TIME MBE
technology innovation management & entrepreneurship

The impact of R&D Expenditures and Patents on Economic Growth

Dissertation submitted

by

Georgios Nicolaou

to

TIME MBE

in partial fulfilment of the requirements for the degree of

Master in Business Economics

Supervised by: **Dr. Nikolaos Tsakas**

30 May 2023

Table of Contents

Table of Tables

Table of Figures

1. Introduction

The significance of innovation has escalated in the context of corporate success, technological supremacy, and economic expansion, at both national and regional levels (Buswell, 1987; Malecki, 1991). Innovation, as a crucial factor of production, exerts a significant impact on the process of development and plays a pivotal role in the evolution of nations. Porter (1990) asserts that innovation, irrespective of its association with processes, products, or organizations, plays a crucial role in enhancing a nation's competitiveness. This is primarily demonstrated by the capacity of companies to innovate and enhance their operations. In contemporary times, particularly since the onset of the previous decade, there has been a growing demand to scrutinize and quantify the correlation between innovation and economic advancement in both emerging and established nations.

Since the beginning of the Industrial revolution, the nation has used numerus ways to try and find a way to stay on top. For example, they have already tried to increase their productivity and innovation in businesses in within each nation’s borders respectively, in hopes that they will be able to increase their comparative advantage in relation to neighboring countries. In the last few years, there has been a dramatic increase in the dissemination towards the world economic integration, and because of that there has also been a significant expansion of the economic level of competition. For many years, the idea of national competitiveness stemmed from the study of microeconomic factors (Vahalík and Staníčková, 2014). Recently however, it has been rising to prominence at the macroeconomic level (Vahalík and Staníčková, 2014). According to Porter (1990) the pursuit of international competitiveness is widely recognized as a paramount economic goal for governments across the globe (Krammer, 2017). The impact of various factors on competitiveness has been extensively studied, with innovation being recognized as a significant contributor, particularly through scientific breakthroughs and the development of novel technologies (Freeman, 2002; Krammer, 2017; Hall and Jones, 1999; Rosenberg, 2004; Gibson and Naquin, 2011; Wang et al., 2007; Cameron, 1996).

The importance of technological innovation in today's world economy is undeniable. Innovation indeed stands out as one of the most important parameters for development at the level of the national economy. When comparing national economies, differences in competitiveness and per capita income may be ascribed, at least in part, to variations in the degree to which novel goods, processes, or services have been developed. In other words, the knowledge economy, and the huge mass of information within it has created a new kind of competition at national level. All the countries up till now are competing to gain an advantage since it is very clear that by ensuring a leadership role globally in the new world knowledge economy, they accomplish economic successfulness.

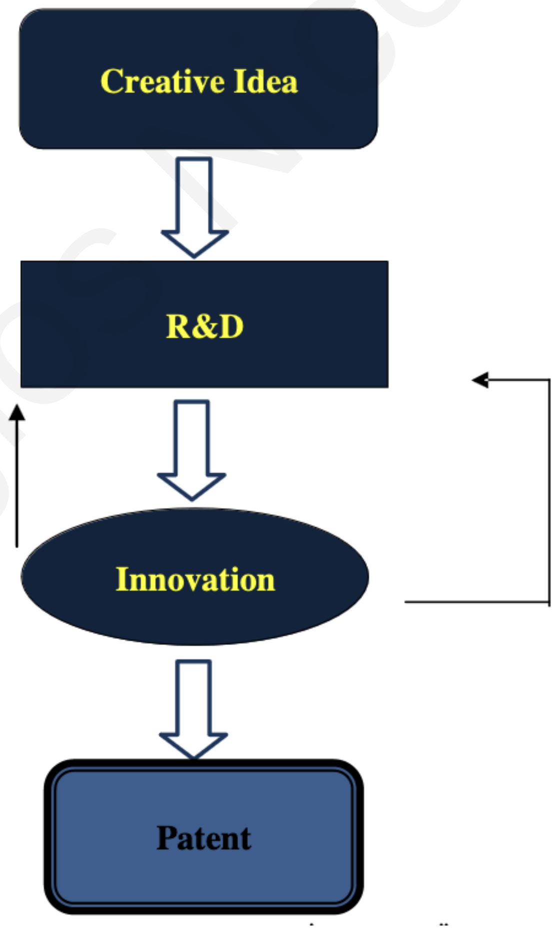
The process of converting novel concepts and knowledge into fresh products and services, commonly known as innovation, is a crucial aspect of fostering economic expansion and advancement. The capacity to generate economic worth through the introduction of novel products to the market, reconfiguration of the production process, and restructuring of organizational practises is of paramount importance to the competitive edge and expansion of firms, industries, and nations (Feldman, 2004; Ramadani and Gerguri, 2011). In contemporary knowledge-driven economies, innovation is widely acknowledged as a crucial factor, and as such, most developed nations accord it a high degree of significance. The variation in national innovation capacity across countries can be attributed to the differences in the allocation of resources towards innovation, as noted by Furman et al. (2002). Consequently, nations are endeavoring to narrow the disparity in innovation and bridge the gap with their more advanced counterparts. The significance of national innovation systems in this particular context has been extensively examined in the international literature by scholars such as Nelson (1993), Freeman (1987), Lundvall (2007) and Patel and Pavitt (1994). Therefore, it is crucial to underscore the significance of innovation in fostering economic growth and prosperity of nations, particularly in the contemporary economic landscape. The significance of economic history has been emphasized since the late 18th century. Contemporary endogenous economic growth models posit that productivity is enhanced by innovation and research and development (R&D) endeavours. These activities are deemed crucial in generating superior products and production processes, and are instrumental in the economic performance of firms, as well as the economic growth and development of nations. In contemporary times, there has been a surge in empirical research endeavours aimed at exploring the correlation between innovation and economic growth in developed and developing nations. This has been achieved through the use of contemporary econometric techniques and indicators. Based on empirical evidence, a robust correlation has been observed between economic growth and innovation in developed nations, with causality typically flowing from the former to the latter. On the contrary, in underdeveloped nations, where research and development resources are limited, the correlation is comparatively weaker.

According to the OECD, research, and development (R&D) refers to a systematic and creative effort aimed at expanding the existing knowledge base, encompassing knowledge pertaining to human beings, culture, and society. The objective of R&D is to utilize this knowledge to develop novel applications. The literature on theoretical and empirical growth recognizes R&D activities as one of the principal factors that determine economic growth. (OECD, 1993, p.29). The literature on endogenous growth theories, initially addressed the significance of research and development (R&D) in the growth process. This perspective approaches growth as a phenomenon that is contingent upon technological advancements and productivity. As per the aforementioned theories, technological advancements are a consequence of endogenous factors and emerge from research and development endeavors that utilize human capital and the pre-existing knowledge base within the economy to generate novel knowledge (Romer, 1986). Grossman and Helpman (1994) posited that the ongoing improvement in the standard of living can be attributed to the technological advancements that have arisen from research and development endeavors and investments. The literature recognizes that the outcomes of research and development endeavors have a favorable impact on economic progress. This is achieved by enhancing the competitive advantage of firms and nations through cost reduction, product quality improvement, and the creation of novel products and production techniques (Rouygari and Kızıltan, 2014, p.33; Üzümcü, 2012, p.237).

The quantification of patents serves as a significant metric for gauging a nation's technological innovation prowess, specifically its ability to generate novel technological advancements. A strong correlation exists between research and development (R&D)

expenditures and patents, which refer to the legal entitlement of an innovator to manufacture, utilize, distribute, or import their proprietary idea or product within a specified timeframe. According to Saygılı (2003), technological innovation is facilitated by research and development activities, while patents serve as the resulting output. This suggests a relationship between R&D and patents in the context of technological innovation. From a certain standpoint, it can be argued that research and development (R&D) endeavors result in a rise in patent numbers by generating novel ideas. In turn, patents can enhance profitability by granting inventors a monopoly and incentivizing further R&D pursuits. According to Zhang (2014), a functional patent system has the potential to increase productivity and expedite economic development through its facilitation of technology creation and dissemination of technical knowledge, promotion of economic expansion, enhancement of national and international competitiveness, and encouragement of research and development initiatives (p. 507-508). The figure 1 below presents the innovation process, which shows how R&D expenditures and Patents are correlated:

Figure 1. The Innovation Process



Source: Kaya, İ. (2009). Ar-Ge ‘den Patente Uzanan Süreçte İstemlerin Önemi, Mühendis ve Makina, Cilt. 50, Sayı.596.

The literature has observed a rise in the number of studies examining the impact of research and development (R&D) activities as a means of inputting technological innovations, and patents as a means of outputting technological innovations, on the growth process of countries. This increase in research can be attributed to the recognition of technological innovations as a key driver of sustainable growth, as posited by endogenous growth theories. Following the discussion above, this paper seeks to investigate the following research question:

- What is the impact of R&D expenditures and patents on economic growth?

The objective of this research is to examine the causality relationship between economic growth and R&D expenditures, as well as patent applications, through a panel data analysis, for 18 countries from 1996 - 2020. Additionally, the objective is to provide empirical support to the existing literature of the study of the impact of innovation on economic growth by incorporating R&D expenses and patents as indicators. Lastly, the objective is to derive to meaningful insights that will help stakeholders and policymakers promote innovation to achieve economic growth.

This research is anticipated to provide a valuable addition to the existing literature due to its unique estimation method, the time frame analyzed, and the range of countries investigated. The present manuscript is arranged in the following manner. The second section presents a comprehensive summary of the latest research findings in the fields of research and development expenditures, patent applications, and economic growth. The third section pertains to the theoretical framework employed in the study, while the fourth chapter delineates the data and methodology utilized in the analysis. The fourth section presents the empirical findings derived from the analysis as also further discussion on the results. The final segment presents the concluding remarks.

2. Literature Review

This chapter provides a comprehensive review of the existing literature pertaining to the influence of research and development expenditures and patents on economic growth. Innovation is a popular growth indicator in empirical studies since it can be easily quantified. To measure innovation, researchers are often use inputs such as research and development (R&D) expenditure (Mansfield, 1972) or innovation outputs, such as patents (Griliches, 1990). The emphasis on innovation and technological advancement has resulted in a significant body of empirical research. The research conducted has indicated that the degree of technological advancement plays a significant role in the economic output, specifically at the microeconomic level.

As it has been observed from the literature, in contemporary times, econometric methodologies have been utilized to analyze time series data. These methodologies include correlation tests, cointegration tests, and causality tests. The major goal of these methods is to examine the connection between time series data at the national or subnational level. Additionally, studies have been conducted to investigate the relationship between time series data for multiple countries based on aggregate cross-sectional data or panel data. The academic debate in the field of literature has predominantly centered on developed nations such as the United States, Japan, South Korea, and European countries, given their substantial investments in research and development. Nonetheless, a body of literature exists that examines the correlation within emerging economies, with a particular focus on nations situated in East and Central Asia.

2.1. R&D Expenditures and Economic Growth

Investments in research and development (R&D) have been proved to be important for economic growth in both theoretical and empirical literatures (Pessoa, 2010). Several theoretical models like Romer's (1990), Grossman's and Helpman's (1991) Aghion's and Howitt's (1992), highlight the significance of R&D as a growth engine and show why the government has to play a role in reaching an optimal amount of R&D. On the empirical front, a number of scholars demonstrate that the relevance of R&D returns should not be ignored (Pessoa, 2010). As a consequence, a number of governments have significantly boosted their policy commitment to innovation, which has had a substantial influence on the levels of R&D spending in their respective nations. These governments are primarily basing their decisions on the impact that technological advancements have on the performance of the economy. Nevertheless, the outcomes of these governments' efforts have been extremely varied (Pessoa, 2010). Yet, this approach runs the danger of increasing R&D intensity above the level that is optimal (Pessoa, 2010). In economic terms, the presence of positive effects justifies public support for R&D investments. Although, there are some other authors like Stokey (1995) and Jones and Williams (2000) who note that R&D has both positive and negative externalities (‘stepping on toes effect’, ‘creative destruction’, ‘fishing out hypothesis’, etc.) which makes the measurement of this correlation uncertain (Pessoa, 2010).

For example, Kadir, Afriana, and Azis (2020) have conducted research that looks at the correlation between R&D and economic development in 33 OECD nations. The findings indicated that internet availability, government research, and gross domestic spending on R&D are the three independent factors that have an impact on economic growth. However, in their study there is a negative correlation between government research and development spending and GDP growth. Sylwestern's (2001) research, which examines the connection between economic development and R&D in OECD nations, is unlikely to discover a link. Another study undertaken for OECD nations with higher income levels examines the link between R&D spending, innovation, and economic development using a panel causality analysis. This study found that all three variables (R&D, economic growth, and innovation) were significantly and positively related to one another (Güloglu and Tekin, 2012).

In a different piece of research, the correlations between research and development (R&D) and economic growth were put through a panel data causality test over the years 1997 to 2008. This particular research looked at 34 nations. It has been discovered via a test of causation that was carried out on a group of thirty-four nations that investments in research and development always bring about growth in their respective economies (Genç and Atasoy, 2010). Another research that is connected to this one analyses the data collected about 15 different OECD nations from the period of 1990 to 2011 and uses a panel data model to investigate whether or not there is a correlation between R&D spending and economic development in those countries. This study demonstrated that R&D spending boost economic development in 7 OECD countries. Yet, it is also claimed that in other 4 OECD countries, a boost in R&D spending has an unforeseen negative impact on economic growth (Özcan, ArÕ, 2014). Although there is a vast amount of research on R&D Expenditures and Economic

Growth, opinions differ. Some scholars argue that there is a correlation between them, and some others argue that there is a negative impact.

The study conducted by Lichtenberg (1993) examined the correlation between R&D expenditures and economic growth in 74 countries across the public and private sectors during the period of 1964 to 1989. The results indicated that while there was no significant association between R&D expenditures and economic growth in the public sector, there was a positive impact on growth in the private sector as a result of R&D expenditures. In their study, Gittleman and Wolff (1995) examined the correlation between research and development (R&D) endeavours and the growth of the economy. The authors utilized panel data spanning from 1960 to 1988, which included metrics such as real gross domestic product (GDP) per capita, R&D spending, and other R&D metrics such as the number of engineers and scientists (Türedi, 2016). The empirical results indicate that research and development (R&D) endeavours were a significant driver of economic growth solely in developed nations, while they did not contribute to growth in underdeveloped nations with low incomes (Türedi, 2016).

Braconier (2000) carried out a study on ten OECD nations using panel data from 1973-1992. The findings indicated that an increase in per capita income was positively associated with a rise in R&D expenditures, with the percentage increase ranging from 1.83% to 2.93%. Yanyun and Mingqian (2004) conducted a dynamic Generalized Method of Moments (GMM) estimation on a sample of eight countries. Among these countries, three were members of the Association of Southeast Asian Nations (ASEAN). The researchers employed the Cobb-Douglas production function in their analysis (Türedi, 2016). The study revealed that the public sector's investment in research and development (R&D) had a more significant impact on the economic growth compared to the R&D investments made by the private sector (Türedi, 2016).

Samimi and Alerasoul (2009) conducted a panel data analysis of thirty developing countries, to examine the impact of R&D expenditures on growth. They argued that R&D expenditures enhance innovation and productivity, thereby promoting growth. However, their findings revealed that the research and development expenditures were found to have no significant impact on the economic growth of developing nations due to their low levels (Türedi, 2016). Altın and Kaya (2009) employed time series analysis to assess the correlation between research and development (R&D) investments and economic growth in Turkey during the timeframe spanning from 1990 to 2005. The study conducted an empirical analysis utilizing the Johansen-Juselius cointegration and error-correction technique. The findings indicated the absence of a short-term association between the aforementioned variables (Türedi, 2016). However, the study established that R&D investments were a significant determinant of economic growth in the long run (Türedi, 2016).

The study by Mehran and Reza (2011) aimed to comparatively analyse the influence of research and development (R&D) expenses on the economic growth of OECD countries and underdeveloped countries. The study was conducted using the fixed effects panel data methodology by the researchers. According to Türedi's (2016) findings, it was determined that research and development expenditures had a positive effect on economic growth in both groups of countries. However, the extent of this effect was found to be more significant in the countries belonging to the Organisation for Economic Cooperation and Development (OECD).

The impact of research and development spending on GDP growth in Sub-Saharan African nations was studied by Gyekye et al. (2012) using the Cobb-Douglas production function. They used fixed-effects panel regression estimate to determine that an increase of 1 percent in R&D spending resulted in 0.326% more GDP growth in the nations studied (Türedi, 2016). In their research, Akıncı and Sevinç (2013) utilized the least squares approach to investigate the impact of R&D expenditures on growth in Turkey between 1990 and 2011. Their findings revealed that R&D expenditures in the private sector, higher education, and overall had a favorable influence on growth (Türedi, 2016). However, R&D expenditures in the public sector did not exhibit a positive effect on growth during the same period (Türedi, 2016).

2.2. Patents and Economic Growth

According to Crosby (2000), in 1966, Schmookler conducted a comprehensive analysis of the value of patents data. He determined that patents data serve as supplementary information on significant inventions and that it is appropriate to view patent statistics as a gauge of the quantity of inventions generated for the private sector across various domains and timeframes (Schmookler, 1966, p. 23). Schmookler's research revealed a significant correlation between patent statistics and the number of R&D expenditure. The aforementioned findings align with the notion that patent data can serve as a valuable indicator of innovation. Devinney's (1994) study examines the patenting behavior across a group of countries and evaluates the correlation between economic growth and patents within this panel (Crosby, 2000). Devinney's analysis examines the correlation between fluctuations in two variables, with a focus on short-term (high frequency) patterns. Specifically, he observes a positive correlation between growth and patents. In contrary to Schmookler's arguments, it has been posited that while long-term relationships may exhibit a positive trend, short-term relationships may demonstrate a negative trend (Crosby, 2000). Josheski and Koteski (2011) conducted an empirical analysis that examines the dynamic connection between GDP growth and patent growth in G7 nations. Long-term analysis using the ARDL model found a favorable correlation between quarterly patent growth and GDP growth (Josheski and Koteski, 2011). Quarterly patents growth and GDP growth have a negative association in the near term with delays of one or two years (Josheski and Koteski, 2011). According to Johansen's cointegration procedure, there exists a positive relationship between the long-term multipliers of GDP and patent growth in G7 economies (Josheski and Koteski, 2011).

The development of the new idea of endogenous economic growth led to the start of research on the link between economic growth and patent protection around the turn of the 20th century (Azevedo, Silva, and Afonso 2012; Romer 1990; 1994). The findings of this research represent a variety of perspectives about the influence of intellectual property rights, including patents, on the innovation processes that drive economic growth (Myszczyszyn, 2020). Researchers highlight, during the course of their investigations of alterations to patent protection laws, that the aim of protection is to encourage both innovation and economic development (Myszczyszyn, 2020). On the other hand, they point out that there is very little evidence that can be considered trustworthy that patents are in fact the instrument that is used to accomplish this objective (Myszczyszyn, 2020). While sanctioned intellectual property rights boost innovation rewards, they may also impede the diffusion of technology and future developments (Nordhaus, 1969; Scherer, 1972; Green and Scotchmer, 1995). Ginarte and Park (1997) examined how patent law affects GDP growth, investment, and R&D spending using the patent right index. A correlation between patent legislation and economic growth was not discovered. In their study of the relationship between the number of patents and the rate of economic growth in the G7 countries (using quarterly data for the years 1963–1993), Josheski and Koteski (2011) found a long-term positive relationship between the number of patents and the rate of economic growth, but a short-term negative one.

Sinha (2008) conducted a study to examine the correlation between economic growth and the number of patents granted in Japan and South Korea using time-series and panel data methodologies. The study posited that innovation was a significant contributor to economic growth (Türedi, 2016). The findings of the time series analysis indicate that a correlation between the two variables was not observed in South Korea. However, a two-way causality relationship between the variables was identified in Japan. The findings from the panel data analysis indicate that the causal relationship previously mentioned is unidirectional, with growth having a significant impact on the number of patents (Türedi, 2016). Ortiz (2009) conducted a regression analysis using cross-sectional data from 23 countries spanning the years 1820 to 1990. The study found a significant and positive correlation between the number of patents per capita and long-term per capita income (Türedi, 2016).

In their research, Kim et al. (2009) investigated the manufacturing industry in South Korea. The study aimed to examine the impact of patent applications on total factor productivity, a crucial determinant of growth (Türedi, 2016). The findings revealed that nonresident patent applications had a greater influence on productivity enhancement than resident patent applications. Saini and Jain (2011) posited that sustainable development is contingent upon economic growth and investigated the impact of patent applications on economic growth across nine Asian nations. The results derived from the regression analysis indicate that patent applications had a statistically insignificant impact on the economic growth of Singapore, Japan, Thailand, and Vietnam (Türedi, 2016). Their impact on economic growth was detrimental in China, Indonesia, and Malaysia, whereas it was beneficial in India and the Philippines (Türedi, 2016). According to Guo and Wang's (2013) research, the Chinese economy experienced a positive impact on growth as a result of patent applications. The empirical analysis conducted during the examined period revealed that a marginal increase of 1% in patent applications was associated with a corresponding increase of 0.26% in economic growth in China (Türedi, 2016). Işık (2014) conducted research in Turkey and found that patent expenditures were a contributing factor to economic growth. The study suggests that a systematic approach to patent expenditures is necessary to achieve sustainable growth.

To summarize, the variables of patents, and R&D expenditures provide an imperfect measure of innovation. The objective of this manuscript is to furnish empirical support regarding the correlation between R&D expenditures and patents with economic growth. The aspiration is that the aggregation of evidence from diverse origins will enhance our comprehension of this association. It is not within my purview to contend that this paper, or any other within this empirical literature, comprehensively encapsulates the correlation between innovation and growth.

3. Theoretical framework

3.1. Endogenous Growth Theories

In the 1980s and 1990s, the theory of economic growth reached a new level, allowing for the discussion of the "new growth theory" (Sharipov, 2015). Most crucially, advancements in science and technology have been seen as an endogenous, or self-generated, growth force (Sharipov, 2015). American economist Paul Romer (1955-present) initially proposed the endogenous nature of the most significant technological advancements as a result of investment (input) in technological progress and human capital in formal economic models (Sharipov, 2015). Apart from superficial similarities, neo-classical growth models and endogenous growth models are quite different (UN, 2011).

Paul Romer's (1990) research kicked off the continuous development of endogenous growth models when he realized that conventional hypothesis failed to account for its predictions with the precise perceptions that, over time, countries seem to have increased growth rates and, within nations, growth rates varied greatly. Unlike other neoclassical economists, Romer argued that a thriving economy is the consequence of internal factors rather than external ones (Tadele, Sirany and Nsiah, 2021). Hypotheses on endogenous growth assume that long-term growth is governed by multiple economic incentives. The most widely accepted models of this kind continue to assume that inventions are intentional and result in technical spillovers that reduce the cost of subsequent breakthroughs (Tadele, Sirany and Nsiah, 2021). To put it simply, these models show how a well-educated labor population may have a decisive impact on the rate of technological progress and the economic trajectory of a country over the long term (Mankiw, 2010; Zhao, 2019). Romer's model is more complicated since it includes three sectors—R&D, intermediate capital products, and final goods—and openly analyses their inner workings, as Zhao (2019) explains. According to Sharipov (2015) paper, endogenous growth theories use the following criteria to describe the importance of intense, high-quality causes of economic development:

- The level of investment in people's growth, and hence the quality of their human capital (health, education).
- Protection of intellectual property in the face of imperfect competition via the establishment of appropriate frameworks and circumstances.
- Government funding for research and innovation in the STEM fields.
- Government's participation in encouraging productive investment and luring cutting-edge innovations.

In contrast to neoclassical ideas, endogenous growth theories support government involvement in the process of development (Sharipov, 2015). Two categories of hypotheses are distinguishable. The first category of theories comprises those that highlight human capital as a key factor in determining economic expansion (Sharipov, 2015).

The method of Romer is predicated on the study of a specialized sector in the creation of knowledge (El Yamani, 2020). This activity in research and development makes use of human capital in addition to pre-existing knowledge in order to produce new information (El Yamani, 2020). Knowledge, in Romer's view, is a production component distinguished by the fact that its use is not competitive. As a result of the positive technology externalities, academic institutions are more likely to openly share their research findings (Romer, 1990).

The second set of ideas emphasizes R&D as a driver of development. Hence, the influence of endogenous high-tech innovations on economic growth rates is described by the hypothesis of J. Grossman (1953-present) and E. Helpman (1946-present) (UN, 2011). These writers have proved that R&D subsidies in a scientifically and technologically advanced nation would boost economic development. Protectionist trade policy may help nations with little R&D flourish, but it hurts those with significant scientific and technological potential (Sharipov, 2015).

This group comprises P. Aghion (1956–present) and P. Howitt's endogenous technological advancement hypothesis (1946 – till now). This theory states that rivalry between enterprises, the creation and implementation of long-term goods, and technological innovation drive economic development (Sharipov, 2015). Each innovation introduces new intermediate items (products, technologies) that may improve product output. The potential for monopoly rents in the event that ideas are successfully patented is the primary factor that encourages businesses to participate in research and development activities (Sharipov, 2015). So, the endogenous movement of experts between the sector of intermediate products production and the R&D sector plays a crucial role in determining the pace of economic development. The link between the mechanics of economic development and the process of acquiring and collecting new information, which is manifested in technical breakthroughs, was thus formalized by endogenous growth theories (Sharipov, 2015). These theories investigate the causes of the disparities in the growth rates of various nations, the efficacy of various measures of the state's industrial, scientific, and technological policies, as well as the effects of trade and integration processes on global economic development.

Following an extended period of economic downturn, the globalization of markets, trade imbalances, and political-economic discussions and policies implemented by various governments (Kennedy, 1987), the significance of macroeconomic, microeconomic, and business conditions and policies in causing variations in economic growth rates among nations is highlighted by Porter (1990), both in modern and historical contexts. According to his perspective, economies at the national level that are dominated by business sectors comprising of minimally innovative firms exhibit slower growth rates as compared to economies dominated by business sectors led by highly innovative firms.

4. Empirical and analytical methodology

4.1. Model specifications

Panel data, also known as longitudinal or cross-sectional time-series data, consist of time-series observations that are aggregated in a cross-sectional format for economic units such as countries and companies. The aforementioned data enables us to conduct longitudinal monitoring of the units, as multiple observations can be made for each unit. The bivariate nature of this approach, encompassing both cross-sectional (I) and time-series (t) dimensions, renders it highly appropriate for the development and evaluation of intricate behavioral models, particularly when contrasted with univariate cross-sectional or time-series analyses. Panel data are extensively utilized in the applied literature Hsiao, 2003, p.1; Baltagi, 2007, p.28-30; Hsiao, 2006, p.3-7). The study utilizes the fixed effect model as a fundamental framework to estimate the causal association between economic growth and R&D expenditures as well as patent applications. The data used in this analysis is derived from a panel of 18 countries. The model is structured in the following manner:

$$GDP_{i,t} = \beta_0 + \beta_1 R\&D_{i,t} + \beta_2 PATENTS_{i,t} + \beta_3 POPULATION_{i,t} + \beta_4 \text{UNEMPLOYMENT}_{i,t} + \beta_5 INFLATION_{i,t} + \beta_6 FDI_{i,t} + a_i + \varepsilon_{i,t}$$

Hypothesis:

H_0: b_1, b_2= 0 (these variables have no statistically significant effect)
H_1: b_1, b_2 ≠ 0 (at least one of the variables has a statistically significant effect on GDP)

If the p-value <0.10, at the 90% level of statistical significance, the null hypothesis is rejected, and the alternative is accepted. In each regression there are elements that provide us with the necessary information about the suitability of the model, the nature, the relationship, and the intensity of the variables. For each independent variable in each regression we will perform, the following data are available: the estimates of the Least Squares method (coefficients), the standard errors of the estimators (standard errors), the number of observations (observations) and the coefficient of determination R2 (R-squared). Standard Error is the standard deviation of the sampling distribution that measures how much the sample mean deviates from the true population value. The coefficient of determination R2 presents the degree of fit of the regression line to our data and takes values in the interval (0,1). As we approach the unit, the better our regression is. For each regression, the estimates of the model parameters are reported, as well as how statistically significant the effect of each X variable (p-value) is.

The value (Constant) is the value at which the least squares line intersects the vertical axis y'y and shows the effect of the independent variable X on the dependent Y (for each increase in X by 1 unit, the estimated mean value of Y will change by b units). The coefficient b (constant) as well as the estimated coefficients of the variables Patents, R&D expenditures, government spending, inflation, population, unemployment and FDI reveal that for each increase in these variables by 1 unit the economic growth (GDP) will change by the specific value of each estimated coefficient, depending on sign of its price each time. The p-value shows whether the relationship between variables X and Y is statistically significant. More specifically, if the p-value is less than 0.01, 0.05 and 0.10, then the relationship is statistically significant for Confidence Interval 99%, 95 % and 90%, respectively then the estimated parameter B can be interpreted. In other words, the closer to 0 the values of the estimated coefficients are, the more reliable our model will be. By rejecting the null hypothesis that the coefficient B of a variable X is equal to 0 (H1≠0), when p-value <0.01 or 0.05 or 0.10 for each significance level of 1%, 5% and 10%, as stated and above, it is concluded that there is at least one independent variable in the model that affects the dependent one and its value interprets it significantly, thus making the model appropriate.

4.2. Data Sample

The methodology involved the creation of a dataset comprising cross-sectional and time-series observations of multiple countries over various time periods, thereby constituting panel data. In detail, data were collected for 18 countries (Austria, Belgium, Canada, Czechia, Finland, France, Germany, Hungary, Japan, Korea, Netherlands, Poland, Slovakia, Spain, Türkiye, USA, Israel, Romania), for the time-period of year 1996 to 2020, annually observed. To answer the research questions of this thesis, secondary data were used. The collection of the data was made from two main databases. The World Bank database and the OECD database, which are both trusted sources for collecting economic data. For our methodology, GDP per capita is the dependent variable while the independent variables are R&D expenditures and patents. To be able to derive to valid results in the analysis, it is important to also include other factors that affect GDP per capita. These other factors should be taken into consideration as the explanatory variables in the analysis, and these are: Population, Unemployment, Inflation and Foreign Direct Investments (FDI). The choice of these factors was made based on the literature on the factors impacting GDP per capita. The data for the explanatory variables were also collected from the two abovementioned databases.

4.3. Empirical Analysis

The initial stage of the empirical analysis involved the declaration of the dataset as panel data after the quantitative analysis. Initially, the panel data set was unbalanced. Consequently, it was deemed necessary to limit the data set to T=24 and N=18, resulting in a significantly balanced data set. This approach enables more precise outcomes and facilitates the conclusions that are made. Regression analysis has been chosen as the method of statistical analysis since the research's emphasis is on the link between R&D spending, patents, and economic development. Additionally, because the data set is a panel data set, time series regressions have been determined to be excluded from the study.

4.3.1. Regression Model

The method that was used for the regression analysis is the Fixed Effects (FE). The Fixed Effect (FE) method is employed in situations where the objective is to examine the impact of time-varying variables. The approach examines the association between the estimator and the reliant variables within a unit, such as a nation, an individual, or an enterprise. Consequently, the estimator is theoretically designated as the "Within effect estimator". Each individual entity exhibits unique characteristics that have the potential to impact the variables of the estimator, although this is not always the case (Wooldridge, 2009).

As Torres-Reyna (2007) suggests, the political system of a nation may exert an impact on its Gross Domestic Product (GDP) or trade, while the business practices of a corporation may influence its stock value. In the context of the FE model, it is assumed that any parameter associated with an entity has the potential to impact the estimator or dependent variable, and therefore requires appropriate control measures. The rationale for positing a correlation between the perturbation term and the variable estimators is as follows: The Fixed Effect (FE) method endeavours to eliminate the influence of all those attributes that remain constant over time, with the ultimate objective of evaluating the actual, net impact of the estimators on the reliant variable. The Fixed Effects approach operates under the premise that the immutable attributes of each unit are solely associated with that particular unit. Consequently, it is imperative to note that every entity is unique, and as such, its disturbance and fixed term, which captures its specific attributes, should not exhibit any correlation with those of other entities. The mathematical expression of the FE model is given by the formula (Wooldridge, 2009):

$$Y_{it} = a_i + \beta \chi'_{it} + \varepsilon_{it}$$

It is observed that the constant term a_i also known as the intercept, exhibits variability across entities, whereas the coefficient of the variable β commonly referred to as the slope, remains consistent.

The STATA software calculates the FE model by removing the time variable from entity transformations. As an initial step, the means of both the independent and dependent variables are computed in order to attain this objective. When combined, these procedures form the FE estimation approach, which ultimately determines the relationship between the rates of change of independent and dependent variables. To sum up, the fixed effects model effectively accounts for all non-varying dissimilarities among entities, resulting in unbiased coefficients in the estimated models. This is due to the exclusion of non-time-varying attributes such as race, culture, and religion.

4.3.2. Descriptive Statistics

To be able to analyze the correlation between R&D expenditures, patents, and economic growth, datasets were created that included data for 18 countries from 1996 – 2020. The following table lists the most significant descriptive statistics of the independent variables used. In Table 1, data such as number of observations, mean, standard deviation, minimum and maximum value etc. are shown. Before analyzing the statistical results in the following table, the most important descriptive statistics of the independent variables used in the study are reported. To begin with, Obs refers to the Sample (number of observations), Mean refers to the mean, Minimum and Maximum refer to the minimum and maximum values that each variable can take, respectively, and Std. Deviation shows the degree of concentration of the values of the variable around the mean.

Table 2. Summary Statistics

Variable	Obs	Mean	Std. dev.	Min	Max
GDPPerCapita	450	27752.35	15558.1	1577.323	65120.39
rdValue	450	50966.95	104703	528.58	671963.3
patentsvalue	450	41414.35	89142.44	155	387364
fdivalue	450	4.01E+10	8.52E+10	-3.30E+11	7.34E+11
unemployment	450	7.892422	4.049388	2.01	26.09
population	450	5.04E+07	6.94E+07	5124573	3.32E+08
inflation	450	4.691115	12.15995	-1.544797	154.7635

5. Results

5.1 Correlation Test Results

The tables below show the correlation between the variables in the model. Through the correlation, the degree of dependence of the independent variables, as well as the nature of the correlation (positive, negative, or zero.) can be seen. The correlation coefficient between the two variables takes values from -1 to 1. A coefficient value in proximity to -1 indicates a robust negative linear correlation, whereas a coefficient value in proximity to 1 indicates a strong positive linear correlation. Finally, if the value of this coefficient is close to 0, the variables have no linear correlation. As it can be seen from the results of the test below, unemployment and inflation have almost negative correlation with all the variables. The most important correlation to look at here is the correlation between patents and R&D expenditures. The value of the correlation between them is 0.74 which is considered to be a moderate positive linear correlation. Even though the two major variables are moderately correlated, they are considered to be in a different stage of the innovation process. Patents are serving as the output, while R&D expenditures are considered as input. This will help the research to explore and understand how R&D efforts are being finalized into tangible assets and hence influence economic growth. Lastly, the results of the regression will be interpreted with caution in order to derive to accurate results.

Table 3. Correlation Test

	GDPPer~a	rdValue	patent~e	fdivalue	unempl~t	popula~n	inflat~n
GDPPerCapita	1.0000						
rdValue	0.4501	1.0000					
patentsvalue	0.3371	0.7490	1.0000				
fdivalue	0.4023	0.5975	0.2964	1.0000			
unemployment	-0.3086	-0.2209	-0.3332	-0.1436	1.0000		
population	0.3319	0.9581	0.7441	0.5613	-0.1546	1.0000	
inflation	-0.3785	-0.1151	-0.1295	-0.0988	0.0045	-0.0380	1.0000

5.2 Fixed Effect Regression Results

The fixed effects model was utilised to execute the regression for our model using the econometric programme STATA. The regression outcomes are presented in a table form below:

Table 3. Fixed Effect regression model

Fixed effects (within)	regression	Number of Obs	=	450
Group variable: Time		Number of groups	=	25
R-squared:		Obs per group:		
Within = 0.3918		min	=	18
Between = 0.7852		avg	=	18
Overall = 0.4298		max	=	18
		F (6,24)	=	125.34
corr (u_i, Xb) = 0.2240		Prob > F	=	0

GDPPerCapita	Coefficient	std. err.	t	P>t	[95% conf.	interval]
rdValue	0.1355612	0.012582	10.77	0.00	0.1095933	0.1615291
patentsvalue	0.0111439	0.006309	1.77	0.09	-0.0018772	0.0241649
fdivalue	3.57E-08	8.35E-09	4.27	0.00	1.84E-08	5.29E-08
unemployment	-508.943	72.30371	-7.04	0.00	-658.1705	-359.7154
population	-0.0001647	0.0000191	-8.63	0.00	-0.0002041	-0.0001253
inflation	-264.2168	64.86763	-4.07	0.00	-398.097	-130.3366
_cons	32515.75	879.0096	36.99	0.00	30701.56	34329.94
sigma_u	4738.5704					
sigma_e	11220.728					
rho	0.15134964	(Fraction of variance due to u_i)				

The regression reports the results for the relationship between GDP, R&D expenditures, and patents. The dependent variable, GDP, was regressed on the independent variables, R&D expenditures, and patents, to determine the extent to which R&D expenditures and patents affect GDP. It is important to acknowledge that the probability of F is below the 5% threshold, rendering the null hypothesis unacceptable. Consequently, our independent variables collectively exhibit statistical significance in elucidating our model. Based on the obtained p-values, it can be inferred that all variables, with the exception of the variable "patents", show statistical significance at the 1% and 5% levels of significance. At the 10% significance level, all variables including the patents variable are statistically significant. More specifically, R&D expenditures ($\beta = 0.1355612$, $p < 0.10$) and patents ($\beta = 0.0111439$, $p < 0.10$) are statistically significant ($\beta = 0.1355612$, $p < 0.10$), indicating that one unit increase in R&D expenditures is associated with a 0.1355612 increase in GDP, and one unit increase in patents is associated with a 0.0111439 increase in GDP. It is also important to mention that a robust standard error test was performed so that to use the more accurate robust statistical results regarding the significance of the variables.

6. Conclusion

This paper studies the impact of R&D expenditures and patents on economic growth using panel data consisting of 18 countries from 1996 - 2020. The contribution of R&D expenditures and patents, as an activity for the development of the economy, expresses the effort of each country to gain a competitive advantage in the world economy. This research examines the relationship between economic growth and the following variables: R&D expenditures, patents, population, unemployment, inflation, and FDI covering the period 1996-2020. To derive to results, data were collected to run a regression analysis using the Fixed Effects (FE) method analysis. The sources from where the data were collected for both the dependent and the independent variables are the World Bank and the OECD databases.

The results of the analysis in this study, showed that R&D expenditures are statistically significant and affect the GDP growth of the economies of the selected countries, while patents are only statistically significant at the level of 10%. Regarding the explanatory variables: population, inflation, unemployment, and FDI, all of them have an impact on economic growth. The results of the analysis are consistent with the endogenous growth theory. The findings of the current investigation provide corroboration for the postulation of endogenous growth theories, which posit that economic growth is positively influenced by R&D expenditures and in some cases, it is also influenced by patents, through the era of technological advancements and subsequent enhancement of productivity. In light of the fact that innovation is the primary catalyst for economic advancement, nations aspiring to achieve a substantial and enduring economic expansion ought to devote greater resources towards research and development endeavours, while simultaneously instituting a robust patent framework that facilitates the dissemination of innovative ideas throughout the economy and fosters further research and development initiatives.

The implication of this research is to help stakeholders and policymakers. More specifically, policymakers could create environments that encourages entrepreneurship and innovation such as promote the cooperation between industry and academia or provide access to funding opportunities. Also, they could take measures to protect innovations and encourage businesses to make investments in the R&D. Additionally they could invest in education in order to build skilled workforce and lastly, they could promote international cooperation through bilateral agreements and initiatives that are focused on innovation internationally.

Bibliography

Abdulkadir, A., Afriana, W., & Azis, H. (2020). THE EFFECTS OF R&D EXPENDITURES ON ECONOMIC GROWTH IN OECD COUNTRIES. Airlangga Journal of Innovation Management, 1(2), 175–183. https://doi.org/10.20473/ajim.v1i2.21607

Aghion, P., Howitt, P., (1992) A model of growth through creative destruction. Econometrica 60 (2), 323–351.

Akıncı, M., Sevinç, H. (2013). Ar-Ge Harcamaları ile Ekonomik Büyüme Arasındaki İlişki: 1990 – 2011 Türkiye Örneği. Uluslararası Sosyal Araştırmalar Dergisi, 6 (27), 7-17.

Akcay, S. (2011), "Causality Relationship Between Total R&D Investment and Economic Growth: Evidence from United States", Journal of Faculty of Economics and Administrative Sciences, 16 (1), pp. 79-92.

Altın, O., Kaya, A. (2009). Türkiye'de Ar-Ge Harcamaları ve Ekonomik Büyüme Arasındaki Nedensel İlişkinin Analizi. Ege Akademik Bakış, 9 (1), 251- 259.

An, M. H., Ri, G. Y., & Rim, G. N. (2020). Intellectual product and method of assessing the competitiveness of an enterprise with It. Journal of the Knowledge Economy, 11, 1059–1085. https://doi.org/10.1007/s13132-019-00593-5

Archibugi, D. (1992), "Patenting as an indicator of technological innovation: a review", Science and Public Policy, 19 (6), pp. 357-368.

Azevedo, M.L., Silva, S.T., Afonso, O. (2012) Intellectual Property Rights and Endogenous Economic Growth – Uncovering the Main Gaps in the Research Agenda, Technological Change. Aurora A.C. Teixeira, IntechOpen, DOI: 10.5772/37768. https://www.intechopen.com/books/technological-change/-intellectual-propertyrights-technological-change-and-economic-growth-uncovering-the-main-gaps-in-t

Basberg, B.L. (1987), "Patents and the measurement of technological change: a survey of the literature", Research Policy, 16, pp. 131-141
Braconier, H. (2000). Do Higher Per Capita Incomes Lead to More R&D Expenditure?, Review of Development Economics, 4 (3), 244–257.

Buswell, R.J. (1987), "Research and development and regional development: a review", In A Gillespie (ed.), Technological Change and Regional Development, Pion, London

Cameron, G., (1996) Innovation and Economic Growth. Centre for Economic Performance, London School of Economics and Political Science.

Cetin, M. (2013), "The hypothesis of innovation-based economic growth: a causal relationship", International Journal of Economic and Administrative Studies, 6 (11), pp. 1–16.

Crosby, M. (2000), Patents, Innovation and Growth. Economic Record, 76: 255-262. https://doi.org/10.1111/j.1475-4932.2000.tb00021.x

Cuaresma, J.C. and Wörz, J., (2005) On export composition and growth. Review of World Economics, 141(1), pp. 33-49.

Devinney, T. (1994). 'Characterising International Patent Behaviour', Working Paper 94-024, Australian Graduate School of Management

Eaton, J. and Kortum, S., (1999) International technology diffusion: Theory and measurement. International Economic Review, 40(3), pp. 537–70

EL YAMANI K. (2020) «Economic Growth Theories: A Literature Review», Revue Internationale des Sciences de Gestion «Volume 3: Numéro 4» pp: 279 – 289

Ersin, Ö., Ustabas, A. and Acar, T. (2022) THE NONLINEAR EFFECTS OF HIGH TECHNOLOGY EXPORTS, R&D AND PATENTS ON ECONOMIC GROWTH: A PANEL THRESHOLD APPROACH TO 35 OECD COUNTRIES. Romanian Journal of Economic Forecasting. Available at: https://ipe.ro/rjef/rjef1_2022/rjef1_2022p26-44.pdf (Accessed: April 26, 2023).

Esubalew Tadele & Teshome Sirany | Christian Nsiah (Reviewing editor) (2021) The relative choice over destiny in a country's long-run economic growth and economic affluence, Cogent Economics & Finance, 9:1, DOI: 10.1080/23322039.2021.1949133

Fagerberg, Jan. and Verspagen, Bart., (2020) Technological revolutions, structural change & catching up. MERIT Working Papers 2020-012, United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology (MERIT).

Fagerberg, J., (1994) Technology and international differences in growth rates. Journal of economic Literature, 32(3), pp.1147-1175.

Feldman, M. (2004), "The Significance of Innovation", Rotman School of Management University of Toronto: Toronto

Frankel, J.A. and Romer, D.A., (1999) Does trade cause growth? American Economic Review, 89(3), pp.379-399.

Freeman, C. (1987), "Technology, Policy and Economic Performance: Lessons from Japan", Pinter, London

Freeman, C., (2002) Continental, national and sub-national innovation systems– complementarity and economic growth. Res. Policy 31 (2), 191–211.

Furman, J. L., Porter, M. E., and Stem, S. (2002), "The determinants of national innovative capacity", Research Policy, 31 (6), pp. 899-933.

Gibson, D.V., Naquin, H., (2011) Investing in innovation to enable global competitiveness: the case of Portugal. Technol. Forecast. Soc. Chang. 78, 1299–1309.

Ginarte, J.C. Park, W.G. (1997) Determinants of patent rights: a cross-national study. Research Policy, 26, 283-301.

Green, J.R., Scotchmer, S. (1995) On the division of profit in sequential innovation. Rand Journal of Economics, 26, 20-33.

Grossman, G., Helpman, E., (1991) Innovation and Growth in the Global Economy. MIT Press, Cambridge, MA.

Güloglu, B. & Tekin, R. B. (2012). A Panel Causality Analysis of the Relationship Among Research and Development, Innovation and Economich Growth in High-Income OECD Countries, Eurasian Economic Review, 2(1), 32-47.

Genç, M. C. & Atasoy, Y. (2010). Ar&Ge HarcamalarÕ ve Ekonomik Büyüme øliúkisi: Panel Veri Analizi, The Journal of Knowledge Economy & Knowledge Management, 5, 27-34.

Griliches, Z., (1990) Patent statistics as economic indicators. Journal of Economic Literature 28, 1661–1707.

Gyekye, A. B., Oseifuah, E. K., Quarshie, V. (2012). The Impact of Research and Development on Socio-Economic Development: Perspectives from Selected Developing Economies. Journal of Emerging Trends in Economics and Management Sciences, 3 (6), 915-922.

Gittleman, M., Wolff, E. N. (1995). R&D Activity and Cross-Country Growth Comparisons. Cambridge Journal of Economics, 19, 189-207.

Guloglu, B. and Tekin, B. (2012), "A panel causality analysis of the relationship among research and development, innovation, and economic growth in high-income OECD countries", Eurasian Economic Review, 2 (1), pp. 32-47.

Gumus, E. and Celikay, F. (2015), "R&D Expenditure and Economic Growth: New Empirical Evidence", The Journal of Applied Economic Research, 9 (3), pp. 205–217.

Guzman, C.A., Lopez-Herrera, F. and Venegas-Martinez, F. (2012), "A Cointegration Analysis between Patents and Economic Growth in Mexico, 1980-2008", Investigación económica, 71, pp. 83-115.

Guo, Y. and Wang, B. (2013), "Study on the Economic Growth of Patent Output in the High-tech Industry", Journal of Management and Sustainability, 3 (1), pp. 103-107.

Guo, Y., Wang, B. (2013). Study on the Economic Growth of Patent Output in the High-tech Industry. Journal of Management and Sustainability, 3 (1), 103-107.

Hassan, I. and Tucci, C. L. (2010), “The innovation-economic growth nexus: global evidence”, Research Policy, 39 (10), pp. 1264–1276.

Hall, R.E., Jones, C.I., (1999) Why do some countries produce so much more output per worker than others? Q. J. Econ. 114 (1), 83–116.

Ioan, P.O.P.A. and Mihaela, B.E.L.U. (2009) Growth poles and national competitivness, CORE. Available at: https://core.ac.uk/display/6346792?utm_source=pdf&utm_medium=banner&utm_campaign=pdf-decoration-v1 (Accessed: April 26, 2023).

Işık, C. (2014). Patent Harcamaları ve İktisadi Büyüme Arasındaki İlişki. Sosyo Ekonomi, 1, 69-86.

Jones, C.I., Williams, J.C., (2000) Too much of a good thing? The economics of investment in R&D. Journal of Economic Growth 5, 65–85.

Josheski, D., Koteski, C. (2011) The causal relationship between patent growth and growth of GDP with quarterly data in the G7 countries: cointegration, ARDL and error correction models. MPRA, Paper No. 33153.

Krammer, S.M.S. (2017) Science, technology, and Innovation for Economic Competitiveness: The role of smart specialization in less-developed countries, Technological Forecasting and Social Change. North-Holland. Available at: https://www.sciencedirect.com/science/article/pii/S0040162517308582#bi0005 (Accessed: April 26, 2023).

Kaya, İ.(2009). Ar-Ge ‘den Patente Uzanan Süreçte İstemlerin Önemi, Mühendis ve Makina, Cilt. 50, Sayı.596.

Kim, T., Maskus, E., Oh, Y. (2009). Effects of Patents on Productivity Growth in Korean Manufacturing: A Panel Data Analysis. Pacific Economic Review, 14 (2), 137-154.

Kennedy, P., (1987) The Rise and Fall of the Great Powers: Economic Change and Military Conflict from 1500 to 2000. Random House, New York.

Lee, J., (2011) Export specialization and economic growth around the world. Economic Systems, 35(1), pp. 45-63.

Lawrence, R. Z. (2002). Competitiveness. In D. R. Henderson (Ed.), Concise Encyclopedia of Economics (1st ed.). Library of Economics and Liberty. OCLC 317650570, 50016270, 163149563.

Lichtenberg, F. (1993). R&D Investment and International Productivity Differences. NBER Working Paper Series, No: 61.

Lundvall, B. Å. (2007), "National Innovation Systems: analytical concept and development tool", Industry & Innovation, 14 (1), pp. 95-119.

Mankiw, N. G. (2010). Macroeconomics, (7th Int. ed.)

Mansfield, E., (1972) 'Contribution of Research and Development to Economic Growth of the United States', Papers and Proceedings of a Colloquim on Research and Development and Economic Growth Productivity, National Science Foundation, Washington, DC.

Mehran, M., Reza, M. (2011). A Comparative Investigation of the Relation of R&D Expenditures to Economic Growth in a Group of the Less Developed Countries and OECD Countries. Journal of Social and Development Sciences, 2 (4), 188-195.

Malecki, E. J. (1991), "Technology and economic development: the dynamics of local, regional, and national change", Longman Scientific & Technical, New York.

Myszczyszyn J., (2020) The Long-run Relationships between Number of Patents and Economic Growth. European Research Studies Journal Volume XXIII, Issue 3, pp. 548-563.

Markatou, M. (2014), "Patents as Indicators of Technological Innovation in Greece: Analysis for a Period of 25 Years", World Review of Business Research, 4 (2), pp. 255-263.

Mankiw, N.G., D. Romer, and D.N. Weil., (1992) A contribution to the empirics of economic growth. Quarterly Journal of Economics, CVII, pp. 407-437

Nelson, R. R. (1993), "National Innovation Systems: A Comparative Analysis", Oxford University Press.

Nordhaus, W.D. (1969) Invention, Growth and Welfare: A Theoretical Treatment of Technological Change. MIT Press, Cambridge, MA.

Özcan, B. & ArÕ, A. (2014). AraútÕrma-Geliútirme HarcamalarÕ ve Ekonomik Büyüme øliúkisi: Panel Veri Analizi, Maliye Dergisi, 166, 39-55.

OECD (2023), Gross domestic spending on R&D (indicator). doi: 10.1787/d8b068b4-en (Accessed on 12 May 2023)

Ortiz, J. M. (2009). Patents and Economic Growth in the Long Term: A Quantitative Approach. Brussels Economic Review, 52, 305-340.

Pradhan, R. P., Arvin, M. B., Hall, J. H., and Nair, M. (2016), “Innovation, financial development and economic growth in eurozone countries”, Applied Economics Letters, 23 (16), pp. 1141–1144

Patel, P. and Pavitt, K. (1994), “National Innovation Systems: Why They Are Important, and How They Might Be Measured and Compared”, Economics of Innovation and New Technology, 3, pp. 77-95.

Pessoa, A. (2010). R&D and economic growth: How strong is the link? Economics letters, 107(2), 152-154.

Porter, M.E., (1990) The Competitive Advantage of Nations. Macmillan, London.

Ramadani V. and Gerguri S. (2011), “Innovation: Principles and Strategies”, Advances in Management, 4(7), pp. 7-12.

Romer, P. (1989a), Endogenous technological change, National Bureau of Economic Research, Cambridge, MA.

Romer, P. (1989b), "Human Capital and Growth: Theory and Evidence," NBER Working Papers 3173, National Bureau of Economic Research, Inc.

Romer, P. (1990). Endogenous Technological Change, Journal of Political Economy, vol 95, pp. 71-102.

Rosenberg, N., (2004) Innovation and economic growth. Innov. Econ. Growth.

Romer, P.M. (1994) The origins of endogenous growth. Journal of Economic Perspectives, 8(1), 3-22.

Samimi, A. J., Alerasoul, M. S. (2009). R&D and Economic Growth: New Evidence from Some Developing Countries. Australian Journal of Basic and Applied Sciences, 3 (4), 3464-3469.

Sinha, D. (2008). Patents, Innovations and Economic Growth in Japan and South Korea: Evidence from Individual Country and Panel Data. Applied Econometrics and International Development, 8 (1), 181-188.

Saini, A. K., Jain, S. (2011). The Impact of Patent Applications Filed on Sustainable Development of Selected Asian Countries. International Journal of Information Technology, 3 (2), 358-364.

Schmookler, J. (1966). Invention and Economic Growth. Harvard, Massachusetts.

Solow, R. (1956), “A Contribution to the Theory of Economic Growth”, The Quarterly Journal of Economics, Vol. 70 No. 1, pp. 65-94.

Solow, R. (1957), “Technical Change and the Aggregate Production Function”, The Review of Economics and Statistics, Vol. 39 No. 3, pp. 312-320.

Sylwester, K. (2001). R&D and Economic Growth, Knowledge, Technology and Policy, 13(4), 71-84.

Svetlana Sokolov-Mladenović, Slobodan Cvetanović & Igor Mladenović (2016) R&D expenditure and economic growth: EU28 evidence for the period 2002–2012, Economic Research-Ekonomska Istraživanja, 29:1, 1005-1020, DOI: 10.1080/1331677X.2016.1211948

Scherer, F.M. (1972) Nordhaus’ theory of optimal patent life: a geometric reinterpretation. American Economic Review, 62, 422-427.

Stokey, N.L., (1995) R&D and economic growth. Review of Economic Studies 62, 469–489.
4 See Mehra and Prescott (1985).

TORRES-REYNA, Oscar. (2007) Panel Data Analysis Fixed and Random Effects using Stata. Princeton: Princeton University.

Türedi, A. P. D. S. (2016). The Relationship between R&D Expenditures, Patent Applications and Growth: A Dynamic Panel Causality Analysis for OECD Countries. Anadolu Üniversitesi Sosyal Bilimler Dergisi, 16 (1), 39-48. Retrieved from https://dergipark.org.tr/en/pub/ausbd/issue/26453/278539.

Ulku, H. (2004), “R&D, innovation, and economic growth: an empirical analysis”, International Monetary Fund Working Papers, 4 (185), pp. 2-35.

UN (2011), Tashkent: UWED, UNDP, 2nd ed., available at: http://www.undp.uz/en/publications /publication.php?id=317 Accessed: 04/04/2023

Ustabaş, A. and Ersin, Ö., (2016) The effect of R&D and high technology export and economic growth: A comparative cointegration analysis for Turkey and South Korea. International Conference on Eurasian Economies, pp. 44-55.

Vahalík, B. and Staníčková, M. (2014) Comparison of regional competitiveness index after EU enlargement in 2013, Digitální knihovna UPCE. Univerzita Pardubice. Available at: https://dk.upce.cz/handle/10195/58655 (Accessed: April 26, 2023).

Wang, T.Y., Shih-Chien, C., Kao, C., (2007) The role of technology development in national competitiveness - evidence from Southeast Asian countries. Technol. Forecast. Soc. Chang. 74, 1357–1373.

Wooldridge, J.M. (2009) Introductory econometrics: A modern approach. Mason: South Western college publishing.

World Economic Forum. (2019), The global competitiveness report 2017–2018. Retrieved May 09, 2023.

Yanyun, Z., Mingqian, Z. (2004). R& D and Economic Growth: Panel Data Analysis in ASEAN+3 Countries" A Joint Conference of AKES, RCIE and KDI: Korea and the World Economy, III, July 3-4, Sungkyunkwan.

Yu-Ming, W., Li, Z. and Jianxia, L. (2007), "Cointegration and Causality between R&D Expenditure and Economic Growth in China: 1953-2004", International Conference on Public Administration, http://web.cenet.org.cn/upfile/113225.pdf.

Zhao, F., & Feng, X. (2007). Comparative analysis on the international competitiveness of trade in services between China and the US: Structural imbalance of China's trade in services. Journal of World Economic Research, (9).

Zhao, R. (2019) Technology and economic growth: From Robert Solow to Paul Romer. Department of Economics, University at Albany, Albany, New York. Available at: https://onlinelibrary.wiley.com/doi/full/10.1002/hbe2.116 (Accessed: April 27, 2023).