic growth in the long-run. However, the sum of population growth, technological progress and technological depreciation does not have any effects on economic growth both in the short- and long-run. With regard to innovation, our results suggest that innovation inputs (R&D expenditures) have no effects on economic growth both in the short- and long-run. However, innovation outputs (patent applications to the EPO and patents granted by the USPTO) have a negative effect on economic growth in the short-run and a positive effect on economic growth in the long-run. These results indicate that although total R&D expenditures do not influence economic growth, the subset of R&D expenditures that

Table 3 Estimation results (innovation variable: patents—USA)

Long-run coefficients	Pooled mean group	Mean group
Gross fixed capital formation	0.026844**	0.002226
	(0.0112)	(0.0287)
Population growth	0.037379	−0.11599
	(0.0297)	(0.1642)
Patents—USA	0.009117**	0.011674
	(0.0041)	(0.0145)
Crisis	−0.01328***	−0.02719**
	(0.0038)	(0.0107)
Error correction coefficient	−0.95097***	−1.09134***
	(0.0600)	(0.0852)
∆Gross fixed capital formation	0.227675***	0.256426***
	(0.0521)	(0.0528)
∆Population growth	0.041008	0.152529
	(0.0881)	(0.1051)
∆Patents—USA	−0.00344	−0.00352
	(0.0039)	(0.0075)
Intercept	0.143151***	−0.431
	(0.0120)	(0.5496)
Hausman Test	1.27	
P Value	0.8663	
Observation	168	168

Standard errors are in parentheses. The chosen lag structure is Autoregressive Distributed Lag (1, 1, 1, 1). The models are estimated by using xtpmg routine (Blackburne and Frank 2007) in STATA®. The Hausman Test indicates that the Pooled Mean Group estimator is more consistent and efficient than the Mean Group estimator

**$p \leq 0.05$, ***$p \leq 0.01$

Source Authors' estimations

transforms into patents has a positive influence on economic growth in the long-run. The reason that patents negatively affect economic growth in the short-run is because it takes time for a patent to become profitable. Hence, while patents have a negative effect on economic growth in the short-run because of the huge R&D expenditures, this effect turns out to be positive in the long-run.

Conclusion

Since the 1980s, together with the theoretical developments, technological progress and innovation have been accepted in the economic growth literature as the main drivers of economic growth. In parallel with these developments in the theoretical sphere, empirical analyses that investigate the effect of innovation on economic growth have significantly increased. Although there are many studies analysing the influence of innovation on economic growth in the existing literature, most of these studies do not take into account the quality aspect of innovation and its impact on economic growth. Moreover, the number of studies that examine this issue in the Central and Eastern European countries is low in comparison with the number of studies that focus on Western/high-income countries. This study contributes to the existing literature by investigating the effect of innovation on economic growth in the Central and Eastern European countries. Unlike most of the previous studies, both the quantity and the quality aspects of innovation are taken into account in the empirical analysis.

The results of the empirical analysis indicate that whilst innovation inputs, which are R&D expenditures, do not have any effects on economic growth, innovation outputs, which are patent applications to the EPO and patents granted by the USPTO, have a positive influence on economic growth in the long-run. Although empirical results show that patents negatively affect economic growth in the short-run, this result may stem from the fact that in order for a patent to become profitable a certain period of time is needed, and high R&D expenditures, which are required for new inventions and patents, have a negative effect on economic growth in the short-run.

According to all of these empirical results, we suggest that R&D expenditures that transform into patents should be supported by policy-makers as these expenditures have an increasing effect on economic growth in the Central and Eastern European countries. Hence, innovation incentives that are granted according to firms' patent performance can be beneficial to the level of economic growth and development in the Central and Eastern European countries.

Notes

1. For a review of earlier empirical analyses, see Cameron (1998). For a review of related literature, see Wang (2010).
2. *p* and *q* are the lag of the dependent and independent variables, respectively.
3. It is also important to decide the order of integration of the variables since Mean Group and Pooled Mean Group estimators (Pesaran and Smith 1995; Pesaran et al. 1997, 1999) can be applied as long as the variables are either stationary or integrated in the first order. However, our dataset covers a short period of time (only 22 years) and since it is very unlikely to find series that are integrated in the second or higher order when the time period is short we do not apply a panel unit root test in this analysis.

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