CHAPTER 2

TECHNOLOGICAL INNOVATION CAPACITY AND ECONOMIC GROWTH NEXUS

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Abstract

As suggested by the literature on endogenous growth, technological innovation plays a significant role in economic growth. The goal of this study is to explore the empirical link between technological innovation capacity and economic growth over the period between 2000 and 2016. By utilizing panel-type econometric models, we specifically ask whether a number of indicators such as research and development expenditures, patent applications and high-technology exports as the proxy of innovation play a role in the GDP formation of 20 developed and developing countries. The evidence suggests that total patent applications growth, total labor force growth and gross capital formation growth are statistically significant and positively correlated with economic growth. Our results suggest interesting policy implications for the long-term growth and competitiveness benefits of investing in technological innovation capacities and also some important insights into how investment in human capital may contribute to an increase in economic growth.

Keywords: Innovation, competitiveness, economic growth, endogenous growth theory.

JEL Classifications*:* G32, L10, O31, P20.

1. Introduction

Human history teaches us, however, that economic growth springs from better recipes, not just from more cooking. New recipes produce fewer unpleasant side effects and generate more economic value per unit of raw material.[1]

Paul Romer (2018 Nobel Prize Winner)

Economic growth is defined as an increase in the total output produced in a country, including both goods and services in a period of time. The higher the produced output is, the wealthier the country is. It means more consumption, export, wealth and prosperity. Therefore, determinants of economic growth are important for the maintenance of economic prosperity. Many classical economists have argued that economic growth was determined by a few factors such as labor, agricultural production and exports and generating surplus and its reinvestments are the essential part of classical economic growth theory. Therefore, the success of the economic growth process depends on the reinvestment of this surplus.

Quesnay (1758, 1972) was the first who suggested that agriculture was the only sector capable of generating a surplus. According to Adam Smith, the manufacturing sector and commerce were also capable of producing profits and the returns in agriculture were diminishing. The diminishing returns in agriculture was a key aspect of Malthus' theory (1798) of population. Thus, agriculture was classically accepted as the fundamental sector for growth process. Eltis (2000) stated that according to Quesnay, surplus was the excess of agricultural output over wages and farmers' necessary costs. For Smith (1776, 2010) and Ricardo (1891) it was the excess of output over wages in industry, agriculture and commerce while it was the excess of output over wages in industry and agriculture alone for Marx (1849). Most studies in the field of classical theory of economic growth have focused only on the question of where surplus springs from. The study of the determinants of economic growth was first carried out by Solow (1956) from a different point of view to that of neoclassical growth theory. In Solow's model, output per labor was explained by the number of qualified labor instead of population and capital formation per labor. Moreover, Solow suggested that an unexplained variation in economic growth was dependant on technological innovations. In other words, technological innovation was an exogenous variable in Solow's model.

1 See, https://paulromer.net/economic-growth/ (Romer, (undated). accessed on 08/26/2019).

In the literature on endogenous economic growth theory, the relative importance of technological innovations has been subject to considerable debate. As Romer (undated) states, new technologies generate more economic value per unit of raw material and leads to an increase in economic growth. Knowledge, knowledge spillovers, increase in human capital, increase in research and development expenditures, and patent laws may contribute to development and sustainable economic growth. As mentioned in Pack (1994), endogenous growth theory has the advantage of attempting to explain the forces that give rise to technological change, rather than following the assumption of neoclassical growth theory that says such change is exogenous.

This study focuses on the effects of an increase in technological capacity of a country on its economic growth. In particular, we examine whether a number of indicators such as research and development expenditures, patent applications and high-technology exports as the proxy for innovation play a central role in the GDP formation. We also use renewable energy consumption as an explanatory variable where energy is an essential factor in a typical production process and any improvement in the usage of energy may provide a reduction in production costs. Moreover, increasing demand for energy has severe environmental implications such as climate change. As it is stated by Irandoust (2016), it is widely believed that renewable energy as an almost carbon free energy source can serve as a potential solution to both energy safety and climate change problems. However, from another point of view, an improvement in the efficiency of energy consumption may lead to a kind of paradoxical outcome. As it is emphasized in Clark and Foster (2001), Jevons (1865) claimed that an increase in efficiency in the usage of a natural resource, such as coal, only generates an increased demand for that resource, not a decreased demand as one might expect. This was because improvement in the efficiency of that resource led to further economic expansion. Therefore, we included both renewable energy consumption and CO2 emissions in our model to investigate whether or not the improvements in the efficiency of energy resources as an innovation in energy consumption influence GDP growth in a paradoxical way as Jevons (1865) suggested. Moreover, Jevons' paradox also implies that increased efficiency of a resource leads to an increased demand for that resource and further economic expansion. As a result it also gives rise to an increase in environmental issues in particular climate change depending on the increased demand of energy.

Our analysis contributes to the existing literature by including several variables in the same regression model for both developed and developing countries. The study is organized as follows. We first provide a brief overview of the theoretical background of economic growth and a literature review in Section 2. Section 3 is concerned with the data and methodology used for this study. Section 4 presents the findings of the research. Finally, the conclusion section gives a brief summary and critique of the findings.

2. Theoretical Background and Literature Review

The first serious discussions and analyses of economic growth emerged during the 1950s with Solow (1956). Neoclassical growth theory, as developed by Solow (1956) suggests that net output is produced with the help of two factors of production: capital and labor. Represented by a production function, technological possibilities show constant returns to scale as seen below:

$$Y = F(K,L) \quad (1)$$

According to Solow, an economy with an initially low capital-labor ratio will have a high marginal product of capital (Grossman and Helpman, 1994). As stated in Romer (1994), a simple version of the neoclassical model can be expressed in the Cobb-Douglas production function below:

$$Y = A(t)K^{1-\beta} L^{\beta} \quad (2)$$

where Y denotes net national product, K denotes the stock of capital, L denotes the stock of labor and A denotes the technological capacity in equation (1) and equation (2). In equation (2), β and 1- β denote the elasticities of labor and capital, respectively. In the neoclassical growth model, technological changes are exogenous and cannot be explained by the model.

Under perfect competition in the final goods market and under the assumption of constant returns to scale, β and 1- β should be equal to the shares of capital and labor in national income, respectively, that is 1/3 and 2/3 approximately in the U.S. case. However, Romer (1987) estimated the elasticities to be higher than the value predicted by Solow model (Aghion and Howitt, 1998). After the 1960s, more attention was focused on the effects of technological progress and innovations on economic growth. Several attempts have been made to explain the role of technological development as an endogenous factor on economic growth. "Endogenous growth theory" emerged in the 1980s with a growing body of theoretical and empirical literature (i.e., Arrow, 1962; Romer, 1986, 1987, 1990; Lucas, 1990, 1993). Endogenous growth theory suggested that not only the accumulation of capital, but mainly the development and accumulation of knowledge and technological change leads to increased and sustainable growth (Kokkinou, 2011). Romer (1987, 1990) investigated the role of knowledge and knowledge spillovers on sustainable growth. Based on Romer's model

(1990), an economy with a larger total stock of human capital will experience faster growth. The results also suggest that free international trade can act to speed up growth. Krugman (1991) also found evidence for the impact of knowledge spillovers on the increasing returns and growth rate. Mankiw et al. (1992) found that the rate at which countries converge to their steady states is slower than that predicted by a Solow model with a capital share of 1/3. The empirical results suggest a share of broad capital in output of around 0.7-0.8. The Solow model was augmented to include a role for human capital (H) specified in the following production function (Aghion and Howitt, 1998):

$Y = K^{\alpha} H^{\beta} (AL)^{1-\alpha-\beta}$ (3)

Where Y is output, K is the stock of capital, H is human capital, A is technological capacity and L is labor. As it can be seen from equation (3), it is assumed that returns to scale is constant.

Barro (1991) states that human capital plays a special role in a number of models of endogenous economic growth. As Nelson and Phelps (1966) and Romer (1990) suggested, human capital generates new products and new ideas which underlie technological progress. Long-run growth was explained by focusing on technological progress and R&D in several studies such as Romer (1990), Grossman and Helpman (1991a, 1991b) and Aghion and Howitt (1992) in the endogenous growth literature. In these models, technological progress results from the search for innovation and the discovery of an innovation raises productivity, and such discoveries are ultimately the source of long-term growth (Jones, 1995).

To examine technological change in Britain since 1870, Nicholas (2012) analyzed the effects of patent laws and innovation prizes that were designed to promote technical progress. Although Britain improved productivity growth from the early 1970s, the evidence supports the traditional story of British failure in generating large payoffs from technological development. Petrariu et al. (2013) examined the empirical evidence on the link between innovation and economic growth in Central and Eastern European countries (CEE). The results of their study indicate that innovation makes a significant contribution to national competitiveness and economic growth and the gap between the Western and Eastern economies can be reduced by investing in innovation. Inekwe (2015) examined the role of R&D spending on the economic growth of developing economies. The results reveal that the effect of R&D spending on growth is positive for upper middle-income economies while insignificant in lower income economies. Ciocanel and Pavelescu (2015) tested the links between innovation and competitiveness. The results of the study indicate that improving innovation performance leads to an increase in national competitiveness and economic growth. Pece et al. (2015) analyzed whether the long-term economic growth is influenced by the innovation potential of an economy for CEE countries (Poland, Hungary and Czech Republic). In order to quantify the innovation, they selected various variables such as number of patents, number of trademarks, and R&D expenditure. Their results suggest that there is a positive relationship between economic growth and innovation.

Gumus and Celikay's dynamic panel data model (2015) for 52 countries showed that R&D expenditure has a positive and significant effect on economic growth in the long run, which is consistent with the relevant literature. However, for developing countries, the effect is weak in the short run but strong in the long-run, as expected. A study by Irandoust (2016) examined the relationship between renewable energy consumption, technological innovation, economic growth, and CO2 emissions in the four Nordic countries (Denmark, Finland, Norway and Sweden). A modified version of the Granger non-causality test was employed in the study in order to analyze the causality among the selected variables. The results show a unidirectional causality running from renewable energy to CO2 emissions for Denmark and Finland and a bidirectional causality between these variables for Sweden and Norway. The findings also indicate a unidirectional causality running from technological innovation to renewable energy and from growth to renewable energy for the four Nordic countries. Interestingly, the results could not confirm any causality from renewable energy to economic growth.

Another work on energy consumption and growth nexus was undertaken by Antonakakis et al. (2017). They used the data on energy consumption (and its subcomponents), carbon dioxide emissions and real GDP in 106 countries classified by different income groups over the period from 1971 to 2011. The results of the study reveal that the effects of the various types of energy consumption on economic growth and emissions are heterogeneous on the various groups of countries. They could not report any statistically significant evidence that renewable energy consumption leads to economic growth. This finding implies the fact that renewable energy consumption is not able to promote growth in a more efficient and environmentally sustainable way. Terzic (2017) investigated the role of innovation in developing economies. Findings reveal that the economic growth and competitiveness of developing economies are powerfully connected to their innovation status. Akinwale (2018) analyzed the short- and long-run relationships between energy consumption, technology innovation and economic growth in Saudi Arabia. The study reveals that policy makers are required to form policies that will continue to encourage government investment in R&D that would generate technology innovation so as to reduce the extent of energy consumption.

3. Data and Modelling Strategy

3.1. Data

For the empirical analysis, we used real per capita GDP growth as the dependent variable. Our main independent variables are R&D expenditure as a percentage of the GDP and total patent applications (residents and nonresidents). We also used several control variables which are widely used in the empirical literature such as high-technology exports as a percentage of manufactured exports, labor force, gross capital formation per labor, CO2 emissions (kg per GDP 2010 US$ of GDP), and renewable energy consumption as a percentage of total final energy consumption. We use a panel dataset involving 20 developed and developing countries[2] during the period of 2000-2016. Data for all variables was compiled from the World Development Indicators database[3]. GDP per capita and gross capital formation per labor are expressed in constant 2010 US$ prices. The model was estimated using all variables in their first differences. Table 1 describes the variables.

Table 1: The Variables Used in the Models

Variables	Definition
GDP per capita (constant 2010 US$) (GDP)	GDP per capita is gross domestic product divided by mid-year population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products.
Research and development expenditure (% of GDP) (RDE)	Gross domestic expenditures on research and development (R&D), expressed as a percent of GDP. They include both capital and current expenditures in the four main sectors: business enterprise, government, higher education and private non-profit. R&D covers basic research, applied research, and experimental development.
Total Patent Applications (TPA)	Patent applications are worldwide patent applications filed through the Patent Cooperation Treaty procedure or with a national patent office.
High-technology exports (% of manufactured exports) (HTE)	High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.
Labor force, total (TLF)	Labor force comprises people aged 15 and older who supply labor for the production of goods and services during a specified period. It includes people who are currently employed and people who are unemployed but seeking work as well as first-time job-seekers. Not everyone who works is included, however. Unpaid workers, family workers, and students are often omitted, and some countries do not count members of the armed forces. Labor force size tends to vary during the year as seasonal workers enter and leave.

2 Selected countries are Austria, Belgium, Brazil, Canada, Denmark, Finland, France, Germany, Hong Kong Japan, Netherlands, Norway, Poland, Portugal, Russian Federation, South Africa, Sweden, Turkey, the UK, and the US.

3 Available at: https://databank.worldbank.org/source/world-development-indicators/Type/TABLE/preview/on# (accessed on 07/25/2019).

Gross capital formation (constant 2010 US$) per labor force (GCF)	Gross capital formation consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and "work in progress." According to the 1993 SNA, net acquisitions of valuables are also considered capital formation.
CO2 emissions (kg per 2010 US$ of GDP) (CO2)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.
Renewable energy consumption (% of total final energy consumption)	Renewable energy consumption is the share of renewable energy in total final energy consumption.
Source: World Bank (2019).	

Table 2 provides descriptive statistics for all variables used in this study. There are considerable variations in indicators across countries. For example, GDP per capita ranges from a low of 5937.626 to a high of 91617.28. Moreover, R&D expenditure as a share of GDP ranges from a low of 0.46 to a high of 3.91.

Table 2: Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
GDP	340	37278.29	20011.41	5937.626	91617.28
RDE	332	1.893864	0.899704	0.46493	3.91382
TPA	340	53974.24	124773	146	605571
HTE	339	14.7954	7.385512	1.474043	35.80657
TLF	340	3.05E+07	3.84E+07	2404600	1.63E+08
GCF	340	16498.83	9116.238	2321.949	48155.44
CO2	300	0.354084	0.338906	0.083519	1.637187
REC	320	18.01201	16.18271	0.597432	60.18813

Notes: See Table 1 for the definition of variables. Obs, Std. Dev., Min, Max stand for observation, standard deviation, minimum and maximum, respectively.

Table 3 shows the correlations among the variables. We observed that there is a high correlation between RDE and GDP. A very high correlation is also observed between GCF and GDP. A high correlation between the independent variables may cause a multicollinearity problem in the regressions. Therefore, we chose to use one independent variable at a time and also to use all variables at the same time to see whether their explanatory powers changed due to the multicollinearity issue.

Table 3: Correlation Matrix.								
	GDP	**RDE**	**TPA**	**HTE**	**TLF**	**GCF**	**CO2**	**REC**
GDP	1							
RDE	0.7612	1						
TPA	0.0311	0.2225	1					
HTE	0.6638	0.6347	0.3983	1				
TLF	-0.3982	-0.0779	0.7880	0.0464	1			
GCF	0.9669	0.7105	-0.0309	0.5530	-0.4351	1		
CO2	-0.7476	-0.5299	0.1855	-0.4400	0.4197	-0.7374	1	
REC	0.0481	0.2098	-0.3018	-0.1896	-0.2116	0.0739	-0.2467	1
Notes: See Table 1 for the definition of variables.								

3.2. Modelling Strategy

The goal is to develop an empirical strategy that would enable us to explore the relation between technological innovation capacity and economic growth. The basic regression model that we aim to estimate can be expressed as follows:

$$GDPG_{i,t} = \beta_0 + \beta_1\, RDEG_{i,t} + \beta_2\, TPAG_{i,t} + \beta_3\, HTEG_{i,t} + \beta_4\, TLFG_{i,t} + \beta_5\, GCFG_{i,t}$$
$$+ \beta_6\, CO2G_{i,t} + \beta_7\, RECG_{i,t} + f_i + \epsilon_{i,t} \quad (4)$$

where $GDPG_{i,t}$ represents the real per capita GDP growth for country *i* in period *t*. $RDEG_{i,t}$ represents the logarithmic change in research and development expenditure, $TPAG_{i,t}$ represents the logarithmic change in total patent applications, $HTEG_{i,t}$ represents the logarithmic change in high-technology exports, $TLFG_{i,t}$ represents the logarithmic change in total labor force, $GCFG_{i,t}$ represents the logarithmic change of gross capital formation per labor force, $CO2G_{i,t}$ represents the logarithmic change in the CO2 emissions kg per GDP, and $RECG_{i,t}$ represents the logarithmic change in renewable energy consumption. f_i denotes country fixed effects, and $\epsilon_{i,t}$ is the usual error term. Our main parameters of interest are β_1, β_2 and β_3 which approximately describe the percentage change in economic growth as a response to one percentage increase in innovation measures. Country-fixed effects are included to control for any differences in the calculation of the variables and other unobserved time-invariant differences across countries.

This study uses panel data analysis in order to estimate the model. As Gujarati and Porter (2003) say, "panel data methods are used because they can provide 'more informative data, more variability, less collinearity among variables, more degrees of freedom and more efficiency." In the panel data model, f_i is called a "random effect" when it is treated as a random variable, and a "fixed effect" when it is treated as a parameter to be estimated for each cross section observation (Wooldridge, 2001). The term fixed effect means that one allows for arbitrary correlation between the unobserved effect f_i and the observed explanatory variables. Accordingly, f_i is called an "individual fixed effect." In the regression model, the zero conditional mean assumption - where the mean of the error terms given a specific value of the independent variable is zero is the necessary condition for consistent fixed effects and random effects estimations.

The regressions are estimated with the fixed-effects (FE) model since fixed-effects estimators are considered to be quite efficient in the case of panel data analysis. In order to see if it is safe to use fixed-effects, the analysis also includes the Hausman test indicating that, since the fixed-effects model is consistent when observed explanatory variables and unobserved effects are correlated, but random-effects (RE) model is inconsistent, a statistically significant difference is interpreted as evidence in favor of the fixed-effects model.

4. Empirical Results

In our panel model, we used real per capita GDP growth as the dependent variable in order to analyze the effects of explanatory variables on economic growth. Since our model is designed as a log-dif model, namely in logarithmic growth form, a possible data stationarity problem is eliminated. Therefore, the unit root test results are not reported in order to save space.

Table 4 provides the regression results obtained by using the OLS estimator as a benchmark model. According to the findings of the panel OLS regression, research and development expenditures, total patent applications and high-technology exports do not explain the long-run economic growth (Columns 1-4). As it can be seen from Table 4, total labor force growth and gross capital formation growth are positively and statistically significantly associated with economic growth while renewable energy consumption growth is negatively and statistically significantly associated with economic growth.

Table 4. Panel OLS Results (Dependent variable: GDPG)									
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
RDEG	-0.008 (0.026)							0.015 (0.019)	0.016 (0.019)
TPAG		0.013 (0.012)						0.017* (0.009)	0.016* (0.009)
HTEG			-0.008 (0.012)					0.004 (0.009)	0.004 (0.009)
TLFG				0.217* (0.128)				0.234*** (0.089)	0.257*** (0.091)
GCFG					0.192*** (0.016)			0.199*** (0.016)	0.202*** (0.016)
CO2G						-0.025 (0.022)			-0.020 (0.018)
RECG							-0.035** (0.014)		-0.010 (0.011)
Constant	0.007 (0.006)	0.009*** (0.003)	0.008** (0.003)	0.007* (0.004)	0.010*** (0.002)	0.014*** (0.003)	0.008 (0.005)	0.007** (0.003)	0.012*** (0.003)
Observations	310	320	318	320	320	280	300	308	272
R-squared	0.467	0.470	0.469	0.474	0.709	0.493	0.485	0.730	0.749
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Notes: Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.									

As we stated in Section 3.2, the OLS estimator is biased and inconsistent, though it provides a benchmark estimation for the coefficients, and therefore we focus on the results of the Fixed-Effects estimator, where the results are presented in Table 5. According to the FE test results, total patent applications growth is positively and statistically significantly associated with economic growth (Columns 2, 4 and 5). However, we did not observe any significant relationship between research and development expenditure and economic growth. On the other hand, total labor force growth and gross capital formation growth are positively correlated with economic growth. Other variables are statistically insignificant. The results did not change when we put all variables in the same regressions (Columns 8 and 9), ignoring the multicollinearity problem. Moreover, when we compared the estimated coefficients of the OLS and FE models, we observed that the magnitudes of the variables are smaller in the FE estimations, as expected.

Table 5. Fixed Effects (FE) Results.

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
RDEG	-0.032 (0.025)							0.008 (0.014)	-0.007 (0.017)
TPAG		0.012* (0.006)							0.015* (0.007)
HTEG			-0.011 (0.011)						0.004 (0.007)
TLFG				0.119* (0.065)				0.263** (0.097)	0.231** (0.086)
GCFG					0.176*** (0.018)			0.181*** (0.020)	0.180*** (0.018)
CO2G						-0.017 (0.015)			-0.005 (0.013)
RECG							-0.015 (0.015)		0.008 (0.011)
Constant	0.010** (0.004)	0.009** (0.004)	0.007 (0.004)	0.008* (0.004)	0.010*** (0.003)	0.010** (0.004)	0.010* (0.005)	0.008** (0.003)	0.006** (0.003)
Observations	310	320	318	320	320	280	300	310	272
R-squared	0.558	0.554	0.559	0.553	0.780	0.603	0.570	0.793	0.819
Number of Country	20	20	20	20	20	20	20	20	20
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

The FE results indicate that if gross capital formation increases by 1%, it leads to a 0.17% increase in economic growth. Similarly, if total labor force increases by 1%, economic growth increases by 0.12%. Total patent applications have a positive but a smaller impact on economic growth. If patent applications increase by 1%, it leads to a 0.01% increase in economic growth. However, renewable energy consumption is not related with economic growth and this result supports the findings of Antonakakis et al. (2017). Moreover, renewable energy consumption is also not statistically significant based on the FE results and our finding is consistent with the existing empirical studies such as Irandoust (2016) and Antonakakis et al. (2017). Such results support the neutrality hypothesis which implies that energy is a relatively minor component of real GDP and thus it should have no significant impact on economic growth (Irandoust, 2016). From another point of view, based on Jevon's Paradox (1865), energy-efficiency improvements will increase rather than reduce energy consumption (Sorrell, 2009). An improvement in renewable energy technologies may lead an increase in total energy consumption and this may result in an increase in total expenditure on energy consumption. CO2 (kg per 2010 US$ of GDP) is also found statistically insignificant in both OLS and FE estimations. In all countries, CO2 emissions were declining during the observation period. It may be related with the innovations in renewable energy technologies that help to reduce CO2 emissions. Therefore, CO2 emissions may not be directly related to the GDP growth. High technology exports (% of manufactured exports) are also found statistically insignificant in our estimations. Apart from Belgium, France, Norway and Poland, the proportion of high technology exports in total manufactured exports was declining during the observation period.

Our findings on research and development expenditures are inconsistent with the relevant literature. These results may imply that the output of research and development activities could occur only in the long run and it could be in association with the economic growth in next periods but not today's economic growth. From another point of view, after the 2008 global financial crisis, in most of the countries in our sample, the increase in research and development expenditures was greater than the increase in GDP. This may result in an inverse relationship based on the findings of the model. Pack (1994) argued that the model proposing that R&D has an important effect on growth rates has not generated much confirmation in an economy-wide context (Griliches, 1988). Gross capital formation appears to be the most effective factor to explain economic growth based on the Fixed-Effects results. This result is consistent with both neoclassical growth theory and endogenous growth theory.

5. Concluding Remarks

This study explored the empirical link between technological innovation capacity and economic growth over the period between 2000 and 2016 for the panel of 20 developed and developing countries by utilizing the panel-type econometric models. Based on neoclassical and endogenous economic growth theories, in particular, we ask whether a number of indicators such as research and development expenditures, patent applications, high-technology exports and renewable energy consumption as the proxy of innovation play a role in the GDP formation for Austria, Belgium, Brazil, Canada, Denmark, Finland, France, Germany, Hong Kong, SAR-China, Japan, the Netherlands, Norway, Poland, Portugal, the Russian Federation, South Africa, Sweden, Turkey, the United States and the United Kingdom.

According to the results of the Fixed Effects model, total patent applications growth, total labor force growth and gross capital formation growth are statistically significant and positively correlated with economic growth. However, the findings of the current study do not support the previous research on research and development expenditure and economic growth nexus. On the contrary, our results support the neutrality hypothesis, which implies that energy is a relatively minor component of real GDP and thus it should have no significant impact on economic growth. As a policy suggestion, incentives for innovation and investments in R&D sector may support a sustainable growth in the long run. As innovation has profound effects on economy and it can lead to higher productivity, hence economic growth in the long run, the policymakers, even central banks, should be aware of its developments and research the economic and social preconditions that enable and support innovation.

Although our results did not provide a strong contribution of innovation capacity to economic growth we should keep in mind that the results might differ based on the selection of countries and the length of the time period. Future studies on the current topic are, therefore, recommended. In future investigations, it might be possible to use different proxies for technological innovations and a longer time period in order to test the endogenous growth theory.

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