Measurement of Innovation in Economic Growth Research

Nataša Stanojević[1], Slobodan Kotlica[2], Katarina Zakić[3]

[1,3]Institute of International Politics and Economics, Belgrade, Serbia
[2]Faculty of Business and Law, MB University, Belgrade, Serbia

[1]natasa.stanojevic@diplomacy.bg.ac.rs, [2]kotlica@gmail.com [3]katarina@diplomacy.bg.ac.rs

Abstract—**Research belongs to the field of methodology of economic sciences. The article analyzes the causes of the inability of economic models and indicators to measure the impact of knowledge and innovation on economic growth, despite the general agreement about their positive effects. The article presents the evolution of the inclusion of the knowledge variable and technological achievements in models of economic growth. Second, the quantitative innovation indicators were classified, and their limitations were assessed. Finally, two current processes that present new challenges for measuring the economic effects of innovations are analyzed: mass digitalization and the increasingly frequent occurrence of open instead of closed innovations. The goal is to separate obstacles for evaluating innovative effects that can be overcome from those that cannot due to the fluid nature of innovation. This distinction determines the optimal relationship between the methods and framework of economic growth research. The article results showed that reliable economic growth research must be primarily based on the measurement of direct innovative output, while input criteria (investment in R&D) and indirect outputs (number of patents) can only be auxiliary criteria. As data collection on the direct outputs of innovations implies extensive work by researchers, a lot of time and emphasized flexibility in data collection, and a significant geographical or sectoral narrowing of the research subject.**

Keywords - innovation, knowledge, economic growth models, digitization, open innovation.

I. Introduction

There are few concepts in economic theory about the meaning and role of which there is such broad agreement as innovation. The term innovation implies: the introduction of new products or services; improving the quality of products or services; methods and processes by which they are created; or methods and processes of production organization. Beyond these basic elements of the concept, the authors also add the introduction of new raw materials and semi-products, breakthrough to new markets [1]; changes in the context in which the product or service is used, so called positional innovation [2]; application of new marketing methods including significant changes in design, marketing and promotion of products–marketing innovations, etc. Despite the large number of elements that authors attach to the concept of innovation, not one of them has been contested by other authors. In addition, there is general agreement about the positive role of innovation in the modern economy. Knowledge, technologies and innovations have an undeniably important role in increasing productivity, developing new products and services and creating competitive advantages for companies, which further contribute to accelerating the growth of the entire economy.

Despite the seemingly clear idea of the role of innovation in the growth and development of modern economies, evaluation and even less precise measurement of this impact have remained beyond the reach of macroeconomic research and models. The most commonly observed sources of the "elusiveness" of these effects differ to some extent. They often refer to the incompleteness of the available data or the fact that these data 'represented only a proxy measure reflecting some aspect of the process of technological change' [3]. As early as 1962, Simon Kuznets observed that 'the greatest obstacle to understanding the economic role of technological change was a clear inability of scholars to measure it' [4].

Innovation implies creation (invention) and the use of new knowledge to offer products or services with greater value for users. One of the essential elements of innovation is its verification on the market, i.e., commercialization. Innovation is 'invention plus commercialization' [5]. The criteria for evaluating the success of innovative activities and innovations are more commercial than technical, and innovation is considered successful if its commercialization provides a return on invested funds and a corresponding profit. However, the fluid nature of innovation does not allow a complete insight into all the manifestations of its application. Knowledge and ideas are the essential components of the innovation process, and the commercialization process is a confirmation of the success of R&D activities. The linearity of the process from the idea, through scientific discovery, invention, innovation, and technology, to the market is a one-way and unambiguous process that leads to technological and commercial success.

The goals of this research are to:

1) explain the results of previous research on the statistically invisible effects of knowledge and innovation in models of economic growth;
2) identify the advantages, disadvantages and scope of the set criteria for measuring innovation effects; and
3) explain the new challenges for establishing precise and reliable methods for measuring their effects, which are set by the action of two current processes – digitization and the prevalence of open innovations instead of closed ones at the beginning of the 21st century.

These results will enable the separation of obstacles for evaluating innovative effects that can be overcome from those that cannot, and based on that, to determine the optimal relationship between the methods and framework of economic growth research.

II. Technology, Innovation and Missing Variables in Economic Growth Models

For a long time, economic theory recognized only the importance of new machines, that is, technology, as a source of economic growth, while knowledge and innovation were viewed as default factors that did not need explanations. Technological growth and development is treated as an exogenous factor of economic activity, which has its own laws of a non-economic character and is beyond the subject and interest of economic science. According to the classic model, the product (output) is generated using two factors of production, labor L (labor) and capital K (capital). Any increase in productivity, therefore, would have to be caused by an increase in invested capital or the number of workers:

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

The sudden technological rise of the 1980s, the growth of investments in IT and the evident application of new technological solutions in the economy did not show up in productivity statistics. According to econometric models, productivity growth in the world economy lagged during the 1970s and 1980s, while at the same time, the computer and technological revolution was apparently making production more and more efficient. An economist Robert Solow famously said in 1987 that the computer age was everywhere except in productivity statistics. Similarly, Freeman [6] believes that there is a paradoxical situation between the general agreement that technological change is the most crucial source of dynamism in capitalist economies and the relative neglect of this issue in large part of the significant literature in the economic and social sciences.

At the same time, the model of economic growth begins to show increasing values of residuals, which means that significant causes of economic growth remained outside the equation and understanding of researchers.

Significant progress in the discovery of this phenomenon was represented by the works of Abramovitz [7], Denison [8,9], and Solow [10,11], who put forward the neoclassical theory of economic growth. In their empirical research and theoretical elaborations based on it, they pointed out that economic growth, apart from the nature of labor and capital, is influenced by other, unconventional factors, such as the role of knowledge, technique and technology in economic growth [12]. Knowledge and innovation are also seen as exogenous factors, but for the first time, they are included in models of economic growth. However, more than a decade passed before their inclusion in the methodology of economic research, that is, until it was possible to assess their impact. In 1988, Lucas developed an alternative growth model based on externalities arising from the process of human capital accumulation, either through formal education or 'learning by doing' [13]. Lucas's model includes investments in human capital that are transposed into raising the technological level of the economy. Technological progress and knowledge are viewed at the level of overall knowledge of science, that is, as an exogenous factor in relation to the economy under investigation.

The most often cited model of exogenous growth is the Solow-Swan model of long-term economic growth, which, in addition to capital accumulation, labor or population growth, explains economic growth by increasing productivity caused by technological progress. The model has the following form:

$$Y(t) = K(t)^{\alpha}\left(A(t)L(t)\right)^{1-\alpha}, \qquad (2)$$

where t denotes time, $Y(t)$ total production in a certain period, while A is the exogenously determined level of technical progress or total factor productivity, so that $A(t)L(t)$ represents the effective workforce, instead of only the previous L, which refers to the number of workers.

In parallel with this approach, an approach was developed on technological changes and technological progress as an endogenous, cumulative and interactive process in relation to the economy and society. This point of view, which developed mainly within the Neo-Schumpertian and evolutionary approach to economic phenomena, prevailed in economic science for a short time. The endogenous growth theory and technological progress, based by Arow [14], offers more radical explanations of long-term growth. Like the previous model, growth is attributed to technological progress, with the critical difference being that it originates from within the economic system – a state or a company [14-16]. The model implies that the long-run equilibrium growth rate is determined by the level of accumulated human capital [17]. These authors assumed that investment in R&D and intellectual improvement of labor, helped foster endogenous innovation and fuel constant economic growth.

One of the most frequently cited endogenous growth models is Romer's [16]. It can be presented in the following way:

$$Y(t)=K(t)^{\alpha}\left(A(t)L(t)\right)\left(A(t)H(y)\right)TL, \qquad (3)$$

where K is capital; A – knowledge, ideas; L – labor in production; H – human capital – which includes activities such as formal education and training of employees; TL – the index of technology level.

The measure of internal innovation potential is shown as the ratio between the number of researchers in relation to the number of employees in production. Romer emphasizes that economic growth is more substantial with a more favorable relative relationship between the amount of human capital and ordinary labor.

These assumptions also cannot be accurately measured. Not a single model has fully explained the nature of modern economic growth because each contains a smaller or larger value of residuals (unexplained factors). This value decreased during the evolution of the economic growth model from the classic to the endogenous growth model. Reducing the impact of unknown factors can be attributed to difficult-to-measure changes such as improved work quality, better training and experience, and inventions embodied in the construction and application of new machines. However, in a large number of cases of structural or dynamic analysis of the growth of a particular economy, the residuals remained very high; that is, the influence of unknown factors was too often and remains unacceptable.

In response to the missing variables of knowledge, technology and innovation in models of economic growth, several international organizations have offered different variants of a composite index for measuring innovation in the past decade. As these are not econometric models, statistical relevance cannot be assessed, nor can the size of the residuals, i.e., the indices themselves are not subject to evaluation. We will mention only a few: EU with Innovation Union Scoreboard (IUS), World Economic Forum (WEF), Bloomberg, and World Intellectual Property Organization – WIPO. The selection of factors in very diverse combinations has no theoretical basis and is left to the relatively arbitrary judgment of the experts involved in creating the index. The absence of a system is attempted to be compensated by a large number of variables, so these indices include several dozen, even over 100 factors, although the number of variables itself is not necessarily related to a more precise measurement. Bearing in mind the numerous specificities that occur in economies and societies, composite indices can hypothetically lead to moving away instead of approaching a precise evaluation of achievements in innovation. International databases on national innovation achievements have remained a source of tentative estimates, finding their place more often in political rhetoric than scientific research. To date, no simple criteria and methods have been identified for measuring the effects of innovations in the conditions of the modern global economy.

III. Quantitative Indicators of the Innovation Effect and Their Limitations

At the heart of the challenge of measuring innovation effects is the issue of selecting criteria for their evaluation. In the broadest sense, all indicators used to quantify innovations (either for their use in economic models or indices) can be classified into three groups:

1) direct input into the innovation process, such as costs or funds allocated for research and development (total, domestic, foreign, state or company level, etc.); the number of researchers in absolute number or concerning the number of employees in the company or the national economy, the number of highly educated workers employed; IT inputs in the form of equipment or number of qualified users, etc.;

2) an intermediate output of the innovation process through the number of innovations that have been patented, the number of inventions that have been registered in accordance with the norms of copyright protection and intellectual property rights;

3) a direct measure of the innovative output of the innovation process, which valorizes what is not only patented but also applied. These can be new technological procedures, processes, means and methods that are effected in a new technology, product or service [17].

In the conditions of the modern economy based on knowledge, these factors show increasing limitations and decreasing precision due to the disrupted usual links between consumption, production and investment.

Regarding the first group of quantitative criteria – inputs, even in theory, there is no convincing evidence that more significant allocations to the R&D area result in higher quality and economically applicable knowledge production. A high level of allocation for R&D purposes is neither a necessary nor a sufficient assumption for the high effectiveness of the innovation process. When there is no adequate coordination and interaction with all other essential elements of the inventive-innovative chain, investment in R&D does not lead to innovation. Even when research investment leads to innovation, it does not mean that it will contribute to economic growth because the capacity to absorb inputs and generate outputs is very different between countries.

The next problem of input criteria is the fact that not all innovations are generated by R&D expenditures. In fact, the largest number of innovations are the so-called incremental innovation. In contrast to radical innovations that bring novelty on a global level, incremental ones arise during the work process and refer to the improvement of products, processes and methods without significant investment in research. Although they are not the result of radically new technological knowledge and scientific breakthroughs, they have significant economic consequences over time. The effects of incremental innovations cannot be precisely measured. In contrast to operational innovations, which make previous technical and conceptual solutions uncompetitive and replace them relatively quickly, incremental innovations are implemented in parallel with previous solutions in an undefined scope and duration.

The second group of quantitative criteria refers to the quantification of intermediate output, measured by the number of registered patents and other forms of intellectual property in relation to GDP or the number of SMEs with new products concerning the total number of companies, etc. The problem with this quantification criterion is that patents measure inventions rather than innovations, and secondly, firms often use methods other than patents to protect their innovations.

Due to the specificity of economies and societies, these two groups of readily available quantitatively measurable data can exhibit an unlimited number of deviations. Although these criteria cannot provide precise measures for researching the economic effects of innovations on a broader level (sector, national economy, global level), they are essential for evaluating the effects of innovations on a microeconomic level, i.e., within the framework of companies. In addition, the criteria of inputs and indirect results are necessary at the level of a group of companies located in a specific geographical area, that is, in the same environment, which are homogeneous in terms of the mentioned possible differences.

The third group of criteria – the direct economic results of innovations – are quantitatively measurable only at the lowest aggregate level – insight into the results of individual innovations. Research which is based on these criteria provides the most appropriate information on the impact of innovation on economic growth and provides a basis for further quantitative research on the relationship between economic parameters and the innovation process. The problem is collecting them. A common problem of existing innovation statistics is the lack of the 'output' side of the innovation process. One of the more extensive examples is the U.S. Small Business Administration Innovation Data Base, which compiled the data by examining over one hundred technology, engineering, and trade journals, spanning every industry in manufacturing. As such a database is not helpful for researchers outside the US, direct output innovations require field research and often involve surveys of targeted groups of businesses in a specific geographic area. Only research based on these criteria can provide meaningful and valuable assessments of the effects of innovation on the economic growth of a specific geographic area or a clearly defined product group (by summarizing the effects of individual innovations). Measuring the effects of innovation at the macroeconomic level using these criteria is possible but unlikely. It requires forming a kind of interactive mass database with the decisive participation of the companies themselves or innovators – entrepreneurs, who generally have no interest in this additional expenditure of time.

It seems that the very fluid nature of knowledge and innovation presents researchers with the alternative of reliably measuring the economic effects of innovations at a narrow level – a sector, a group of companies or a geographical area, or a rough assessment of the effects at a national (or broader) level.

IV. New Challenges in the Evaluation of Innovation Effects

At the beginning of the 21st century, economic research methodology is facing new challenges and missing variables, even in research limited to sectors, geographical areas or a group of companies. Two current processes in the field of innovation further relativize the results of measuring innovation effects. The first is the expansion of innovation in digital technologies; the second is the expansion of open versus closed innovation.

A. Digitization

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Newer digital technologies such as cloud computing, e-commerce, mobile internet, artificial intelligence, machine learning and the internet of things, although apparent products of the knowledge economy, have broader impacts than can be assessed by quantitative criteria related to their use. Digital technologies improve production in a sense that goes far beyond the optimization of economic processes in the classical sense. Business models are being fundamentally transformed, value chains are changing, and the boundaries between economic sectors are blurring.

Several models have emerged over the past few years, designed to assess a company's digital status. Primarily developed and published by practitioners, the academic value of these models remains apparently unclear. Most existing models are tested through actual data, but the quality of the methods and approaches applied broadly differs or cannot be evaluated at all. The results of the extensive analysis of Thordsen, Murawski and Bick of the existing models for measuring companies' digital maturity pointed out several shortcomings [18]. The models were evaluated on established academic criteria, such as generalizability or theory-based interpretation, and the results showed that these models could not have a general character; that is, they do not represent a universal method of measuring digitalization.

The impossibility of measuring the effects occurs in all evaluation phases, from defining the shift in digitalization in a specific company or sector through defining measurement procedures and theoretical foundation of methods to the problem of generalization [18].

B. *Open Innovation*

Another process is the growing influence of open versus previously dominant closed innovation, whether driven by digitalization or strategically set as a goal by companies.

Until the end of the 20th century, models of the innovation process were, more or less, closed innovation models. The process of development and commercialization of new products and services took place within the framework of a specific company or group of companies in the internal R&D process. In a closed innovation system, employees within the organization develop innovative ideas internally without exchanging ideas with the external environment (Fig. 1).

Since there are many ideas at the beginning of that process and significantly fewer at its end, it is possible to visually represent the innovation process as a funnel with numerous ideas that enter at its wide end (on the left of the figure), are transformed, with complex and extensive but invisible work within the funnel itself in several more significant innovations that appear on the market through the narrower part (on the right side of the figure). Although this direct effect of innovation on economic growth is immeasurable at the national level, the results were satisfactorily measurable at the level of companies and groups of companies.

At the beginning of the 21st century, companies from various industries, especially from the field of high technologies, are significantly changing or have already changed the dominant model of innovation activity. The innovation process is increasingly complex and involves an increasing number of participants to realize the commercial potential of innovative ideas as successfully as possible. Instead of focusing on internal idea generation and

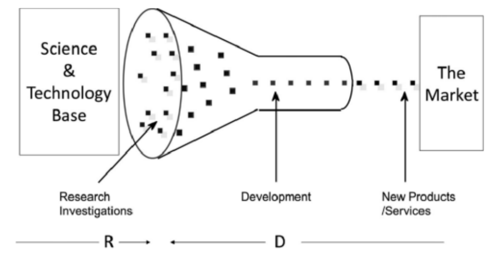

Figure 1. Model of closed innovation [21]

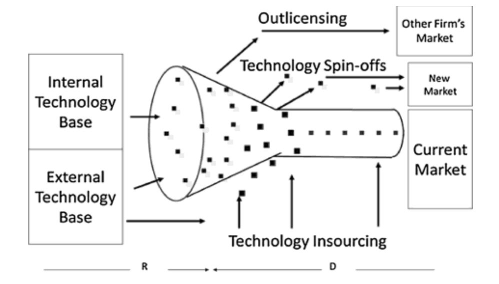

Figure 2. Model of open innovation [21]

development, it combines internal and external ideas with internal and external paths to market to advance the development of new technologies [19].

One of the authors with the most significant contribution to open innovation research, Henry Chesbrough, explained them as follows: 'Open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. This paradigm assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology' [20].

The part of open innovation that is directed from the environment to the firm opens the company's innovation process to numerous types of external inputs and contributions (e.g. consumers, suppliers, scientific institutes, universities, and engagement of external resources through an open call (crowdsourcing). The opening of the innovation process from the company to the environment implies that the organization enables unused or little-used ideas to leave the company and for other companies to use them in their operations and business models (commercialization of ideas and technologies by paths beyond the borders of the company and its business model). As the idea of the futility of trying to protect intellectual property becomes dominant, open innovation is equated with open-source software development.

The modern concept of open innovation is characterized by very fluid interactions between internal and external innovation activities. Ideas, people and resources move in different directions, and the boundaries between internal and external activities and the essential business environment of the firm are more porous (Fig. 2). Inflow and outflow of innovation contribution are possible at every point between innovation inputs and market placement. This leads to the fact that even previously functional quantitative criteria related to inputs and intermediate outputs are becoming less and less precise.

V. Conclusion

Although innovation is considered one of the most critical drivers of economic growth, evaluating this impact seems to remain a constant challenge for economic science. The fundamental problem is the absence of adequate measures which would enable a reliable evaluation of innovation activities at the macro level, such as the impact on economic growth, comparison between economies, regions, industries or different phases within one economy.

In modern knowledge-based economies, the usual links between consumption, production and investment have been significantly altered so that a certain amount of input produces very different outputs. Although economic growth models in a certain period of recent history allowed for relatively precise analyzes of economic structure and dynamics, in the conditions of the knowledge economy, positive economics faced the impossibility of achieving the reliability of natural and technical sciences. The decades-long efforts of positive economics to establish economic relationships as causal, instead of viewing them as stochastic, which is the nature of all social phenomena; to set the empirical model as a goal instead of as a means to support the creation of economic policies; they led to the separation of fundamental research from the reality of concrete society. The dynamics of real processes in the global economy are increasingly disproving the fundamental "laws" in the economy. The elusive economic effects of innovations in digital technologies, the porosity of innovation creation channels and the incredible intertwining of economic activities, subjects and states due to intense economic globalization have only made this fact more visible.

This does not mean that the economy should not analyze the effects of innovations but that the content, goals and methods should be adapted to its social nature. In order to quantify innovations, no matter how much their nature changes, the following criteria are used: 1) input into the innovation process (investment of money, technique, experts and time); 2) indirect outputs (patents); and 3) a direct innovative output (economic results of applied inventions, whether they are patented or not).

An objective analysis of the economic effects of innovations must rely on the third group of criteria – a direct innovative output (the financial results of applied inventions, whether patented or not). Criteria related to inputs and intermediate outputs may or may not be analyzed according to research objectives. Collecting data from this group of criteria implies investing a lot of effort, time, flexibility in data collection, and significant geographic or sectoral narrowing of the research subject, which explains a relatively small number of the research involves this kind of measurement.

References

[1] Schumpeter, J. A. (1934). *The Theory of Economic Development*. Harvard University Press.

[2] Francis, D., & Bessant, J. (2005). Targeting innovation and implications for capability development. *Technovation*, *25*(3), 171-183.

[3] Acs, Z. J. & Audretsch, D. B. (2005). Entrepreneurship, Innovation and Technological Change. *Foundations and Trends in Entrepreneurship*, *1*(4), 149-195.

[4] Kuznets, S. (1962). Inventive activity: Problems of definition and measurement. In R.R. Nelson (ed.), *The Rate and Direction of Inventive Activity* (pp. 19-43). National Bureau of Economic Research, Conference Report, Princeton, NJ.

[5] Freeman, C., & Soete, L. (1997). *The Economics of Industrial Innovation*. Frances Pinter Publishers.

[6] Freeman, C. (1994). The economics of technical change. *Cambridge Journal of Economics*, *18*(5), 463–514.

[7] Abramovitz, M. (1956). Resource and Output Trends in the United States Since 1870. *American Economic Review*, 46, 5-23.

[8] Denison, E. F. (1962). *The Sources of Economic Growth in the United States and the Alternatives before Us.* Committee for Economic Development, New York.

[9] Denison, E. F. (1979). *Accounting for Slower Economic Growth examines labor productivity and productivity accounting during the 1970s in the United States.* Brookings Institution.

[10] Solow, R. (1957). Technical Change and the Aggregate Production Function, *The Review of Economics and Statistics, 39*(3), 312-320.

[11] Solow, R. (1959). Investment and Technical Progress. In K. Arrow, & Suppes (Eds.), *Mathematical Methods in the Social Sciences,* Stanford.

[12] Kotlica, S., & Stanojević, N. (2017). *Technology, innovation and competitiveness in a globalized economy*, Dositej, Belgrade. [Tehnologija, inovacije i konkurentnost u globalizovanoj privredi].

[13] Lucas, R. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, *22*(1), 3-42.

[14] Arrow, K. (1962). Economic Welfare and the Allocation of Resources for Invention. *The Rate and Direction of Inventive Activity: Economic and Social*

Factors, 609-626. National Bureau of Economic Research, Inc.

[15] Romer, P. M. (1986). Increasing Returns and Long Run Growth. *Journal of Political Economy*, *94*(5), 1002-1037.

[16] Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy*, *98*(5), Part 2, 71-102.

[17] Mervar, A. (2003). An essay on recent contributions to the theory of economic growth. *Ekonomski pregled, 54*(3-4), 369-392. [Esej o novijim doprinosima teoriji ekonomskog rasta]

[18] Thordsen, T., Murawski, M., & Bick, M. (2020). How to Measure Digitalization? A Critical Evaluation of Digital Maturity Models. In *Responsible Design, Implementation and Use of Information and Communication Technology*, *19th IFIP WG 6.11 Conference on e-Business, e-Services, and e-Society*, South Africa, (pp. 358-369).

[19] Kotlica, S., & Stanojević, N. (2020). From closed to open innovation. *Ekonomski vidici*, *25*(3-4), 155-170. [Od zatvorene ka otvorenoj inovaciji].

[20] Chesbrough, H. W. (2006). Open innovation: a new paradigm for understanding industrial innovation. In Chesbrough, H. W., Vanhaverbeke, W., West, J. (ed.). *Open innovation. Researching a new paradigm*. Oxford University Press.

[21] Chesbrough, H. W. (2012). Open Innovation, Where We've Been and Where We're Going. *Research-Technology Management,* Special Issue: Open Innovation Revisited, *55*(4), 20-27.