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Innovativeness and Company Innovation Index – Theoretical and Methodological Aspects

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Dimiter Blagoev[*] [1]

Abstract

The report examines the impact of all types of innovations on the overall level of innovation capacity and innovativeness of companies. Special and main attention is paid to the methodological aspects of innovativeness and innovation capacity function at company level. The innovations are presented as a part of the so called innovation capacity function. This function determines the companies' innovation capacity, and the last strongly affects the production output, described by the production function.

We considered a basic theoretical approach for the innovations, and applied it to evaluate the innovation index and innovation capacity for companies of industry (but not only). On that base, the innovation development of a companies can be traced for a long period of time in the past (using monthly or annual data). In order to perform the analysis different kind of relevant data can be used, provided by the National Statistical Institute and Eurostat.

Our main statement is that in an uncertain and unstable economic environment, innovations can be successfully used to ensure economic stability and production growth. On the other hand, using a function and index to evaluate the innovativeness of companies can be useful for establishing their position in the market (in terms of their innovativeness) and developing future innovation strategies.

There are already some innovations (product, technological, organizational) in the Bulgarian business sector, but they are of low added value. Generally, these innovations are at the regional and national level.

To ensure their development and growth, companies of the Bulgarian industry have to develop innovations with higher added value on international level. The dependence between innovations and growth can be observed in the innovativeness function.

Keywords: innovations, investments, innovativeness, production function

JEL: C50, C80, L66, O31

Introduction

The innovations topic has been attracting special attention during the past several decades. Traditionally, innovations are considered as the engine of the economy and the overall progress of humanity. Scientific research indicates that there is a direct and strong connection between the degree of

[*] University of National and World Economy, Department of Industrial Business

innovation and the development level of the economy. Most of the indexes of innovation are created for the macro- or meso-level of analysis, and very few are developed for a micro-level usage. These micro-level innovation indexes are rather conclusive than possessing a prediction capacity for the future improvement of innovations. The innovation indexes (at national and company level) are useful at least in two directions: (i) they are a marker for the company leadership and show the company position as compared to its competitors, and (ii) they can be the basis on which to rank the companies when particular funding in the innovation sphere is addressed.

The present study aims to propose a new approach, which is based on the conception of the production function and when the index of innovation is developed at a company level. This index is adaptable and can be successfully applied to meso- or macro-level analysis. To achieve our goal, we stress on innovations in the products (as the most important part of the production function). We also consider some of the well-known innovation indexes at national and sector level, and identify their key elements, which could be applied at a company level. Thus, we can develop an innovation index that is based on the Cobb-Douglas production function. In order to accomplish this goal, we use methods of observation, comparative analysis, and mathematical modeling. Using the suggested approach, we developed an innovation index at a company level. We also propose a scale for the ranking of the companies, based on their realized innovation capacity, with the help of the developed innovation index. This index can trace the dynamics in the realized innovation capacity of the companies and can be used for prediction purposes via data extrapolation. This, however, should be done only when accounting for the specific characteristics of each particular company.

Research Background

The innovations have always been an important factor for the development and growth of the companies' activities. They are particularly important in an unstable economic environment and in times of financial and economic crises. The major role, among all types of innovations, is played by product innovations. Anyway, they are closely related to the other types of innovation in an enterprise - technological, organizational, etc.

Fundamentals and peculiarities of innovations and their role in innovation activities of the companies – Theoretical consideration and empirical data.

Innovations, e.g. product innovations, organizational innovations, technological innovations, etc., are all mutually related. Creation of new or modifying of existent products often requires an improvement of already applied technologies or the development of entirely new ones. And vice versa, development of new or improving known technologies is generally a prerequisite for obtaining new or significantly modified products or services.

The development and marketing of new products, services and technologies, are fundamental factors for the improvement in the economic activities of the industry sector companies, and for the rise in their competitive capacity. They are also important factors for balance regulation of current selling positions and profits, and the respective selling, marketing and profitable potential of the companies in the future. Products can be classified as new, according to market conceptions, or definitions of the companies

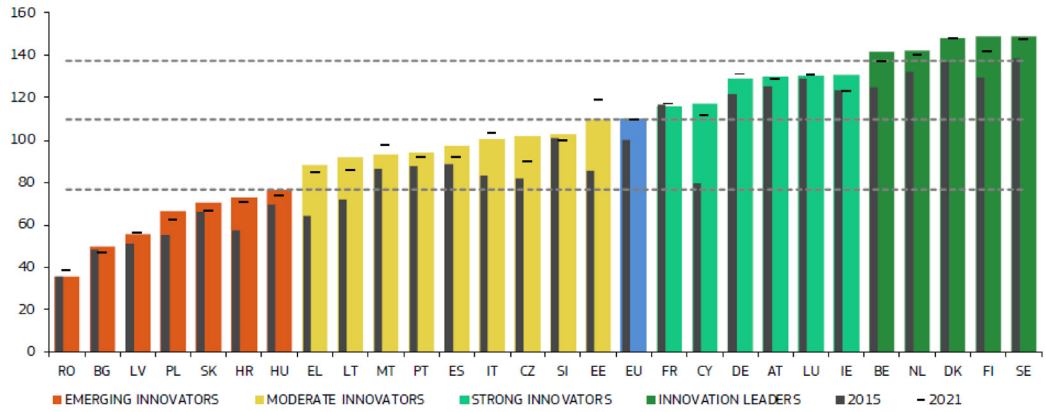

Figure 1. Innovation capacity of EU countries (resp. companies) 2021 compare with 2015

Source: Hollanders, H., Es-Sadki,N. and Khalilova, A. (2022). European Union Innovation Scoreboard, Luxembourg: Publications Office of the European Union, p. 7

themselves. As a result, we have (Georgiev, Tzvetkov & Blagoev, 2013): New products for the world market; New products for distinct countries or regions; New products for a given company.

Based on this classification we could have different cases, which could be distinguished on the basis of the amount of resources needed for their realization and the very enterprise risk evaluation.

Enhancement in the companies' innovation capacity through realization of product innovations.

There is a trend for a slow enhancement in the innovation capacity of Bulgarian companies. No upward tendency was observed 15 years after Bulgaria became a member of EU. That determines in turn their low competitive capacity on European markets and represents a reasonable challenge in terms of the long term economic growth of Bulgaria (Figure 1). The innovation capacity of Bulgarian companies (small, medium-sized or large) is 2-3 times lower compared to the average innovation capacity of EU companies. And what is worse is that this trend is maintained throughout the years of the country's membership in the EU. Bulgaria has consistently been classified as an emerging innovator. Together with Romania, the country ranks in one of the last places in terms of innovativeness of the economy (respectively of companies) (Hollanders, H., Es-Sadki,N. and Khalilova, A., 2022)

Bulgarian companies' innovation capacity is focused mainly on product innovations, as these regard mostly new products for a company itself or its current market. A very small part of this type of innovation is defined as new for the world market (Figure 2 and Figure 3).

There is a trend of increasing the innovation activity of companies. The share of types of companies in realized different types of innovation for 2021 can be seen in Table 1.

All of the other types of innovations, e.g. process innovations, organizational innovations, and marketing innovations share a minor part of the innovation capacity. Some of the companies do not focus on a single innovation type, but combine several types to obtain a synergic effect. Unfortunately, these

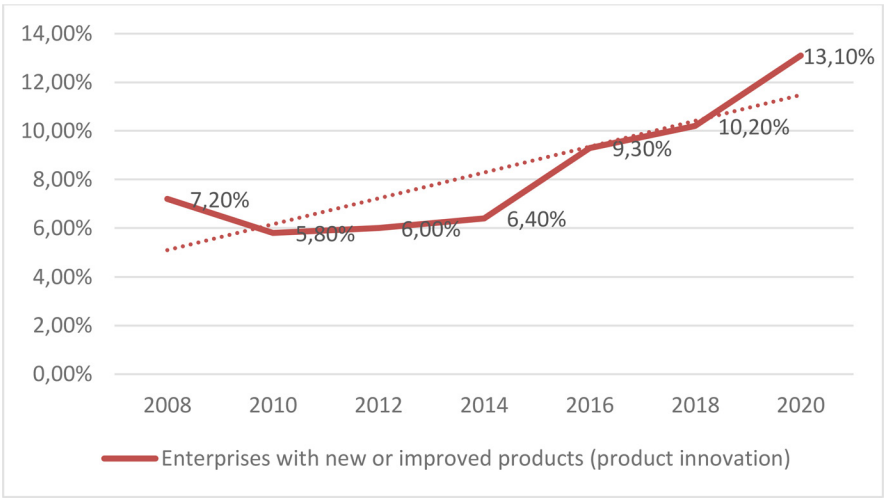

Figure 2. Share of companies that implemented product innovations
Data Source: National Statistical Institute

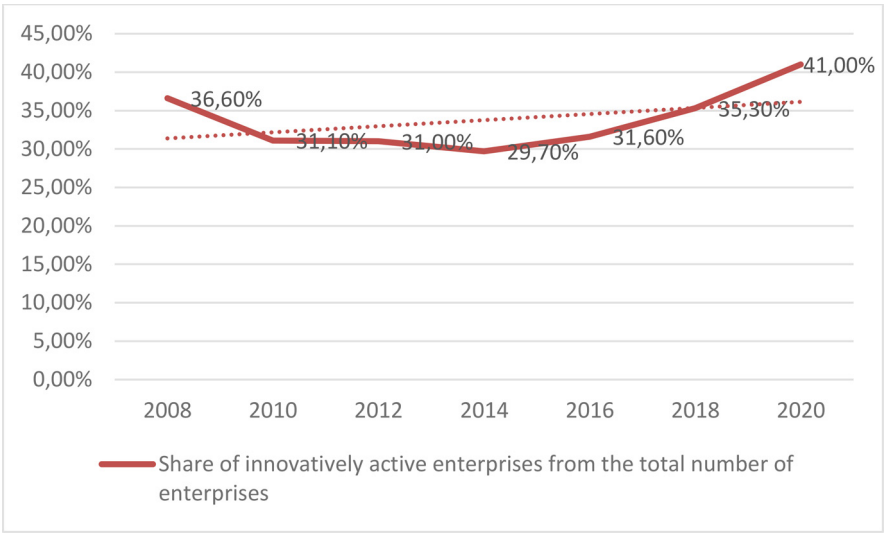

Figure 3. Share of innovatively active companies from the total number of companies
Data Source: National Statistical Institute

companies represent a negligible part of all the companies involved in industry, which results in their products having a quite low added value.

Although the innovation capacity of Bulgarian companies is relatively low, more and more companies realize the crucial role of innovations for their competitiveness, and that the competitiveness of single companies would result in overall competitive knowledge-based Bulgarian economics. Moreover, innovations explicitly define the margins of production capacity, and higher capacity

Table 1. Type of innovation and innovation companies in Bulgaria

Innovation companies	Total	Micro companies	Small companies	Medium-sized companies
	%	%	%	%
Product innovations	21.76	19.52	31.29	40.74
Process innovations	10.79	8.13	19.63	38.27
Organizational innovations	14.98	10.67	38.65	40.74
Marketing innovations	4.56	2.25	17.18	18.52
Total	33.29	30.12	47.85	58.02

Data Source: National Statistical Institute and Eurostat

means higher productivity and lower resource consumption.

All these factors determine the need to measure the innovativeness at the company level, as it is measured at the national level. At the same time, almost all used indices to measure innovativeness are on macro or mezzo level. Companies evaluate their innovation and innovativeness rather intuitively than based on any mathematical (or statistical) methods. In practice, there are many macro-level indices to evaluate the innovativeness of national economies, which we can refer to in determining the index for evaluation of the innovativeness at the company level.

Existing indexes for assessment of the innovation

As mentioned in the Introduction section, there exists a number of indexes for the estimation of the degree of innovation at national and sector level. There are also studies at a regional level. For example, Beynon, Jones, and Pickernell (2023) have published a study that deals with the innovation willingness of different regions in Europe. Most of the existing innovation indexes cannot be applied directly at a company level, because they contain some specific indicators, which are essential only in the macro frame of a given country or a large region. However, we can analyze these indexes and adapt some of their key elements to a company level.

European Union Scoreboard (EUS).

European Union Scoreboard is the formerly (and recently) used name for the European Innovation Scoreboard (EIS) (Georgiev, Tzvetkov & Blagoev, 2013).

The methodology of the innovation scoreboard relies on measuring 29 indicators for 8 distinct scopes, and they are arranged in 3 basic groups (Hollanders, H., Es-Sadki, N. and Khalilova, A., 2022): *Friendly infrastructure:* represented by the main motive forces for the innovation activities, which are also company-independent elements – "Human resources", "Open and attractive investigation system", and "Funding and support"; *Innovation activities at a company level* are grouped in: "Investments", "Networks and enterprise", and "Intellectual property"; *Innovation activity outcomes are measured in two aspects.* The first defines a company as an innovator, and the second is connected to the achieved economic effects (*** Innovation Union Scoreboard – IUS).

The scoreboard is generally used for assessing the innovations on a macroscale (national level), but under certain

circumstances it might be adapted to measure the innovation on a microscale (company level).

Based on their innovative capacity, the nations included in the investigation are divided into four groups: “Leading innovators”, “Strong innovators”, “Moderate innovators” and “Emerging innovators” (In the previous version of the index: “Innovation leaders”, “Innovation followers”, “Moderate innovators”, and “Modest innovators”).

As mentioned above, the scoreboard for 2022 shows that Bulgaria falls into the group of emerging innovators with poor innovation capacity. It is next to the last among the countries participating in the scoreboard. Bulgaria has relatively good positions with respect to “Digitalization”, “Intellectual assets”, “Sales impacts”, and “ Innovators”. The weak sides are observed at “ Firm investments”, “Use of information technologies”, and “ Finance and support” (***European Innovation Scoreboard, 2022).

Global Innovation Index

The Global Innovation Index (http://www.globalinnovationindex.org/gii/) has been developed by both INSEAD – The Business School for the World and World Intellectual property organization (WIPO). It was launched in 2007 and accounts for the key role of innovations for the economic growth, prosperity and future policies of the emerging markets (***Global Innovation Index, 2011).

The main purpose of the Index is the development of a constantly evolving project that aims to become a quantitative measurement which will define innovation in a more sophisticated way by surpassing the traditional conception of innovation, measured for example by the number of PhD students, number of published research papers, built research facilities, number of patents, funding of research departments, etc.

The Global Innovation Index (Dutta, S., Lanvin, Br., Rivera, L., at al., 2022, p.89) is composed of two sub-indexes: Innovation Input Sub-Index and Innovation Output Sub-Index. Each of them is structured around key pillars. There are five input pillars which define the favorable environment for innovation activities: (1) Institutions, (2) Human capital and research, (3) Infrastructure, (4) Market sophistication, and (5) Business sophistication. There are two main output pillars that validate the results from the innovation activities: (1) Knowledge and technology outputs and (2) Creative outputs. Each key pillar is then divided into sub-pillars, and each sub-pillar is composed of individual indicators. The score of an individual sub-pillar is calculated as the weighted average of its indicators. The main pillar score is calculated as the weighted average of its sub-pillar scores.

The calculation of GII is performed by an iterative method with the help of the following measures: Sub-index “Innovation inputs”, which is the average of the five key pillar input scores; Sub-index “Innovation outputs”, which is the average of the two key pillar output scores; Overall GII score, which is the average of sub-index “Innovation inputs” and sub-index “Innovation outputs”; An Innovation efficiency ratio, which is the ratio of the sub-index “Innovation outputs” over the sub-index “Innovation inputs”;

The approach for the calculation of GII is subjected to a revision every year in an attempt for a continuous optimization of the innovation measuring methods, taking into account eventual changes in the global economic environment. According to the Global Innovation Index, Bulgaria occupies

the 35th position in 2022 (Dutta, S., Lanvin, Br., Rivera, L., at al., 2022, p.109).

Global Competitiveness Index

The Global Competitiveness Index is used by the World Economic Forum for their annual Global Competitiveness Report (Schwab, Kl., Zahidi, S., 2020). The countries are ranked according their micro- and macroeconomic indices that now have single expression under the GCI. The last is calculated as the weighted average of a variety of variables, each measuring some property of the competitiveness. The variables are used for the estimation of three sub-indexes: sub-index "Basic requirements", sub-index "Efficiency enhancers", and sub-index "Innovation and sophistication factors". These three sub-indexes include in total 12 pillars (Schwab, Kl. & Sala-i-Martín, X., 2012; Georgiev, Tzvetkov & Blagoev, 2013); first sub-index: (1) Institutions, (2) Infrastructure, (3) Macroeconomic environment, (4) Health and primary education; second sub-index: (5) Higher education and training, (6) Goods market efficiency, (7) Labor market efficiency, (8) Financial market development, (9) Market size, (10) Technological readiness; third sub-index: (11) Business sophistication, (12) Innovation. The twelve pillars possess more than 110 indicators. Part of them are purely quantitative and are based on statistical data. They use the most recent data which sources are: The World Bank Group, United Nations Organization, The International monetary fund, The International Telecommunication Union, etc. This allows an adequate comparison between the data for different countries. A main feature of the investigation is the conduction of a social survey among representatives of the business for each of the countries included in the report.

According to the GCI report for 2022 (***IMD Competiveness Booklet, 2022), Bulgaria (GCI Score 51.36) was in the 53rd place among 63 countries. That was a rise of the GCI compared to the data from the previous report for 2011/2012 (Schwab, Kl. & Sala-i-Martín, X., 2012), when Bulgaria was in the 74th place among 142 counties. The movement of 12 positions ahead is primarily due to a global decrease of the competitiveness rather than an increase of the competitiveness of Bulgaria, because GCI represents a quite small difference.

OECD Science, Technology and Industry Scoreboard

The scoreboard of science, technology and industry of the Organization for Economic Co-operation and Development (OECD) relies on 50 years of experience in the analysis of innovations and knowledge development in the global economy. More than 180 indicators are now used to predict the main trends in science, technologies, innovations, globalization and industrial dynamics in the countries that are members of OECD, as well as non-OECD countries (notably Brazil, The Russian Federation, India, Indonesia, China and South Africa) (***OECD Science, Technology and Industry Scoreboard, 2019).

There can be distinguished the following five key areas of interest in the STI scoreboard: building knowledge, connecting to knowledge, targeting new growth areas, unleashing innovations in firms, and competing in the global economy.

The Boston Consulting Group/National Association of Manufacturers Index

The International Innovation Index (BCG/ NAM International) has been developed in 2009. It aims to measure the level of innovation both in the USA and the other

countries. The index is built upon a model using two main categories – „Innovation inputs" and „Innovation outputs". Inputs include: 1) government and fiscal policy, 2) education policy, and 3) innovation environment. The outputs are in the frame of 1) patents, technology transfer, other R&D results; 2) overall business performance and 3) impact of innovation on economic growth and society. The business performance includes mainly the labor productivity and the majority of the data is generated via inquiries and interviews. So far there is only one BCG/ NAM index that was published in March 2009.

Innovation.bg index

This is the first and currently the only project of such kind in Bulgaria. The index has been developed by the Applied Research and Communications Fund (ARC Fund) since 2004. It aims to provide a reliable assessment of the innovation performance of the Bulgarian economy and has been published annually. The index is based on five groups of indicators: (1) gross innovation product; (2) entrepreneurship and innovation networks; (3) investment in and financing of innovation; (4) human capital for innovation; (5) information and communication technologies (***Innovation.BG, 2011, p.12). The annual reports are very valuable for the policies in the innovations' sphere. As it has been published for more than 15 years, it provides a strong basis for relevant trend analyses (Georgiev, Tzvetkov & Blagoev, 2013, p. 428).

Innovations and company development

Innovations appear to be a challenge not only at a business level, but also on a national level. During the last years they have started to play an increasingly more important role, because of the unstable economic environment on a global scale.

The effective management of the innovation policies give rise to opportunities for the successful adaptation of the companies, when there are more economic risks and insecurity.

On one hand, the realization of the innovations requires a lot of technological and organizational efforts. On the other hand, the innovation policies represent a complex but quite integrated process, which relies on many prerequisites and specific aspects as qualification of the human resources, funding resources, capital value, favorable environment for research and development activities, etc.

Although there are a lot of factors that could influence different stages of the innovation process, of particular importance for the company growth and progress is its innovativity strength, which is directly linked to the company's competitiveness.

Innovations and competitiveness

The strong connection between innovations and competitiveness is a subject of investigation in many economic analyses, science forums, university courses, etc. Here, we stress on the widespread conception for the presence of a direct connection between the company's innovativity strength, the company competitiveness and the prosperity of the markets via a better satisfaction of the consumers' needs. The more efficiently a company succeeds to manage its resources to increase the innovation capacity, the more opportunities for higher competitiveness and market conquering will rise. It should also be noted that the commercial success of the companies would significantly depend on the innovation policies, which are closely

related to the capability of resolving issues with respect to the company management, production sector and product policies.

The innovativity and competitiveness of a company, a specific economic sector or the whole economy are particular characteristics, which are not intrinsic for all of the market participants. At a company level, of crucial importance are both the innovation capacity and the opportunities of its practical realization. The assessment of innovation capacity spans over several areas and is based on a group of selected indicators. Some authors suggest the following areas for assessment: ability for prediction of the technological development of the branch; ability to predict the innovation strategies of the competitors; company abilities for strategic management of the innovations, etc. (Slavova & Petrov, 1996, p. 37). B. Twiss (1992, p. 54) has pointed out that innovation capacity of an enterprise might be presented as assessment of several areas on a single scale.

Besides the importance of the innovation indicators and the innovation capacity of the company, of significant importance is the presence of a well-defined strategy for its growth. The strategy has to be successfully adapted to the policies and management rules for a specific business branch. In this respect, Cleland and King (1982, p. 182) have argued that the company advantages should be taken primarily into account, and the resources should be concentrated mainly on those branches where the company shows higher competitiveness.

In the modern world all of the enterprises have identical access to the new technologies, knowledge and successful strategies. However, not all of them manage to use these advantages in the same manner. The reasons for this could be hidden in their different capacity to adopt the newly appearing technologies. Cohen and Levintal (1990) have performed a practical investigation, the results of which have shown that the mentioned "adopting capacity" is of crucial importance for the competitiveness of the enterprises and their long-term "survival". According to the authors, this capacity could be defined as the ability of the enterprise to recognize, to master and to utilize knowledge from its surroundings. Finally, the adopting capacity has to be assessed taking into account the continuously changing economic environment. Based on these considerations we may draw two main conclusions: **First**: The innovation capacity of the company significantly depends on the external factors; **Second**: An appropriate and flexible company management could lead to faster and more adequate adaptation to these external factors.

These two conclusions are interrelated. Their focus is on the surrounding factors, which might be stimulating or detrimental to the innovation activities of an enterprise. In this respect, the assessment of the transitory innovativity is becoming more and more important. The last still needs a well-defined mathematical model, which should have a predictive character as well. A further development of such a model may lead to better assessment of the innovation indicators and the innovativity of specific business projects.

Methodology of the research

For performing the study and accomplishing its goals we used the following empirical approaches (Blagoev, D., 2013):

Observation – Gathering of primary and secondary information for innovations, information of innovation activities on the

companies' level, regional level, national level and international level

Comparative study – Establishment of general and uncommon trends in the development of innovations. Identifying the factors which are characteristic of the innovation capacity of different economic objects (e.g. companies), or different economic systems (e.g. local regions and countries). These factors could be specified as a good practice, leading to better results in the sphere of innovations.

Analysis – Gathering and analyzing of the quantitative data on different levels of innovation capacity and innovation potential.

Mathematical modeling – Using the potential of functional dependencies and iterative approaches for the working out of equations, useful for the estimation of the innovation capacity of companies.

To construct the company innovation index, we use the economic activity of the enterprise. The indicators of economic activity are: turnover, production, gross value added, etc. Here, we use the production quantity indicator, which is the basis of the production function. According to the methodology of the Bulgarian National Statistical Institute (***NSI-SBS, 2022), the production quantity is represented by the turnover, reduced by the balance values of sold assets, but excluding the balance values of the long-term own assets.

These indicators may fall into two categories of variables – independent variables and dependent variables. **Independent variables** (X) – the independent variables can be controlled by the researcher and represent the cause; **Dependent variables** (Y) – the dependent variables represent the effect. Their values depend on arbitrary changes in the independent variables.

The present independent and dependent variables can be summarized as follows: (Y) Dependent variables – Innovation index (This –index represents the advances in science and technology. It accounts for the production output dependence on R&D activities) and (X) Independent variables – **labor** (accounts for production output dependence on labor); **capital** (accounts for production output dependence on capital); **resources** (accounts for production output dependence on resources) and **production quantity**.

Based on mathematical transformations, we establish (deduce) some functional dependence between the quantities listed above.

Results and discussion (General considerations)

Methodical notes on the development of the innovation function and innovation index of the companies.

There are a number of approaches for the assessment of the innovation capacity and innovativity of the companies. Most common in Bulgaria is the approach that has been developed by the ARC Fund for the needs of the National Contest "Innovative Enterprise of the Year". The scoreboard of the approach uses the following indicators which are calculated according to a purposely developed assessment scales: Technical levels of new products/processes; Production output; Export capacity; Prospects; Intellectual property protection of new products/processes; R&D expenditure; Number of personnel employed in R&D; Number of new products/processes; Connectivity; Production and company management level;

We developed a modified approach for the assessment of the innovativity of Bulgarian

companies. It is based on the ARC Fund approach and uses the relative weights of groups of indicators. The investigation is part of a scientific project, which is funded by the department for research activities at UNWE – Sofia, Bulgaria (Blagoev, D. 2013, p. 83).

The assessment of the innovativity of a company can be done either during the process of innovation or at the end of it. During the period of introducing innovations it can be most precisely specified if the company falls into high, average or low level of innovativity.

The innovativity of a company can be calculated according to the following equation:

$$I_{inn} = \frac{\left(\frac{A_i}{A_0}+\frac{S_i}{S_0}+\frac{P_i}{P_0}\right)}{3} \quad (1)$$

where:

I_{inn} is the company innovation index;

A_i – Innovation assets used in the company activities;

A_0 – Gross assets needed for the company activities;

S_i – Expected sells of the innovation products or technologies for a year;

S_0 – Total company sells for a year;

P_i – Number of personnel employed in R&D departments in the company or external departments that are involved in the development of innovations for the company;

P_0 – Total number of personnel employed in the company.

However, this company innovation index reflects only a transitional stage in the innovation state of the companies of the economy. It cannot be used for assessing future trends in the innovation capacity dynamics of a company. Or at least it cannot help in building statistical models. But it still could be used for further mathematical development and evolving into a general model. Thus the index might be applied in the development of long-term prognoses for the rates of change in a company innovation capacity and overall innovation-based dynamics. It might also serve for comparative purposes in a time-dependent innovation analysis.

The period of realization of innovations is the important one for the precise evaluation of the companies' innovation capacity (e.g. low, medium or high value of innovation capacity). This index, however, reflects only the current innovation state of companies. It cannot be used for finding expectation trends for the development, or transient variations in the innovation capacity. Or at least it cannot be used for the elaboration of theoretically-substantiated prognosis. This provided us a opportunity to perform a further study of that index and to transform it to a widely applicable model. Thus it could be used as an approach for elaborating long term prognoses of the rate of variation of the innovation capacity and potential, their future trends, and drawing parallels with any current companies' innovation development.

Framework approaches for innovation capacity and innovation potential functions.

In order to define the elements of the companies' innovativeness, we need to stress on the problems, associated with both innovation and general economic development of the companies. The innovativeness of companies and respectively the innovation potential are the result of (Ramos-Hidalgo, Edeh and Acedo, 2022): **first**, the process of utilization of basic innovation factors, the influence of which rises proportionally to the expenses for the development of new products and technologies. **Second**, they are the result of the general development of the companies and their overall marketing. **In the third place**, they are the result of the capacity

and potential of the economic system and the environment for innovations at the national and international level. In other words, companies' innovativeness and innovation potential are quantities dependent on internal company factors, near external factors, and distant external factors.

An important issue of the companies' innovativeness study is the possibility to practically apply the innovation index, and simultaneously to use it for analysis of the influence of innovation capacity over the rest of basic economic factors, namely: capital, labor, and resources of the company. Such an approach for the evaluation of innovations' influence over company efficacy can be represented by the well-known **production function**.

In the investigation of the companies' innovativeness and respectively the influence of innovations over the companies' economic growth (based on the approach of **production function**), of special interest and application is the mathematical modeling. For such kind of analyses and prognoses very popular are the so called "factor models", i.e. those models in which the production increase or its absolute capacity are functions of one or more production factors (Stoyanov, D., 1992).

The "**Single factor**" model (Frankel, 1962) is based on the assumption that the capacities of industrial and overall economic productions are a function of the capacity and dynamics of one factor. In this case, the total result from the interrelation of different production factors is expressed in only one input quantity. The single factor model is reliable and readily applied in the economic analysis and short term prognosis estimation. It, however, does not account for the synergic effects of a series of factors. If we focus particularly on the dependence of the **production function** on innovation factors, it becomes not so readily applicable. According to Stoyanov (1992), most applicable is the "**Two factors**" model in the form of the **production function**.

$$Y_t = A_t.X_{1t}^{\alpha_1}.X_{2t}^{\alpha_2} \quad (2)$$

Where X_{1t} u X_{2t} are the two factors' quantity inputs (labor and capital), which are time (t) dependent. Empirical parameters α_1 and α_2 indicate the dependence of production output dynamics Y_t on the dynamics of production input factors X_{1t} and X_{2t}.

α_1 defines the increase of Y_t, for an increase in X_{1t} at X_{2t} = const.

α_2 defines the increase of Y_t, for an increase in X_{2t} at X_{1t} = const.,

on the condition that $\alpha_1 > 0$ u $\alpha_2 > 0$.

The coefficient A_t in the two factors model has two important properties: on one hand, it adjusts the scale of the factors to the scale of production dynamics Y_t; on the other hand, this coefficient accounts for all production factors not considered in the model.

In accordance with the industrial classification of production factors, the model should be expanded to a "**Three factors**" one:

$$Y_t = A_t.X_{1t}^{\alpha_1}.X_{2t}^{\alpha_2}.X_{3t}^{\alpha_3} = A_t.\prod_{i=1}^{3} X_{it}^{\alpha_i} \quad (3)$$

Now, if we want to account for the influence of innovations and innovation activities of the companies, the **production function** takes the following general form:

$$Y_t = A_t.X_{1t}^{\alpha_1}.X_{2t}^{\alpha_2}.X_{3t}^{\alpha_3}.e^{\pi t} \quad (4)$$

Where $e^{\pi t}$ is a factor accounting for the innovations; e is the Euler's number (e = 2,718); π is a complex index for a total increase of all production factors.

Based on the different modes of the factor model of the **production function** considered above, and accounting for the impact of innovations, we can present it as (Kopeva, D., at al., 2012):

$$P = f(L, C, R, M) = \\ = b_1.L.C.R.e^M + b_0 + \varepsilon \quad (5)$$

Where:

L – labor (accounts for production output dependence on labor)

C – capital (accounts for production output dependence on capital)

R – resources (accounts for production output dependence on resources)

M – advances in science and technology (accounts for production output dependence on R&D activities)

b_1 – coefficient (adjusts the production output dependence on ***L***, ***C*** and ***R***)

b_0 – free parameter (accounts for production output dependence on production incidental factors (not considered in the model))

ε – random variable (accounts for the time dependence of the production output)

The **Production function** is expressed as a product of distinct factors, as there is direct correlation between them. In its contemporary form the **Production function** cannot exist without all three main factors – labor, capital and resources.

On the other hand, the advances in science and technology represent a complex factor (implicitly, the innovations), which strongly enhances the effects of all three main factors as well. Hence, this factor is expressed in an exponential form. On the condition that companies do not have any R&D activities, this will not generally affect their production output as $M = 0$ and $e^M = 1$.

The exponential function arises whenever a quantity grows or decays at a rate proportional to its current value. The graph (Figure 4) of $y = e^x$ is upward-sloping, and increases faster as x increases. The graph always lies above the x-axis but can get arbitrarily close to it for a negative x; thus, the x-axis is a horizontal asymptote. The slope of the tangent to the graph at each point is equal to its y coordinate at that point (i. e. $d(e^x)/dx=e^x$). The inverse function is the natural logarithm $\ln(x)$. A simple mathematical explanation for a better understanding of the innovation related factor.

From the exponential form of the innovation factor, it follows that every single rise in innovation related quantity input will result in a much greater contribution to the companies' total production output, compared to a single rise in L, C or R.

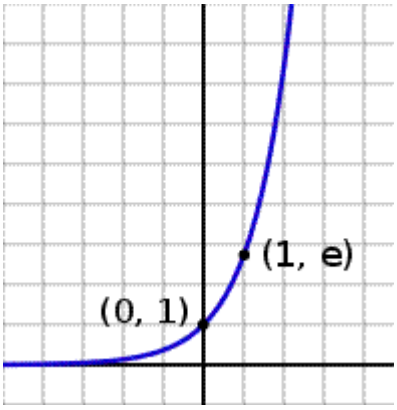

Figure 4. The natural exponential function

Taking into account the considerations made above, now we could specify more rigorously the factors in the **production function**, in order to make the model more flexible and suitable to be used with a lot of data:

1) Labor (L) – it can be expressed as a function of the gross value added for the labor process or:

$$L = f(GVA_L), \boldsymbol{GVA_L} \quad (6)$$

GVA$_L$ - gross value added per employee.

2) Capital (C) – it can be expressed as a function of technical and technological renovations, which are a measure of short-term investments (***Inv***)

$$C = f(Inv) \quad (7)$$

3) Resources (R) – An asset expressed as a function of the production process (***C$_{gs}$***).

$$R = f(C_{gs}) \quad (8)$$

4) Innovations (M) – represents R&D activities as a complex factor, which also enhance the total contribution of all three main factors to the production output. It can be expressed as a function of the expenses for the R&D activities (***Innov***).

$$M = f(Innov) \quad (9)$$

Using equations 5-8, the **production function** (equation 4) can be rewritten in the following form:

$$P = f\left(GVA_L, Inv, C_{gs}, Innov\right) =$$
$$= b_1.GVA_L.Inv.C_{gs}.e^{Innov} + b_0 + \varepsilon \quad (10)$$

In order to focus on the innovation index (*Innov*) and its importance for the companies' development and production growth, we could further process the **production function.** Putting it to logarithmic base results in:

$$\ln P = a_0.\ln L + a_1.\ln C$$
$$+ a_2.\ln R + a_3.m + a_4 + \varepsilon \quad (11)$$

or

$$\ln P = a_0.\ln GVA_L + a_1.\ln Inv$$
$$+ a_2.\ln C_{gs} + a_3.Innov + a_4 + \varepsilon \quad (12)$$

Then, we can extract the innovation index:

$$Innov = \frac{\ln P - a_0.\ln GVA_L - a_1.\ln Inv - a_2.\ln C_{gs} - a_4 - \varepsilon}{a_3} \quad (13)$$

Where: empirical parameters $a_1, a_2,.....a_n$, reflect the degree of dependence of L, C and R of a given company on its innovation activities.

The innovation index can be used for evaluation of the innovativeness (respectively innovation potential) of the companies as a direct consequence of the influence of innovation activities over the companies' total production output.

Conclusions

Innovation capacities of the companies could be classified according to the value of the calculated innovation index as follows: Innovation capacity of first degree – innovation index value between 7.6 and 10.0; Innovation capacity of second degree – innovation index value between 5.1 and 7.5; Innovation capacity of third degree – innovation index value between 2.6 and 5.0; Innovation capacity of fourth degree – innovation index value between 0.5 and 2.5

This classification could be used for grouping companies into two main categories: Companies of high innovation capacity (first and second degree capacities); Companies of medium innovation capacity (third and fourth degree capacities); Companies with

very low innovation index (below 0.5) could be considered as non-innovative.

The evaluation of innovation capacities for companies, according to the suggested approach, could be of use in the development of different strategies in the sphere of innovations and competitiveness at national and international level. The approach could be used also as a prognostic tool, and it could serve as a basis for time dependent comparative analyses of a variety of companies from the national economy.

The developed innovation index could be applied to companies of different types – micro, small, medium-sized and big companies. It could be applied also to different economic sectors, and to countries with a different economic development. This is possible because all of the economic systems, e.g. from a single very small company to the economy of a country, are based on the principles of the production function and the approach of combining the two (or three) production factors, mentioned above. Specific for each one of the economic systems (e.g. company, economic sector, region, country) would be the numbers multiplied by the independent variables of the innovation index. These coefficients can be identified with the help of econometric models provided that enough statistical data is present. For the purposes of the corporate governance and the tracing of the innovation index through the years, the coefficients can be assumed as 1, if the comparison is at a company level and for a given period.

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