Technological Innovation and Economic Growth

Subjects: Economics

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Economic growth is a tool for measuring the development and progress of countries, and technological innovation is one of the factors affecting economic growth and contributes to the development and modernization of production methods. Therefore, technological innovation is the main driver for economic growth and human progress. Spending on innovation, research and development as well as investment in innovation supports competition and progress. Accordingly, sustainable economic growth is achieved. This ensures the preservation of resources for future generations and the achievement of economic and social growth. Moreover, a sustainable educational level of the workforce, investment in research, creation of new products, and investor access to stock markets will be ensured through the development of the public and private sectors and the improvement of people's living conditions.

Keywords: causality relationship ; Granger causality test ; technological innovation ; economic growth ; panel models ; research and development ; education ; developing countries

1. Introduction

Is it possible to achieve economic growth in the long run? If so, what is the decisive factor for the long-term growth rate? Which economies will grow faster? What kinds of approaches should decision makers use to encourage decent living conditions? These issues were central to many who wanted growth in the 1950s and 1960s, and they have continued to revive recent interest in long-term economic performance [1]. Furthermore, with the beginning of the twentieth century, as the importance of the knowledge-based economy increased, fundamental changes and new concepts emerged. Hence, the strength of any economy is based on the extent of its technological progress, as the world is today witnessing rapid developments with the emergence of successive new technologies; the latter playing an important role in developing societies and achieving their prosperity [2][3].

Economic growth is the continuous increase in real income in the long term, and increases in income are considered economic growth. Economic development is a structural and radical change in most of the structures of the national economy, unlike growth, which focuses only on the change in the volume of goods and services obtained by the individual represented by an increase in his average income.

Hence, economic growth is an increase in the economy's ability to produce goods and services during a specified period. It refers to the long-term expansion in the productive potential of the economy to meet the needs of individuals in society. The sustainable economic growth of the country has a positive impact on the national income and the level of employment, which leads to more standards of living. There are many factors that affect economic growth: (1) The amount of physical capital: the availability of more auxiliary tools in production processes leads to more output of goods and services, and accordingly, the output of the individual, in terms of the accumulation of capital, becomes noticeable, to the extent that it was considered at one time, that physical capital is generally the only source of economic growth. For investment opportunities that were not presented before, it is possible for this society to achieve an increase in its production capacity by increasing its balance of real capital. It must reveal, sooner or later, the decrease in the return on capital according to the decrease in its marginal productivity with every increase in the quantity used in the production process. Along this line, one of the most prominent examples of this is the impact of physical capital on the economic growth of the United States. During the current century, that is, despite the significant amounts of marginal capital used in that stage of development in the American economy, the ratio of output to capital has remained proportional to the declining trend and did not deteriorate. Extremely important is that investment opportunities have expanded at the same speed as investment in capital goods. (2) Human resources are one of the most important factors leading to increased economic growth; the quantity and quality of human resources contribute directly to the economy. The quality of human resources depends on a set of characteristics, the most important of which is their ability to innovate and provide education, training, and skills. In the event of a shortage of skilled human resources, this will hinder economic growth. (3) Natural resources are among the factors affecting the economic growth of a country. Natural resources are significant and

include all the natural resources that appear on the surface of the earth or within it, such as plants on land, and water resources. Natural resources within the earth include gas, oil, and minerals. Natural resources differ between countries based on their environmental and climatic conditions. (4) Social and political factors are the factors that aim to play an important role in the economic growth of countries. Traditions, customs, and beliefs constitute social factors, while government participation in policy development and implementation constitutes political factors. (5) Technological development is one of the important and influencing factors in economic growth, and includes the application of a set of productive techniques and scientific methods, and technology is defined as the nature and quality of technical tools, dependent on the use of a certain percentage of the workforce. Technology is defined as "a set of knowledge, experiences, and practices." Technology and the interrelationships between the sub-systems of work, its application, and adoption contributes to satisfying actual or expected economic and social needs [4][5].

In the same context, (6) innovation is one of the factors that affects economic growth; innovation can be defined as "the activity that produces new or significantly improved goods (products or services), processes, marketing methods, or business organizations [6]. This definition focuses on forms of innovation. It may be embodied either in a new or improved product, and it can also be defined as "the successful commercial exploitation of new ideas" and includes all scientific, technological, organizational, and financial activities that lead to the provision of everything new (or improvement) of a product or service [7][8]. Innovation also refers to "the successful exploitation of new ideas" [9]. According to (Sarvan, Atalay, 2013), innovation can be embodied in the following manifestations: creating new products or qualitative improvements in existing products; —carrying out a new industrial process; opening a new market; developing new sources of raw materials or other new inputs; and new forms of industrial organizations [10].

There are several types of innovation, which are usually classified according to the following criteria. Classification of innovation according to the output criterion includes two types: product innovation and process innovation. Innovation is also classified according to market perception criterion, and this classification includes two basic types: continuous innovation and intermittent or discontinuous innovation. Another way innovation is classified is according to the criterion of the size of change (according to degree). According to this criterion, innovation is divided into two types: radical innovation and improvement innovation (gradual—partial). Alternatively, a production method involves the process of achieving and embodying innovation in a tangible form.

Finally, classification of innovation is according to the criteria of specialization into managerial innovation, marketing innovation, and technological innovation." According to Garcia (2014), "Technological innovation is a set of technical, industrial and commercial stages that lead to the launch of manufactured and commercial products and the use of new technical processes [11]." **Figure 1** shows the types of technological innovation.

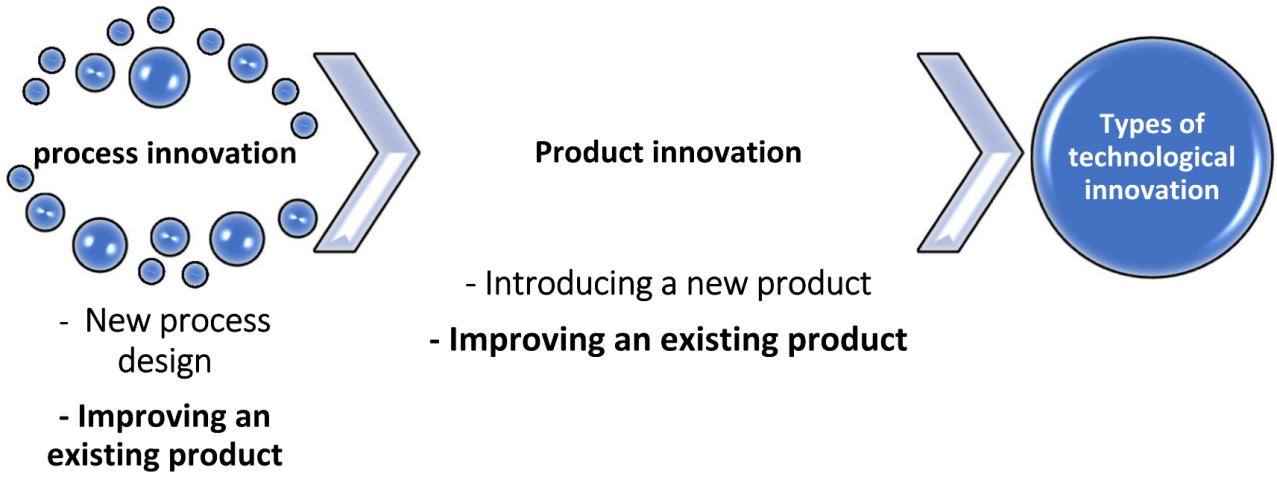

Figure 1. Types of technological innovation. Source: Prepared by the authors based on previous studies.

Figure 1 clearly shows that technological innovation consists of two types: product innovation, which is either introducing a new product or improving an existing product, and process innovation as the second type, which consists of designing a new process or improving an existing process. The innovative process, where countries today depend on the use of modern technology to remove many of the barriers that make the country more open and developed in terms of speed in completion of work and keeping pace with the times, by focusing on the research and development function in a way that allows it to keep pace with these developments and challenges as well as adapt to them. Countries cannot maintain their level of performance, regardless of their capabilities or capabilities, if they rely on traditional methods in the era of the technological revolution. As such, countries must rely on technological innovation, which is one of the most important pillars for the development of countries where they can reach the required level of performance efficiently and effectively.

Therefore, the pursuit of technological innovation is one of the main driving factors that make developing countries more advanced and ambitious. Sustainable development is a new concept that has emerged on the ground, is concerned with preserving resources for future generations and achieving economic and social growth. Moreover, it is also concerned with preserving the environment. In addition, long-term sustainable economic development is one of the most important goals for each country. Thus, the state can achieve this goal by increasing its production. There are two ways to increase GDP: (1) by increasing the production components that researchers use in the manufacturing process and (2) by raising the efficiency of the inputs. This could be by improving productivity by producing innovative goods or by introducing new manufacturing methods.

In the context of developing countries, which have gone through a transition from agricultural to industrial societies, whose economies do not focus on knowledge (creativity and dissemination) and use of science and technology compared to developed countries, whose quality of life is lower, the human development index (HDI) and per capita income are relatively low. While the main share of data production (innovation) takes place in developed countries, innovations in the north “strongly believe in radical development. This does not undermine the importance of innovation (and studies analyzing its processes) in developing countries, although innovation in developing countries does not contribute significantly to the frontiers of global knowledge; at least its impact should be vital and effective in the developing country and increase per capita national income [12].

In this respect, technological innovation has played a leading part in economic growth, creating innovative energy opportunities. One of the positive effects of technological innovation is the diversification of energy sources simultaneously and with the same devices, which contributes to reducing pollution. In addition to producing similar alternatives from more effective materials at the cheapest cost and with less pollution, this contributes to the increase in flexibility of the production system and the reduction of production costs. Moreover, the marketing of modern technologies leads to increased accuracy in production by adhering to the specified standards and specifications according to scientific principles that are not harmful to the environment. In addition, maintaining the latent reserves of renewable materials contributes to maintaining the ecological integrity of these resources. It can be said in another way that the innovation of technologies with scientific specifications works to preserve the environment by avoiding environmental pollution to its surroundings. In addition, upgrading societal prosperity aside from technological alterations has been consistent with most artistic research for a long time. Interestingly, invention creates opportunities in developed countries as much so as in less developed countries [13][14]. Therefore, technological innovation may take three forms: cost savings, quality improvements, or expansion in a variety of products, services, and manufacturing methods. Innovation is finding new and better ways to conduct business and bringing new ideas or new types of products and services to the market [15]. Therefore, innovation is carrying out new things in a new way. Innovation transforms and develops the technological qualities and performance characteristics of goods and processes, and changes organizational forms and market strategies, thereby adding dynamic change and efficiency development to the financial system. To try anything different, companies need to learn—if they do not learn, nothing new happens [16][17][18]. As is the case for many developing countries, foreign R&D is a vital technology resource; the share of domestic R&D in Egypt’s GDP is 0.7%, of which only 8% is undertaken by the business sector [19].

2. Technological Innovation and Economic Growth

There is a substantial amount of empirical literature focusing on technological innovation and economic growth that has consistently shown that technological innovation is a critical catalyst in economic growth. Among the most important studies focusing on this aspect is the research of Freimane et al. who used research and development as a measure of innovative activities [20][21][22][23][24]. The economist Joseph Schumpeter considered that innovation is one of the productive functions and emphasized that entrepreneurs are able to achieve these innovations, and thus, entrepreneurship plays a fundamental role in economic growth [25]. Theoretically, the innovation-based growth hypothesis suggests that there is a positive linkage between innovation and economic growth. According to this hypothesis, R&D plays a major role in innovation, raising productivity, and accelerating economic growth [26][27][28]. Based on existing literature, this entry systematically sorts research related to the relationship of innovation technologies to economic growth from aspects of semantics and characteristics, composition and development, innovation, and management of emerging technologies. Various theories explain the relationship between technology innovation and economic growth. In the neoclassical context, the impact of innovation is seen as part of the Solow residual and thus a major contributor to economic growth and long-term integration [29]. The Solow residual is a number describing empirical productivity growth in an economy from year to year, and decade to decade. Robert Solow, the Nobel Memorial Prize in Economic Sciences-winning economist, defined rising productivity as rising output with constant capital and labor input. It is a “residual” because it is the part of the growth that is not accounted for by measures of capital accumulation or increased labor input. Increased physical throughput, i.e., environmental resources, is specifically excluded from the calculation; thus, some portion of the residual

can be ascribed to increased physical throughput. The example used is for the intra-capital substitution of aluminum fixtures for steel during which the inputs do not alter. This differs in almost every other economic circumstance in which there are many other variables. According to the “Solow surplus” model, the unexplained portion of economic growth, except labor and capital increase, is technological development. The convergence hypothesis, which is one of the main implications of the Solow model, is based on the assumption that technological change is external and constant between countries. Accordingly, per capita output levels of countries will approach each other, and the development differences will automatically disappear in the long term [30].

Technological change is one of the most important challenges facing countries for its strategic role in achieving outstanding performance, maintaining its competitive advantage in the markets, and its sustainability, survival, and success in the fields of work. Technological change is a more comprehensive concept than development, growth, and progress. Technological change is what leads to development; technological development can be defined as a set of activities related to examining, evaluating, and implementing an idea or goal for the purpose of moving from the research mental level to the production level, and includes developing processes for technical capabilities, performance, design, engineering models, and manufacturability. While technological growth means a continuous increase in technology over time, technological progress is the change in the art of production used, leading to an increase in productivity, provided that the ratio of capital and labor use remains constant.

Both Ricardo and Adam Smith emphasize that openness will enhance specialization and thus countries will specialize in the production of goods and services that have advantages and export these goods and services; on the other hand, countries that do not have these advantages will import from those countries and specialize in other types of goods and services, and as a result, resources are allocated optimally. The theory of internal growth indicates that developing countries will benefit from the transfer of advanced technology through a policy of trade openness, this technology can be exploited in productive processes and thus achieve a large production that is directly reflected in economic growth [31].

The neoclassical growth models derived from Solow’s 1957 model consider a technological change to be exogenous and suggest that trade policies do not, therefore, affect economic growth. However, new economic growth theories assume that technological change is an endogenous variable [32].

Thus, modern growth theories have emerged, which are termed internal growth theories, with the contributions of Romer and Lucas, and the theory of internal growth focused on the internal impact of technological change, research and development, human capital, and their impact on the production function [33][34]. In-house designed technological change generates sustainable economic growth, assuming constant returns to innovative research, in terms of human capital used in research and development (R&D). Internal growth models provide an appropriate framework for examining important issues related to the role of technological change in the process of economic growth, as well as design, research and development efficiency and innovation policies. “Barro” focused on infrastructure and public expenditures, and others have focused on economic openness and its role in economic growth [35].

Paul Romer’s model of endogenous growth distinguishes between inputs and outputs. His knowledge takes the form of a number of ideas (designs) that are embodied in the form of a number of (technical) inputs, which in turn are embodied in the form of final goods and services. Hence, Romer’s model links the sector of the production of ideas and designs (research and development), the sector of input production (the sector of production of intermediate goods), the sector of capital production (which is just a mixture of inputs) and the sector of production of goods and services [36][37]. Hence, it can be said—according to Romer’s model—that designs constitute the output of the knowledge economy, while the inputs that are used in the production of capital and in the final goods production sector represent the impact of the knowledge economy on the knowledge-based economy. Thus, this relationship between these sectors is logical to govern—in principle—the logic of designing and building knowledge standards, knowledge economy standards, and knowledge-based economy standards. Romer concludes that growth is often driven by the accumulation of non-competitive inputs (intermediate inputs), but they are partially enumerated, and by competitive inputs, are embodied in human capital, not by the size of the labor force or the size of the population [36]. Thus, the transition from a product economy to a knowledge economy has some consequences, including providing an opportunity to increase returns, such as what happened in the industries software sector, as well as creating the opportunity to benefit freely, by taking advantage of knowledge outputs [38].

In the same context, some studies, including Aghion and Howitt, Chu, and Jinli Zeng, indicate that capital accumulation (both physical and human) and innovation should not be considered as causal factors differentiate, but are manifestations of a single process. On the one hand, capital is used in the innovation process and in new technology applications resulting from research and development activities. Hence, long-term growth depends on both capital accumulation and

innovation. On the other hand, new technologies create new economic opportunities for investment in physical and human capital [39][40][41]. Nelson has indicated that knowledge takes the first priority compared to the traditional factors of production, material, and financial. Unlike land, labor, and capital, which were highlighted by traditional economists as final factors of production, knowledge, and ideas are infinite goods and help to obtain increased benefits; the new economists link the theory of superior growth creativity emanating through the system [42]. Nelson also emphasized that the level of innovative activity in a country is determined by the level of interaction of specialized [43] institutions among them [44]. Hence, a review of these different theories confirms that technological progress appears in them as a supportive factor for productivity growth and thus achieving long-term economic growth [45]. Expenditure on scientific research, technical development, education, and rehabilitation of human capital is one of the most important tools supporting innovation [34].

Hence, most innovation studies are focused on developing solutions to technology problems. Researchers have tried to show how the organization can develop technological solutions to the problems they face, where technology is seen as solutions to problems [46]. In addition, the results of much quantitative research confirm that the development of technological capabilities is a prerequisite for reducing the difference in economic development between countries and thus achieving the so-called catch-up growth in developed countries [47]. This means reducing the difference in the level of income per capita. Many countries, such as Japan, South Korea, and others have also achieved this. The economist Kim interpreted the economic development in South Korea on the basis of the development of its technological capabilities, which is known as the ability to effectively use technical knowledge to imitate, invest, localize, and modify the existing technology. Technology capabilities are also a necessary condition for achieving technology transfer and settlement [48], whereas innovation potential describes a country's ability to produce and market innovative technology over the long term [49]. The financial and scientific resources necessary for innovation and the results of scientific research are the most important factors that affect the innovative potential of a country [50]. Furthermore, human capital, infrastructure, and foreign trade are among the most important factors affecting this country's ability to absorb new technology, achieving development based on innovation and thus achieving economic growth.

Based on the foregoing studies, technological change can be defined as "the use of innovation or creativity outputs for the purpose of bringing about a partial or total change in the production process, or the product that aims to support competitiveness and therefore continuous modification in it to achieve continuity and growth". It is often claimed that the impact of progress on economic development cannot be fully appreciated without considering the social and structural structures of the country. For example, Rodriguez and Crescenzi demonstrated how the interaction between research and socio-economic and institutional conditions shapes the potential for regional innovation [51].

Tuna et al. focused on analyzing the relationship between research and development (R&D) expenditures and economic growth in Turkey, using unit root tests, the concurrent integration test, and Granger's causation. The results of the analysis showed that the time series are stable in the first degree, and there is no simultaneous integration relationship between them. According to Granger's causal analysis, it was revealed that there is no causal relationship between the tested time series [52].

Abdelaoui. et al., aimed to measure the impact of innovation on economic development in Algeria, Tunisia, Morocco, Egypt, the United Arab Emirates, Kuwait, and Saudi Arabia, for the period 2007–2016. It lists several composite indicators that go beyond traditional measures of innovation, such as research and development expenditures and the number of trademarks and patents. The impact of innovation has been measured on the following independent variables: the growth of per capita real output, the unemployment rate, and the human development index, as indicators that measure levels of economic development. The economic measurement of the panel data was used based on the apparently unrelated equations method and the middle of the combined group method. The study concluded that there is a significant positive impact of innovation on the growth of per capita output as well as unemployment, and the results indicated the role of innovation in improving human development levels [53]. Lomachynska and Podgorna examined the causal relationship between innovation, financial development, and economic growth using panel VAR modeling for a sample of 27 OECD countries during the period 2001–2016. The adopted approach allows downloading the triple links between innovation, financial development, and economic growth. The study concluded that there is a one-way causality from economic growth to financial development. The results of the study also confirm the hypothesis of neutrality from financial development to economic growth, as well as between innovation and economic growth and between financial development and innovation [54]. Pece et al., examined whether long-term economic growth is affected by innovation potential through the use of multiple regression models estimated for central European countries using the following measures: with regard to economic growth and patents, a number of trade currencies, research, and development expenditures for innovation, and by using regression models to estimate the relationship between economic growth, investment, and innovation, the results represent a strong relationship between humans, money, and economic growth [55]. Solomon et al., aimed to analyze the dependencies between growth and volatility (the degree of variance in the

trading price series over time, measured by the standard deviation of logarithmic returns) and innovation in the case of the European Union and the two new member countries, and the length of the extension. The multi-regression model used the variable GDP for economic growth, and the innovation index for innovation, the regressions of the GDP growth rate were estimated on its total volatility as well as its partial volatility divided by the variables of the rate of growth related to the role of innovation. The most important results were the following: there is a positive and moral partial correlation between GDP and innovation and there is a positive and moral partial correlation between GDP growth and its fluctuations between stages [56].

Whereas the neoclassical economy recognizes that technological innovation is critical for economic growth and considers the internal technical innovation variable to be external, it may not distinguish the roots of technological development, and exaggerates economic growth as a promotional base for technological innovation.

The current theory of economic growth states that technological progress is affected primarily by considerations such as the allocation of human capital and the number of intellectual services, and identifies different models of research that depend on sophistication and scope. Since the theory of economic growth has undergone a long cycle of development, it has many methods of analysis. However, there is already agreement on the fact that technological innovation is the driving factor behind the progress of economic growth and economic development linked as cause and effect, stimulating, and assimilating each other and often forming a partnership between the two. In other words, technology innovation and economic growth overlap, both of which change in the same direction at the same time, and this relationship shows an enhanced role for technology innovation in economic growth. Growth economists, development economists, and economic historians all seem to agree on the importance of technological innovation for long-term economic growth. Even a recent article in The Economist entitled “Economists understand little about the causes of growth” nonetheless acknowledged that “growth is fundamentally about using technologies to become more productive and uncover new ideas” [57]. Several studies have analyzed the impact of technology innovation (research and development, high-tech exports) on economic growth. According to Maradana and others, the relationship between innovation and economic growth has recently emerged as a major study subject [20]. Research on this topic can be classified into four categories: Supply-leading Hypothesis, Demand-following Hypotheses, The Feedback Hypothesis, and the Neutrality Hypothesis, they are as follows:

- Supply-leading Hypothesis (SLH) suggests a unidirectional causality between innovation activities and economic growth (see, for example, Yang, [58]; Guloglu and Tekin, [35]; Cetin, [26]; Pradhan et al.) [59].

- Demand-following Hypotheses (DFH) suggest unidirectional causality from economic growth to innovation activities (see, for example, Sinha, [60]; Cetin, [26]; Sadraoui et al., [61]; Pradhan et al., [59].

- The Feedback Hypothesis (FBH) suggests a bidirectional causality between economic growth and innovation practices (see, for example, Guloglu and Tekin, [35]; Cetin, [26]; Pradhan et al. [59].

- The Neutrality Hypothesis (NLH) suggests no association between economic growth and innovation activities (see, for example, Cetin, [26]; Pradhan et al., [59].

- Throughout history, nations seeking a successful future have relied on the discovery of the next “great idea,” which often follows the accidental discovery of a great idea that propelled the country forward. Nevertheless, for the country to succeed in competition, and for its growth to continue in the current and ever-changing business environment, it must learn how to develop a thriving innovation culture—that is, a continuous ability to generate, accept, and implement creative ideas—within the country, as can be seen in **Figure 2**.

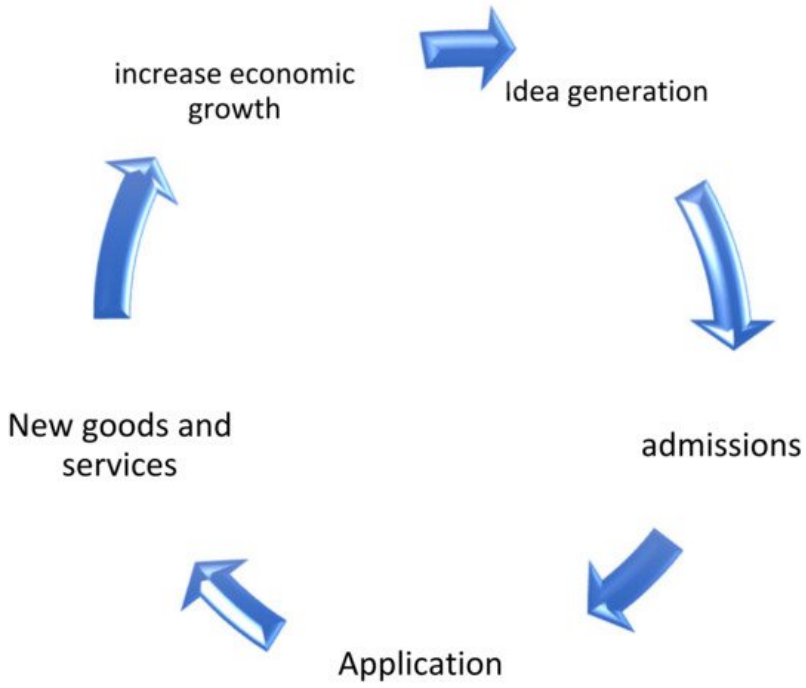

Figure 2. Innovation process. Source: Prepared by the authors.

The innovation process begins by generating creative ideas by finding many ideas, then choosing those that address the current problem/problems, or that make the best use of opportunities to meet the needs of the state; then comes the stage of accepting ideas that help introduce a new product or introducing a new method of production. Hence, innovation is the process of transforming new ideas and new knowledge into new products and services, and thus this activity entails opening new markets, or finding appropriate sources of raw materials. Thus, innovation is the introduction of innovation into a country's national economy, which positively affects economic growth.

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