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Modelling Innovation Contribution to Economic Growth of Industrial Regions

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Abstract: The article considers approaches to determining the innovative contribution to economic growth and economic development. Attempts to make such a determination in the known studies are limited by using methods of: integrated estimation, expert evaluations, multipliers, econometric models. Most of the considered approaches are focused on identifying the innovative impact on economic development, rather than on economic growth. It is proposed to expand the Cobb-Douglas production function by including, in addition to STP, labour costs and capital costs, as well as an innovation factor, which includes: gross domestic R&D expenditures, innovation expenditures, and total education expenditures. To determine the contribution of the innovation factor to economic growth, the "Solow balance method" is used, which, through logarithmization and obtaining logarithmic derivatives in the production function, allows obtaining formalized information about each factor's contribution to economic growth and developing necessary regulatory measures. The method is universal and can be applied to any country, region or type of economic activity.

Key words: economic growth, scientific and technological progress, innovation factors, production function, Solow balance, industrial regions

JEL: B41, C00, O10

Introduction

According to J.A. Schumpeter [2021], innovation is a historically irreversible transformation in the way things are produced. In other words, innovation is the result of investing in the development of new knowledge, innovative ideas for updating various spheres of people's lives and the subsequent process of implementing them, with a fixed value added (profit, lead, leadership, priority, radical improvement, quality advantage, creativity, progress). Innovative processes arise as a result of deviation in the movement of social and economic system from the planned trajectory under the influence of external and internal factors. Therefore, the innovation process is a social, technical and economic process, which, through the identification of social needs, leads to developing new scientific and technical products, the practical use of which contributes to the socio-economic system's development and supports the planned mode of its operation. Thus, the innovation process covers the entire range of activities: from identifying the need for impending change to their practical implementation in the field of application.

The state of investment and innovation as a catalyst for future economic development is a kind of a barometer of the general economic situation and socially expected transformations in society. In the modern period of the productive forces' rapid development, innovation is the main driving force of the dynamic development of social production. Concepts such as "innovation", "innovation processes", "innovation activity", "innovativeness" are firmly entrenched in our lives. However, the questions remain unanswered: what is innovativeness in a strict, mathematical sense, confirmed by quantitative measurements of innovation availability: "yes" or "no", as a percentage of annual growth among other macro factors, the level of innovation as a share of innovation contribution to GDP growth and its efficiency?

The main tool for estimating the contribution of innovative factors to economic growth is the model of the aggregate supply function, usually based on the Cobb-Douglas production function in its various modifications. Moreover, in most publications, the innovative contribution to economic growth is identified with the definition of the impact of scientific and technological progress (STP). STP is recognized worldwide as one of the main factors of qualitative transformations in the economic system and the most important factor of economic growth and development. Neoclassical theory of innovation was further developed in the framework of the innovation theory by J. Tinbergen, who substantiated the operation mechanism of an exogenous (one that is introduced into the system from the outside) factor - STP - i.e., technical-technological and organizational-managerial innovations based on statistical application of Cobb-Douglas production function, where γ is the rate of STP. The rate of STP is determined by the “Solow balance” method and is equal to the difference between the quantity of output growth (or GDP) and the quantity whose increase is explained by capital and labour growth (as well as production technology - GDP share in output), and serves as a measure of ignorance of economic growth causes. In the production function, the rate of STP (γ) is present as an indicator of the degree of the member, which determines the STP contribution to output or GDP, in other words - the total factor productivity, which increases or decreases the impact of other macro-factors. If the rate of STP is negative, then the total factor productivity is less than one, if positive - more than one. As an indicator, there can be used either the root cause - the rate of STP, or its result - the total factor productivity; at the same time threshold values change. Such works include the following studies [Solow, 1991; Denison, 1962; Oppenlander, 1980; Caldor, 1957; Hesse, 1969; Brinkman, 1970; Uhlau & Rall, 1970; Tinbergen & Bos, 1967; Welfe, 2002].

There are also other numerous attempts to determine the impact of innovation factors on economic development and economic growth. Such publications comprise [Abazov, 2021; Aleksander et al., 2020; Arefieva et al., 2021; Boiko et al., 2019; Bogachov, et al., 2020; Borychowski et al., 2020; Chygryn, et al., 2020; Cyfert et al., 2020; 2021; Czakon et al., 2020; Czyżewski et al., 2019; 2020; Dalevska et al., 2019; Dementyev & Kwilinski, 2020; Dementyev et al., 2021; Dyduch, 2019a; 2019b; Dzwigol, 2019a; 2019b; 2020a; 2020b; 2021a; 2021b; 2021c; Dzwigol & Wolniak, 2018; Dzwigol & Dźwigoł-Barosz, 2018; 2020; Dzwigol et al., 2020; Gorynia, 2019; Gorynia et al., 2019; Hysa et al., 2020; Kaźmierczyk & Chinalska, 2018; Kharazishvili et al., 2021a; 2021b; Khrapkina et al., 2021; Koibichuk, 2021; Kondratenko et al., 2020; Kuzior et al., 2019; 2021; Kwilinski, 2018a; 2018b; Kwilinski et al., 2019a; 2019b; 2020a; 2020b; 2020c; Kwilinski & Kuzior, 2020; Kyrylov et al., 2020; Lyulyov & Pimonenko, 2017; Lyulyov et al., 2018; 2020a; 2020b; 2021a; 2021b; 2021c; Maradana et al., 2017; Mlaabdal et al., 2020; Miskiewicz, 2018; 2019; 2020a; 2020b; 2021; Miśkiewicz & Wolniak, 2020; Melnychenko, 2019; 2020; 2021; Polcyn, 2018; Pająk et al., 2016; 2017; Pisarenko et al., 2015; Prokopenko & Miskiewicz, 2020; Saługa et al., 2020; Savchenko et al., 2019; Tkachenko et al., 2019a; 2019b; 2019c; Trąpczyński et al., 2019; Xu & Li, 2020; Wang & Miao, 2021; Van der Waal et al., 2021; Wang & Lu, 2020; Zastempowski et al., 2020].

Based on Lucas's theory of endogenous growth [Xu & Li, 2020], there is used a panel data model and spatial econometric methods to study the relationship between innovative human capital and provincial economies (regional economies with varying degrees of openness).

The article [Wang & Miao, 2021] focuses on evaluating people's living standards and well-being in the context of broader economic growth and technological innovation, as well as political discussions through technology criticism. For such an evaluation, a network analysis of short-term destructive aspects of technological change is proposed. It is noted that the attitude of economic analysis to communication and cultural technologies and public policy is the role of innovation in promoting economic growth and gaming opportunities. The results of this study will determine the impact of continuous development.

The study [Van der Waal et al., 2021] provides an idea of technical innovations related to sustainable development goals, while comparing it with the disclosure of sustainability information allows a better understanding of the strategic coherence between the two topics and to judge the latter. Moreover, innovation efforts can be quantified by R&D expenditures or intellectual property rights. The article expresses an important opinion that there are no single memories of what exactly sustainability means, how it can be achieved and what types of innovations can be called sustainable. The main outcome of this research is to determine the largest MNEs relevant for the purposes of sustainable development of innovations using a new methodology based on content analysis and patents using multidimensional regression analysis.

The article [Wang & Lu, 2020] attempts to explain the impact of structural change on innovation, using a combination of A. Schumpeter's views on innovation and S. Kuznets theory of delay on structural change. Using a global sample from 1970 to 2012 for a group of 75 developed and developing countries using physical instruments (2SLS) and a systematic GMM assessment methodology, the authors find a significant positive effect of the services sector share and a significant negative impact of the agricultural sector share on innovation.

The study [Hysa et al., 2020] identifies the main components of a closed-loop economy that contribute to sustainability and development, examines the impact of these variables on the economic growth of the European Union (EC 28), and checks whether three components of sustainable development (economic, social and environmental) are important for economic growth. The main toolkit of the study is multidimensional regression analysis. The main findings of the research are the confirmation of the positive impact of circular economy indicators and sustainable development indicators (economic, social, environmental) on economic growth, as well as the proof of the need for innovation and cooperation among academia, government, business and civil society. The conclusions are so trivial that you do not need to go to a fortune teller. However, there is no answer to the question: what is the increase (in%) of innovation factors and its share in the economic growth of each of the 28 EU countries?

The article [Maradana, et al., 2017] is devoted to studying the long-term relationship between innovation and economic growth per capita in 19 European countries for the period of 1989-2014. The main research tool is regression models. This study applies six different indicators of innovation: resident patents, non-resident patents, research and development costs, research and development scholars, high-tech exports, as well as articles in scientific and technical journals to study this long-term relationship with economic growth per capita.

Usually, economic development is studied in the long run, with its leading structural indicator being GDP per capita, which reflects the average income per capita without differentiating its distribution by population groups (as the average temperature in the hospital). According to this indicator, countries are divided into developed and developing ones. GDP per capita can be both in nominal and real (taking into account the GDP deflator) monetary terms. Thus, economic development is a multifactorial process that reflects the interaction of many factors of supply and demand, changes in all spheres of the country's economic life, so it can be productively analysed only in the long run, as done in the article. In the short run, economic growth is measured by *the annual growth rate in percentage* relative to the previous period, for which the nominal GDP of the current period is translated into the real one using the GDP deflator of the current period and refers to the nominal GDP of the previous period in percent.

There are also comments on the explanation of indicators in table. 1.

- "GDP – economic growth per capita: economic growth of the country's economy, expressed in gross domestic product per capita." From this definition, it is unclear what GDP means: nominal, real, or as a percentage growth rate?
- "RDE – research and development expenses: expressed as a percentage of real gross domestic product." Thus, nominal GDP is translated into the real one, divided by the GDP deflator of the current period. Since research and development expenses are usually published by government statistic bodies in current (nominal) prices, to determine this ratio, these costs must also be translated into real terms using a research and development cost deflator. If this is not done, all further conclusions and recommendations do not make sense because they are inadequate.

- "THE – high technology exports: expressed as a percentage of real gross domestic product." A similar remark, i.e., high-tech exports, should also be translated into real terms using the high-tech export deflator.

Using the Granger causality test, the study [Maradana, R.P. et al., 2017] reveals the existence of both one-way and two-way causal link between innovation and economic growth per capita. It should be noted that the use of the Granger causality test is not a panacea for all problems. First, the Granger test for causality is a procedure to check the causal (non-causal) relationship between time series. That is, Granger causality is a necessary but insufficient condition of causation.

In this study, the authors use both types of innovation indicators: *costs* and *results*, i.e., *causes* (costs of research and development, researchers engaged in R & D) and the *outcome* of innovation activity (patents filed by residents, patents filed by non-residents, high technology exports, articles in scientific and technical journals and, finally – GDP per capita). Thus, in the study, the outcomes of innovation activity, that is, the consequences, again act as the causes of innovation activity, which affects the global result – GDP per capita, which contradicts the concept of causality according to Granger.

That is, under the influence of a reason (R & D costs, researchers engaged in R & D, and others) there occurred an innovative activity that led to an increase in patents, high technology exports and articles in scientific and technical journals, which was reflected in GDP. To use a repeated consequence as a new cause of the same research is nonsense. In fact, there are a lot more reasons for innovation than the authors of the article think. To determine the impact of innovation factors (and any others) on GDP, there are powerful macroeconomic models of general economic equilibrium, for example [Kharazishvili et al., 2013]. Therefore, the use of much more simplified regression models without confirming their adequacy (R2> 0.9) and predictive capacity (determining the forecasting horizon with a given error) is questionable. It is expedient to use together both types of indicators (costs and outcomes) at an integrated estimation of innovative activity [European Innovation Scoreboards, 2020; Kharazishvili et al., 2021a; Kharazishvili et al., 2021b].

The work of the Ukrainian Institute of Scientific, Technical and Economic Information [Pisarenko et al., 2015] is noteworthy as it considers various methodological approaches to evaluating the impact of innovation activity on economic growth: *method of constructing integrated indicators* refers to international indices, such as innovation capacity index, knowledge economy index, global innovation index and others; *method of expert estimates* – the most commonly used methods are peer review, round table, brainstorming, Delphi, foresight; *method of the system of indicators* – such a system should monitor the progress towards the set goals and evaluate the actions' effectiveness; *methods using econometric models* based on the use of econometric models, in particular the Cobb–Douglas function, which allows determining the influence of individual factors on the overall GDP growth. Another approach proposed by the authors is the multiplier method for estimating the impact of innovation on economic development in Ukraine.

Of the four proposed methods, only one (the latter) is theoretically suitable for determining the impact of innovative factors on economic growth. Others are useful to determine the impact on economic development.

Thus, the purpose of the article is to develop a modification of the Cobb–Douglas function in the aggregate supply model to evaluate also separately the innovative contribution to economic growth along with the contribution of labour costs, capital costs and STP.

A Methodological Framework of the Study

As a result of generalizing examples of applying the Cobb-Douglas production function for estimating the innovative contribution to economic growth, there were revealed remarks that concern using: in the left part of the equation, not GDP, but output; labour costs, not the number of workers or man-hours worked; the effective number of taxpayers, not total employment; the transferred capital taking into account the GDP deflator, consumption of fixed capital and investments of previous periods; capital utilization ratio; dynamic coefficients of elasticity [Kharazishvili, 2018, pp.8-9].

Taking into account the revealed remarks, the model of the aggregate supply function is based on the neoclassical Cobb–Douglas production function with a return sustainability on scale in the form of J. Tinbergen [Tinbergen, 1967], with Hicks-neutral technical progress, decreasing marginal productivity of macro-factors with limitations of their interchangeability. This approach, taking into account the identified remarks, provides a causal functional (rather than statistical) relationship between input and output variables, is characterized by dynamic coefficients of elasticity, capital utilization ratio and allowing for the innovation factor in each period [Kharazishvili & Liashenko, 2021c, p. 10]:

(1) $$V_t^S(P_t) = e^{\gamma t}\left[\xi_t N_t(P_t)\frac{W_t}{P_t}k_{sn}\right]^{a_t}(\vartheta_t K_t)^{1-a_t-\beta_t}\left(\frac{G_{in,\,t}}{P_t}\right)^{\beta_t};$$

where V_t^S is the actual output of aggregate supply; $e^{\gamma t}$ is scientific and technological progress (STP); γ is STP rate; $\xi_t = N_{ef,t} / N_{zag,t}$ is the share of the effective number of taxpayers in total employment; $N_{ef,t}$ is the effective number of taxpayers (hired employees plus another category of employees, reduced to the equivalent of hired employees for all taxes and wages); $N_{zag,t}$ is overall employment; $N_t(P_t)$ is the function of optimal demand for labour, determined from the condition of value equality of the marginal product of labour to the nominal wage rate; W_t is average annual nominal wages of hired employees; $k_{sn,t}$ is a coefficient of social loads; ϑ_t is capital utilization ratio; K_t is capital costs; α_t is a coefficient of elasticity at labour costs; β_t is a coefficient of elasticity at innovation costs; $1-\alpha_t-\beta_t$ is a coefficient of elasticity at cost of capital; $G_{in,t}$ is nominal innovation costs; P_t is GDP deflator; *t* is the period of time.

In equation (1), to determine GDP instead of output, such a transition is provided by taking into account the coefficient of manufacturability (σ_t), which in each period is determined by the ratio of GDP to output according to the macroeconomic identity "*output equals the sum of intermediate consumption and GDP*":

(2) $$GDP_t(P_t) = \sigma_t V_t^S(P_t)$$

Thus, the production function, along with the cost of labour and capital, takes into account the costs, which, in our opinion, reflect the reason (gross internal costs of R & D, innovation costs and total education costs) of the output (consequence) of innovation:

(3) $$G_{in,\,t} = G_{NDR,\,t} + G_{in.vit,\,t} + G_{osv,\,t}$$

where $G_{NDR,\,t}$ is the nominal amount of gross domestic expenditure on R & D; $G_{in.vit,\,t}$ is the nominal amount of innovation costs; $G_{osv,\,t}$ is the nominal amount of total education expenditures.

Formalized equations of the macro-factors' contribution to economic growth are obtained using the method of *"Solow residual"*, namely, through logarithmization and obtaining logarithmic derivatives (in the following formulas to simplify them, the time symbol t is omitted, but implied):

(4)
$$\ln V = \gamma t + a(\ln \xi + \ln N\, 0{,}001 + \ln W - \ln P + \ln k_{sn}) + (1 - a - \beta)(\ln \vartheta + \ln K) + \beta(\ln G_{inn} - \ln P);$$

(5)
$$\frac{d\ln V}{dt} = \frac{\dot{V}}{V} = (\gamma + \dot{\gamma} t) + \dot{a}(\ln \xi + \ln 0{,}001N + \ln W - \ln P + \ln k_{sn}) + \\ + a\left(\frac{\dot{\xi}}{\xi} + \frac{\dot{N}}{N} + \frac{\dot{W}}{W} - \frac{\dot{P}}{P} + \frac{\dot{k}_{sn}}{k_{sn}}\right) - \dot{a}(-\beta)(\ln \vartheta + \ln K) - \dot{\beta}(-a)(\ln \vartheta + \ln K) \\ + (1 - a - \beta)\left(\frac{\dot{\vartheta}}{\vartheta} + \frac{\dot{K}}{K}\right) + \dot{\beta}(\ln G_{inn} - \ln P) + \beta\left(\frac{\dot{G}_{inn}}{G_{inn}} - \frac{\dot{P}}{P}\right),$$

where $\frac{\dot{V}}{V}$, $\frac{\dot{\xi}}{\xi}$, $\frac{\dot{N}}{N}$, $\frac{\dot{W}}{W}$, $\frac{\dot{\vartheta}}{\vartheta}$, $\frac{\dot{K}}{K}$, $\frac{\dot{P}}{P}$, $\frac{\dot{G}_{inn}}{G_{inn}}$, $\frac{\dot{k}_{sn}}{k_{sn}}$ are rates of the corresponding variables; $\dot{\gamma}$, $\dot{a}$, $\dot{\beta}$ are derivatives of the STP rate (acceleration) and coefficients of elasticity at labour costs and innovation costs (N is set in million people, W is UAH per year; all other values are in billion UAH).

The growth rates of these variables are calculated using the appropriate deflators of the current (for output and wages) and previous (for capital) periods. Therefore, the STP contribution to the growth rate of output materialized in labour makes (6),

(6)
$$Tempo\_L = \dot{a}(\ln \xi + \ln 0{,}001N + \ln W - \ln P + \ln ksn) + \left(\frac{\dot{\xi}}{\xi} + \frac{\dot{N}}{N} + \frac{\dot{W}}{W} - \frac{\dot{P}}{P}\right);$$

TP materialized in capital (10):

(7)
$$Tempo\_K = \dot{a}\beta(\ln \vartheta + \ln K) + \dot{\beta} a(\ln \vartheta + \ln K) + (1 - a - \beta)\left(\frac{\dot{\vartheta}}{\vartheta} + \frac{\dot{K}}{K}\right);$$

STP materialized in innovations (8):

(8)
$$Tempo\_Innov = \dot{\beta}(\ln G_{inn} - \ln P) + \beta\left(\frac{\dot{G}_{inn}}{G_{inn}} - \frac{\dot{P}}{P}\right).$$

Knowing the contribution of each factor to the economic growth of output or GDP, it is possible to determine the rate of STP for the equation of GDP or output:

for the GDP equation:

(9)
$$Tempo\_STP = Tempo\_GDP - Tempo\_L - Tempo\_K - Tempo\_Innov - Tempo\_\sigma;$$

for the output equation:

(10)
$$Tempo\_STP = Tempo\_V - Tempo\_L - Tempo\_K - Tempo\_Innov;$$

All these defined equations are an appendix to the equations of the aggregate supply function model, in which all the necessary macro indicators are calculated [Kharazishvili, 2006, pp.62-64].

Results Modelling

The developed methodology for estimating the innovative contribution to economic growth is universal and can be applied to any country, region or type of economic activity. As an example, the areas of the Podilia economic territory of Ukraine were selected: Vinnytsia and Khmelnytskyi regions. After performing the relevant calculations, there were obtained estimates of the macro-factors' quantitative contribution to GRP economic growth as a percentage increase.

The 2001-2020 average results of their impact on the economic growth of these regions of Ukraine are given in Table 1.

Table 1 Average annual values of the contribution of production factors to GRP growth*

% Increase per year

Regions	*GRP Gross regional product*	*STP*	*L Labour*	*K Capital*	σ *manufacturability coefficient*	*Innovation*
Vinnytsia	**4,014**	-3,825	4,014	2,802	0.366	**0.515**
Khmelnytskyi	**3,083**	-5,59	4,548	2,509	0.695	**0.949**

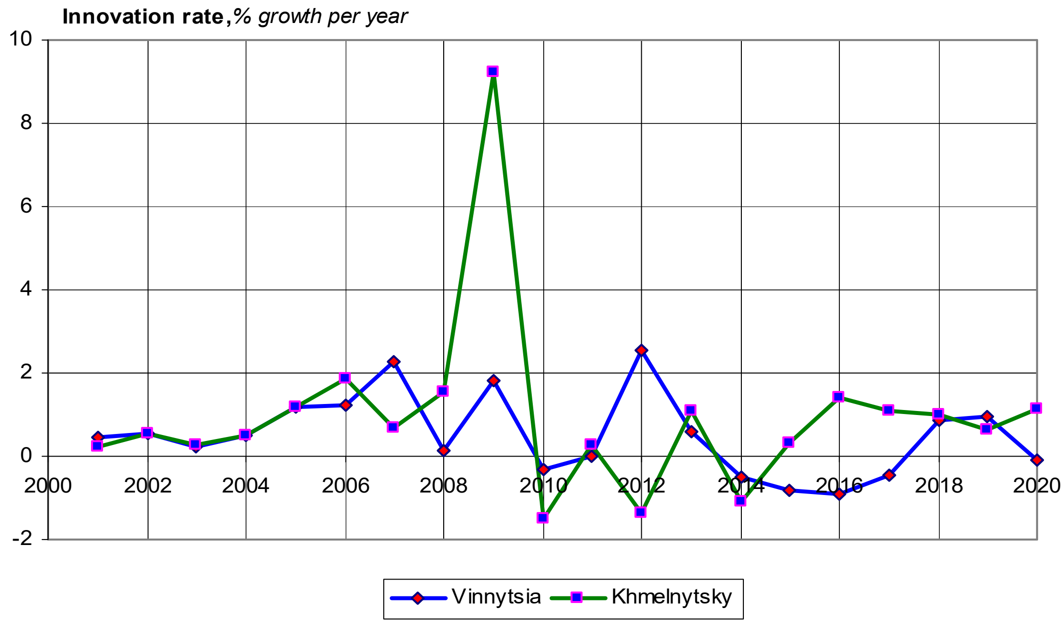
** Calculated by the authors.*

Analysis of the dynamics of the average annual (over 20 years) contribution of production factors to the GRP growth rates in the determined regions of Ukraine shows that the greatest impact on the positive GRP growth was exerted by (in the appropriate sequence):

- in Vinnytsia region: labour costs, capital costs, innovation factors, manufacturability;
- in Khmelnytskyi region: labour costs, capital costs, innovation factors, manufacturability;

Unfortunately, for the determined period, in the considered regions of Ukraine, STP had a negative contribution, i.e., it reduced the return from macro factors. The dynamics of the innovative factors contribution to the GRP economic growth in the regions of the Podilia economic territory of Ukraine is shown in Fig. 1.

Figure 1. The dynamics of the innovative factors' contribution to the economic growth of GRP.



The most promising, high-quality and long-term factors of influence are innovation factors, on which the latest technological developments, the efficiency of innovation results and the transition to a higher technological structure depend. It can be argued that no country or government can be competitive without scientific support, which in turn is achieved through adequate R&D funding, innovation and education spending, and investment in human capital.

Given the calculations done, an important question arises: what percentage of GRP economic growth is provided by innovative factors? Since both the innovative contribution to the economic growth of GRP (annual growth rate) and the growth rate of real GRP in a given period can be both positive and negative, there are four options for calculating this impact (12) (Fig. 2).

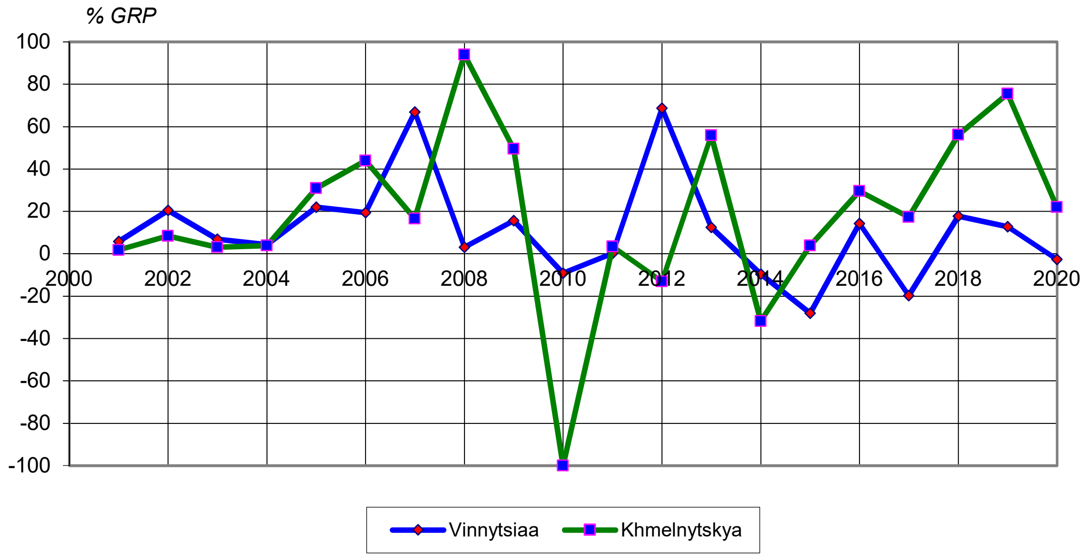
Innovative factors, averaged over 20 years, affect the economic growth of the Podilia economic territory, which is limited to the contribution of 0.52-0.95% growth of real GRP and is reflected in the following *average* percentage contribution to GRP growth:

- Vinnytsia region - 11.1%;
- Khmelnytskyi region - 18.5%;

$$R_{innov,t} = \begin{cases} \dfrac{Tempo\_Innov_t}{Tempo\_GDP_t} \cdot 100\%, \text{ if a } Tempo\_Innov_t > 0, Tempo\_GDP_t > 0; \\ \dfrac{Tempo\_Innov_t}{Tempo\_GDP_t + |Tempo\_Innov_t|} \cdot 100\%, \text{ if a } Tempo\_Innov_t < 0, Tempo\_GDP_t > 0; \\ \dfrac{Tempo\_Innov_t}{|Tempo\_GDP_t| + |Tempo\_Innov_t|} \cdot 100\%, \text{ if a } Tempo\_Innov_t > 0, Tempo\_GDP_t < 0; \\ \dfrac{Tempo\_Innov_t}{|Tempo\_GDP_t|} \cdot 100\%, \text{ if a } Tempo\_Innov_t < 0, Tempo\_GDP_t < 0; \end{cases} \quad (12)$$

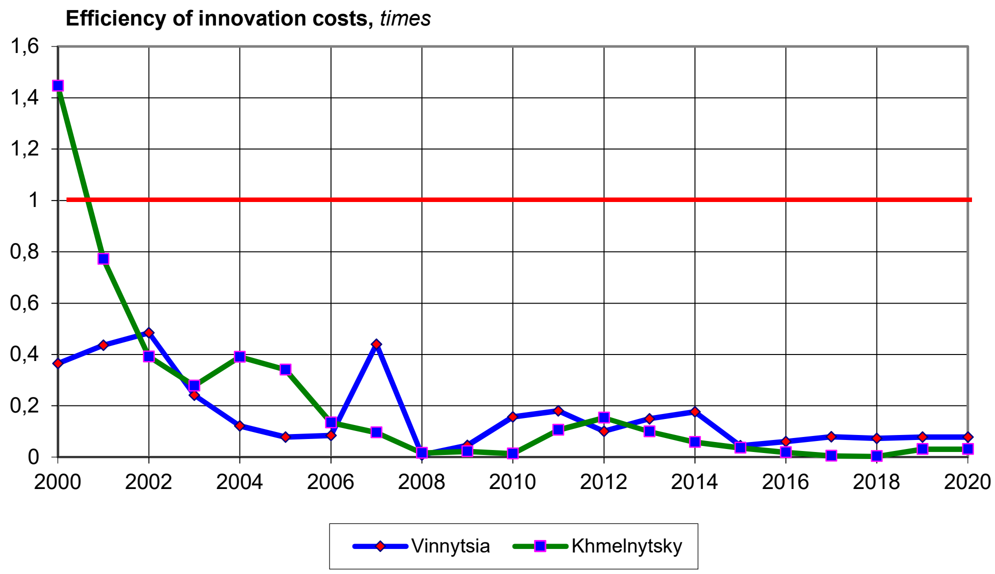
where $R_{innov,t}$ is a share of innovation contribution to GRP economic growth, %.

Figure 2. The share of innovation in the economic growth of GRP.



The effectiveness of costs on innovation factors can be assessed by the ratio of the effect obtained from innovation activities (volume of sold innovative products) to the total cost of innovation factors: (Fig. 3).

Figure 3. Efficiency of innovation costs in the regions of Ukraine



Obviously, if this indicator is more than one, innovative investments can be considered effective. Unfortunately, the effectiveness of innovation costs of the Podilia economic territory for the last 10 years is approaching zero. Moreover, the dynamics of this indicator correlates with the dynamics of the share of wages in output and, accordingly, with the shadowing of the economy, because it is hired employees who are the authors of innovative solutions, and their wages are an incentive to innovate.

Discussion

The analysis of most scientific papers on determining the innovative contribution to economic growth is actually focused on determining this impact on economic development in the long run. This conclusion is confirmed by the final indicator of impact - GDP per capita, which characterizes the overall development in the long run. Different approaches are used for this definition, such as the toolkit of regression equations, the method of constructing integrated indicators, the method of the system of indicators, the method of expert evaluations, the method of multipliers.

The analysis of the approaches used revealed a set of remarks on econometric methods. Unfortunately, correlation-regression analysis of the relationships among macro indicators allows identifying only the average pattern and does not provide strict and accurate correspondence in each case, and only an average correspondence can be observed. Hence there is a low accuracy of such models. Expert assessments are full of subjectivity and do not rule out fundamental errors.

In the short run, economic growth is measured by *annual growth rates as a percentage* relative to the previous period. Based on the analysis of the quantitative assessment of the innovation impact on the dynamics of economic development and determining its endogenous contribution to economic growth, it was found that in foreign publications, it is identified with determining the impact of scientific and technological progress. The main toolkit of this determination is the Cobb–Douglas function in its various modifications, for which a number of remarks are outlined. In this case, the impact of innovation factors on economic growth is not considered separately.

In contrast, there is proposed an approach based on the neoclassical Cobb–Douglas production function with a return sustainability on scale in the form of J. Tinbergen, with J. Hicks-neutral technical progress, declining marginal productivity of macro factors with limited interchangeability, which provides a causal functional (rather than statistical) relationship between input and output variables, which does not require long time series, is characterized by dynamic coefficients of elasticity, capital load factor and the ability to take into account the innovation factor in each period.

In addition to STP, labour costs and capital costs, the expansion of the Cobb-Douglas production function also includes an innovation factor, which comprises: the volume of gross domestic expenditure on R&D, the volume of innovation expenditures, the volume of total education expenditures. To determine the contribution of the innovation factor to economic growth, the "Solow balance method" is used, which, through logarithmization and obtaining logarithmic derivatives in the production function, allows obtaining formalized information about the contribution of each factor to economic growth and developing necessary regulatory measures.

Innovative factors of Podilia economic territory (Vinnytsia and Khmelnytskyi regions), averaged over 20 years, have an impact on economic growth, which is limited to the contribution of 0.515-0.949% of real GRP growth and is reflected in the *average* percentage contribution to GRP growth: Vinnytsia region - 11.1%; Khmelnytskyi region - 18.5%. To calculate the percentage contribution, calculation formulas are derived for all possible cases of the ratio of the growth of innovation factors to the increase of economic growth. To determine the innovation effectiveness, there is calculated the ratio of the volume of innovative products sold to the total cost of innovation, which shows a very low efficiency. The low efficiency of innovation indicates the absence of a causal link between the cost of innovation and its results, or low costs of innovation. Hence the question arises: what should be the funding of innovation to obtain the desired effect?

The proposed method of expanding the Cobb-Douglas production function by including labour costs, capital costs and innovation factor in addition to the macro factors of STP is universal and can be applied to any country, region or type of economic activity. Its application allows obtaining the necessary information on the current impact, which is the basis of strategic planning and development of appropriate strategic scenarios.

The research topic to follow may be a scientific justification of the necessary values of innovation factors to achieve the desired level of GRP growth and the level of innovation. The tool of such research can be methodology of strategizing, which uses the principle *"the future is determined by the trajectory into the future"* instead of the principle of classical forecasting, "the past determines the future" [Kharazishvili, 2019].

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