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Performance Method for Innovative Activity on the Achieved Level of the Country's Socioeconomic Development

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Abstract*: The purpose of this study is to make an attempt to assess the innovation activity on the achieved result, expressed in indicators that determine the socioeconomic level of country development, as it is the purpose of innovation In the applied method of calculating the evaluation of the effectiveness of innovation (Data environment Analysis) these indicators were the results, while the indicators of innovation were considered as a "resource". Rental indicators, Gini index and others, reflecting (directly or indirectly) the result of innovations was also taken into account. The results showed values that were less inconsistent with the estimates for other related indexes and indicators, while the evaluation with existing methods gave more inaccurate results. This suggests that the proposed method gives a more objective assessment of the innovation level in the country and more accurately determines the country's place in the world ranking. The main source of the world economy development today is the innovation, an integrated assessment of which on a national scale can itself act as an indicator of the level of economic and — in a broader sense — the socio-economic level of the country development. From this point of view, an objective assessment of the innovation development level, as well as the development and proposal of methods for its evaluation are still relevant. Up-to-date assessment methods mainly assess the potential of countries to develop innovations, while their achieved level should be assessed, since, with significant differences in the development of countries, these potential opportunities can be realized to varying degrees.

***Keywords*: countries' ranking, data environment analysis, innovation index, world economy development.**

I. INTRODUCTION

When comparing countries by the innovation development level, it has been decided to refer to the global (the Global Innovation Index, hereinafter referred as to – GII) or the European innovation index (Summary Innovation Index [8], hereinafter referred as to — SII, used by the European Union when comparing European countries by the level of opportunities for innovation and the degree of their implementation). It is assumed that these indices determine the level of innovation development (by the value of the index that determines the relative rating of the country on a scale from 0 to 100 in the list of compared countries). Meanwhile, if we give a brief definition of innovation, it is a new product, the introduction of which has led to a certain positive effect. Here we should pay attention to the fundamental difference between the definition of the creative process as a process of creating something new in general and innovation in particular. In the first case, any product of the creative process can be attributed to the result, in the second — the result refers only to a product that has led to a positive effect, that is, creative efforts to create of which were successful. Innovation, thus, largely shall be attributed to economic category (which requires a creative component, but only one among others), rather than to category defining relations only in a creative environment.

The indices listed above are not assessed by the positive effect of creative activity, which allows them to be defined only as indicators that assess the level of creative activity or the potential of the country in terms of innovation, but not their achieved level. For example, when calculating the GII, the number of registered patents, published articles (and their citation index), videos posted on the Internet, feature films released, Wikipedia edits, etc., are taken into account, being classified as "output sub-indices", that is, designed to reflect the result of innovation [5, 6]. However, by the number of the counted patents, it is unclear which part of them have found practical application and what positive effect was reached as a result. Obviously, a greater number of patents in a particular country characterize it from the best side, but it does not determine the achieved level of innovation: if no patent has found practical application, innovations have not occurred and the achieved level of their development is zero. Such views are also valid for the rest of the indicators. In the GII, the "input sub-indices" include indicators of the development of the social environment, education and science, market and business, which are also taken into account in determining the integral estimation of the "innovation development level", but here it is just a characteristic of the environment potency.

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As a result, the evaluation of innovation efficiency, which is defined in GII as the ratio of the sum of output sub-indexes to the sum of input ones, determines the efficiency as the ratio of the results of activity in the creative environment to the environment potency in general (including institutional, infrastructural, business opportunity, educational, etc.). This assessment does not determine either the achieved level of innovation development or the innovation effectiveness. An objective assessment should take into account the positive effect, which automatically reflects the fact of "implementation" of innovations, although, according to the definition, there is no innovation without implementation (which is often not taken into account), and the magnitude of the positive effect suggests a connection with the success of innovation activity, that is, with the level of its development.

Thus, a different approach is required to assess the level of innovation achieved. The effectiveness of innovation should be assessed in a different way. In order to objectively evaluate it, in this paper we propose a method for assessing the effectiveness of innovative activity by its result or positive effect obtained through innovation. At the national level, a generalized expression of such a positive effect is the achieved level of the socio-economic sphere development, the values of the main indicators of which were taken in the article as a result on which efficiency was determined.

II. MATERIALS AND METHODS

A. Formulation of a method for evaluations the innovations effectiveness

Innovation activity ultimately leads to an increase in the socioeconomic level of the country development. If we evaluate the effectiveness of innovation activities on the achieved level of socioeconomic development, the direct solution to this problem involves the correlation of the achieved level of population well-being with the achieved level of innovation. However, at direct matching, there are two problems.

1. The level of socio-economic development depends not only on innovation. Back in 1776, Adam Smith wrote in his treatise "Nature and Causes of the Wealth of Nations": "...Increasing income of private entrepreneurs is a source of growth of common wealth and prosperity." Today we can say that the source of growth is innovation, but the value of the total wealth is influenced by the development of a number of other equally important factors. And, if we evaluate the effectiveness of innovation activities on the achieved level of socio-economic development, it is necessary to take into account only the part that is achieved through innovation.
2. The combination of currently created tangible and intangible goods and services is always the result of innovation, but some of them were introduced long ago, but still have a positive effect. Therefore, when evaluating the effectiveness, it is necessary to take into account only relevant innovations, otherwise the result is meaningless — it will reflect the effectiveness of innovations throughout the history of the country.

These problems were solved by selecting certain indicators that determine the level of innovation and the achieved level of socio-economic development of the country, which were subject to correction in order to resolve these problems. Calculation of efficiency was carried out by the method of "data envelopment analysis" (hereinafter referred as to – DEA or DEA-method).

This method- DEA (Data envelope Analysis), known in the Russian literature as "analysis of operational environment" [4], uses an economic approach to assessing the effectiveness of any activity, which is expressed in the correlation of the results of activities with the resources that have been spent to obtain these results. DEA-method is widely used to solve the problems of management and evaluation of various projects in the financial sector, manufacturing and other industries. Recently, it has been actively used to assess the effectiveness of scientific activities [7, 9, 17-21]. To understand how to assess the effectiveness with the DEA-method, we will briefly explain the method of its calculation.

B. Brief description of the DEA-method

In the classical application, the calculation algorithm is performed as follows. The matrix of input (resource) indicators || *Xij* || and the matrix of output (result) indicators || *Ykj* || are given:

$$j = 1, \ldots, N;$$
$$i = 1, \ldots, M;$$
$$k = 1, \ldots, S,$$

where

N is the number of objects to be evaluated,

M and *S* - the number of input and output parameters of each of *N* – objects, respectively.

The efficiency of the *j*-th object is defined as the ratio of linear combinations of input and output parameters:

$$h_j = \frac{\sum_{k=1}^{S} u_k y_{kj}}{\sum_{i=1}^{M} v_i x_{ij}} \quad (1)$$

The problem of finding the efficiency of the j-th object is reduced comes down to determining the values of the coefficients u_k and $v_i \geq 0$. The efficiency of the *j*-th object is represented as a maximum (1), i.e.

$$\vartheta \equiv \max h_{j0} = \frac{\sum_{k=1}^{S} u_k y_{kj}}{\sum_{i=1}^{M} v_i x_{ij}} \quad (2)$$

subject to limitation:

$$\frac{\sum_{k=1}^{S} u_k y_{kj}}{\sum_{i=1}^{M} v_i x_{ij}} \leq 1 \quad (3)$$

where $v_i \geq 0$ ($i = 1, \ldots, M$), $u_k \geq 0$ ($k = 1, \ldots, S$).

The problem represented by expressions (1) and (2) is solved for each of the *N*-objects.

In the practical application, as it is described in the original work [4, 11] and as it was applied in this study, this action was replaced by a linear programming problem [3]. The main maximum search equation was replaced by the minimum search equation:

$$\tau \equiv \min g_{j0} = \sum_{i=1}^{M} a_{ij} x_{ij0} \quad (4)$$

when

$$\sum_{k=1}^{S} \beta_{kj} y_{kj} = 1 \quad (5)$$

and restrictions are met

$$-\sum_{k=1}^{S} \beta_{kj} y_{kj} + \sum_{i=1}^{M} a_{ij} x_{ij0} \geq 0 \quad (6)$$

For the calculated coefficients, the condition α_{ij}, $\beta_{ij} \geq 0$ is applied.

The equation (4) defines the order of calculation of the coefficient a_{ij} at which the minimum of resources use is reached at the result fixed at the level of "unit" (5) and at fulfilment of the condition (6) which is not allowing possibility of excess of value of the spent resources over the results received on their basis.

The method determines the relative efficiency value for each country from the selected sample. As a result of calculations, the country with the best efficiency receives a value equal to 1, for the rest of the countries the efficiency is estimated as a share of the best result within the range of 0...1.

In assessing the effectiveness of the DEA-method, as resource indicators the indicators of innovation were selected, as result- indicators of socio-economic sphere.

C. Selection of input (resource) and output (result) indicators

All submitted paper should be cutting edge, result oriented, original paper and under the scope of the journal that should belong to the engineering and technology area. In the paper title, there should not be word 'Overview/brief/ Introduction, Review, Case study/ Study, Survey, Approach, Comparative, Analysis, Comparative Investigation, Investigation'.

Analysis of factors influencing the innovation process carried out in works [12, 13, 16, 18], the evaluation of the relationship between innovation and socio-economic development, made in the works [1, 10, 14, 15, 24, 34], have identified the following indicators selected to assess the effectiveness of the proposed approach. As a resource indicator, the GII relative value was chosen, which, as mentioned above, determines the potency of the country in terms of innovative development.

To solve both problems relating to the exclusion of the influence of other factors on the growth of socio-economic development and eliminate the influence of "old" innovations, from this composite index the rate of development of the institutional environment was excluded (that is, calculated without taking into account the values of the indicator of the institutional environment development, hereinafter referred to as – GII/I). This environment has a great impact on the growth of socio-economic development, and its formation takes a long time (decades), so its impact is significant, long-term and stable, so that this part of the resource refers rather to other indicators that allow to create a benefit not at the expense of innovation or allowing "old" innovations to have a positive effect. "Old" innovation here means that, in the broadest sense, all products or services created are the result of innovation, but it is pointless to take them all into account, since the positive effect of "old" innovation does not reflect the current level of innovation development. And if we exclude the positive effect of them in the resulting (the procedure for the exclusion of which will be described below) and resource indicators, the effect of "old" innovation in the calculations will not be taken into account.

As the ***output indicators characterizing the level of socio-economic development***, were chosen:

- *gross domestic product* (GDP), calculated in US dollars at purchasing power parity (GDP, PPP (current international $ – as defined in the World Bank statistical database), normalized by the number of employees in the country (Labor force, total) [31];
- *resource rent* (Total natural resources rents – according to the definition in the World Bank statistical database [22, 28];
- *Gini coefficient* [31].

It should be noted that the resulting indicators are selected taking into account the fact that they should reflect the level of socio-economic development achieved mainly through innovation. Thus, the normalized gross value of the produced product and services determines the efficiency of the process of creating benefits, and resource rent allows to exclude the cost of resources in the creation of which labor costs, and even more innovation, are absent (for example, natural resources – oil, gas, coal, metal, etc.).

Gini index allows you to take into account the following. As a rule, a high degree of income inequality is present in countries where innovations are introduced only in limited segments of the socio-economic sphere. This can be explained by the fact that while relatively high values of normalized value added are achieved nationwide, mainly by individual industries or large companies, the high incomes are distributed between the owners of these companies and the staff working there. That is, there is a direct link between the differentiation of profitability and the uneven distribution of income, so the value of the Gini index also reflects the differentiation of profitability, which, in turn, is directly related to the uneven spread of innovation in the country.

For the DEA-method, the accuracy in determining the quantitative relationship between the Gini index and the degree of unevenness of the spread of innovation is insignificant, it is important that this relationship is determined correctly, and being applied uniformly for all countries and given that the result of the calculations is not a quantitative definition of efficiency, but the determination of the relative rating of the country, the use of the Gini index as an index reflecting the uneven spread of innovation in the country is justified. Speaking about the assessment of the innovation development level across the country,

it should be understood that, with equal values of other indicators, the level of innovation development for the country with a wider involvement of the population in the innovation process should be evaluated higher. Correction to the Gini index does this.

In the future, the resulting indicator was adjusted taking into account the value of the GII/I. This adjustment continued (after the procedure of deducting the share of resource rent from the normalized value of GDP) the "purification" of the indicator of the socio-economic development level from the non-innovative component and the positive effect of "old" innovations. Given that the impact of the institutional environment was excluded from the resource indicator, the impact of the institutional environment was also excluded from the adjustment of the resulting indicator to GII/I. Here, if we consider simplistically the level of socio-economic development as achieved only due to the influence of two factors (innovation and related to the other), the share of innovation component was tied to the value of GII/I. Thus, if its value is averaged over a certain time period, it is possible to consider the potency for innovation as realized and use the value of GII/I (which is within the range of 0-1) as a weighting factor that determines the share in the normalized value of GDP generated by innovation, respectively, the remaining part is attributed to other factors. For example, for Germany the value of GII/I is 53.91, for Russia – 37.07, and then the results achieved through innovation, in the calculation of efficiency will take into account the share of the normalized value of GDP in the amount of 0.54 for Germany and 0.37 for Russia.

Thus, the GII/I was chosen as a resulting indicator, determining the level of socio-economic development and achieved through innovation — an integral indicator (hereinafter referred to as GDP/GII), the value of which was calculated by the formula

$$GDP/GII^{i}_{abs} = \frac{GDP/GII^{i}_{abs} - GDP/GII_{abs\,\min}}{GDP/GII_{abs\,\max} - GDP/GII_{abs\,\min}} \quad (7)$$

where

GDP/GII^{i} - the relative value of the integral indicator for the *i-th* country, from 0 to 100, reflecting the relative position of the country among the countries of comparison, where 100 reflects the best value, 0- the worst one;

GDP/GII^{i}_{abs} - absolute value of the integral indicator for the *i-th* country;

GDP/GII_{abs_max}(GDP/GII_{abs_min}) - minimum and maximum absolute values of the integral index among the compared countries.

In turn, GDP/GII^{i} - was calculated by the formula

$$GDP/GII^{i}_{abs} = (GDP^{i}_{norm}) \times \times (\frac{100 - Rent^{1}}{100}) \times (\frac{GII/I^{i}}{100}) \times \times (1 - Gini^{i}) \quad (8)$$

where GDP^{i}_{norm} - GDP at purchasing power parity of the *i-th* country, normalized by the number of employees in the country, US dollars;

$Rent^{1}$ - resource rent of the *i-th* country, percent of GDP;

GII/I^{i} - GII value of the *i-th* country, calculated without taking into account the institutional environment, relative value from 0 to 100;

$Gini^{i}$ - Gini coefficient of the *i-th* country, relative value from 0 to 1.

The efficiency was determined by the DEA-method, the formal equation for which can be represented as

$$R^{i} = f(GDP/GII^{i}, \quad GII/I^{i}) \quad (9)$$

III. RESULTS

When calculating the efficiency of innovation by the DEA-method, the input values were GII/I, the output – GDP / GII. The calculation results are presented in Fig. 1-6.

Countries' rankings on the relative measure of innovation performance R^{i}, derived from the methodology described above and the methodology used in the GII, differ, but it is obvious that any other methodology will produce a new result. The quality criterion can be a comparison of the indicator's values with indicators of the socioeconomic environment development.

There are enough evidences that there is a high correlation between GDP per capita, the competitiveness index and the level of innovation [2, 23, 32, 33]. Correlation with the Gini index is defined as weak, but also present. As a rule, a country with a high value of any of these indicators has a high value of the remaining indicators, and vice versa. And if you compare the effectiveness of the above indicators to assess the degree of correlation with each of them, the technique, which gives a more objective result, should include the one in which the degree of correlation between the data is maintained. Following this approach, a comparison of the results of the innovation performance evaluation for Ri and GII is carried out as follows. There were two lists of countries compared, in the first of which the relative value of Ri by the value was ranked, in the second – by the value of the relative rating of the effectiveness of innovation, calculated by the GII. In each list, countries were divided into three groups. The first groups included countries whose innovation performance was assessed as high, the second and third groups as medium and low, respectively. After that, the level of efficiency was compared with the previously considered GDP/GII, the competitiveness index [21, 25, 26, 30] and the Gini index (Gini index for comparability with other indicators is recalculated on a scale where a greater relative value means less inequality). The results of countries comparison divided by the value of Ri efficiency are presented in figures 1-3, GII index- in Fig. 4-6.

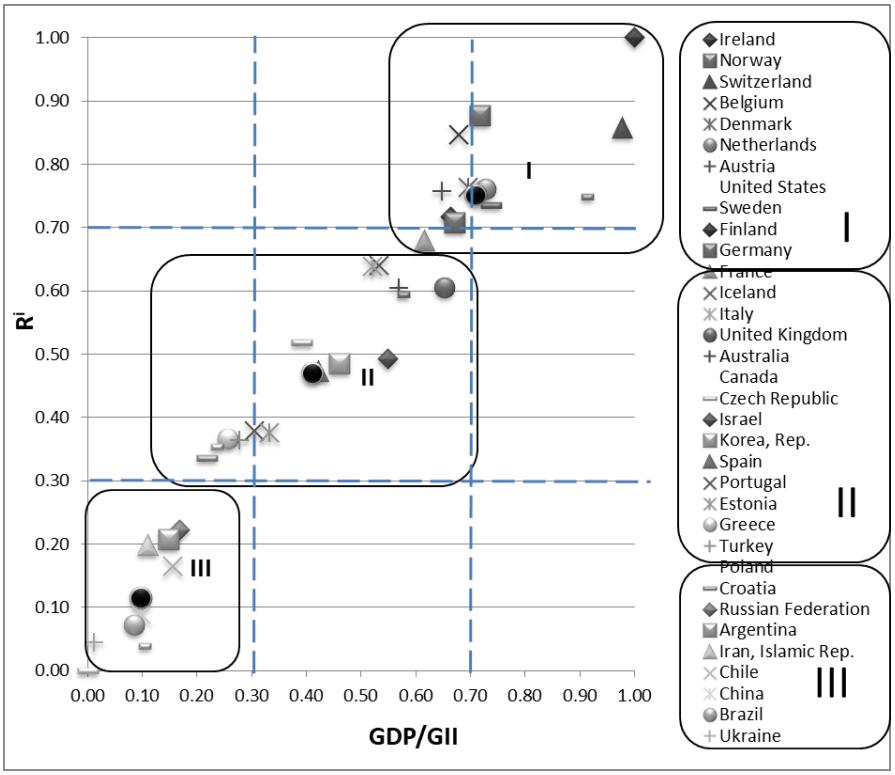

Fig. 1. Distribution of countries by GDP/GII

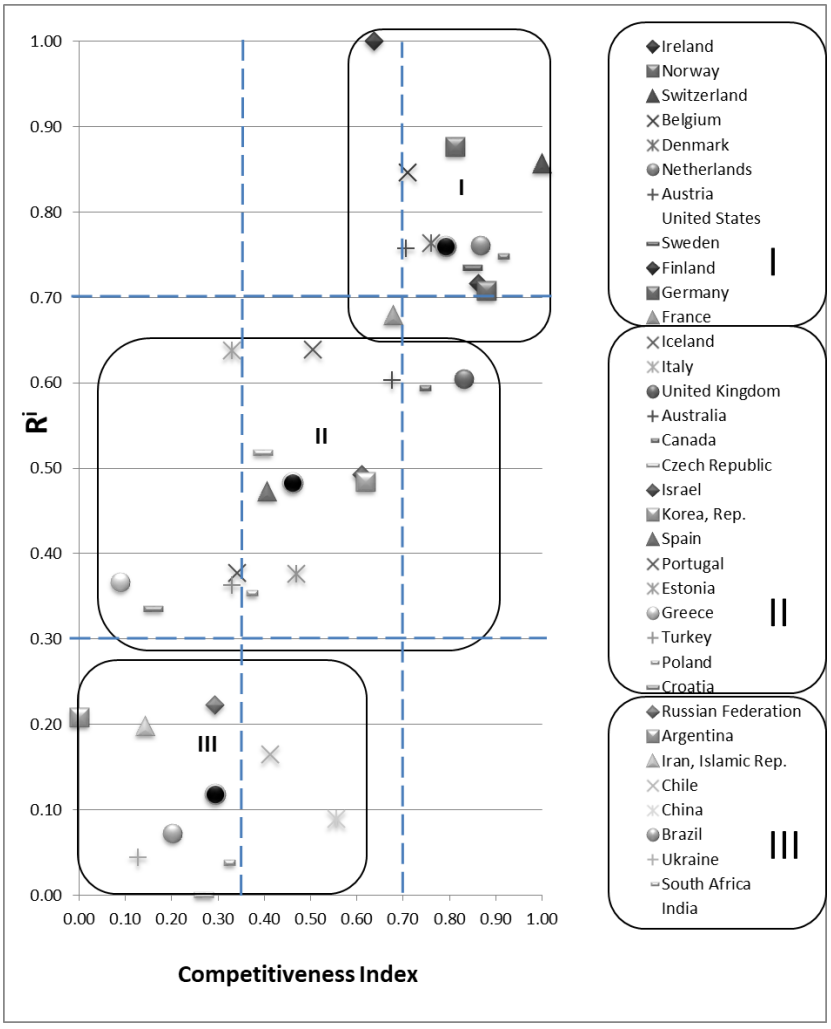

Fig. 2. Distribution of countries by competitiveness indicator

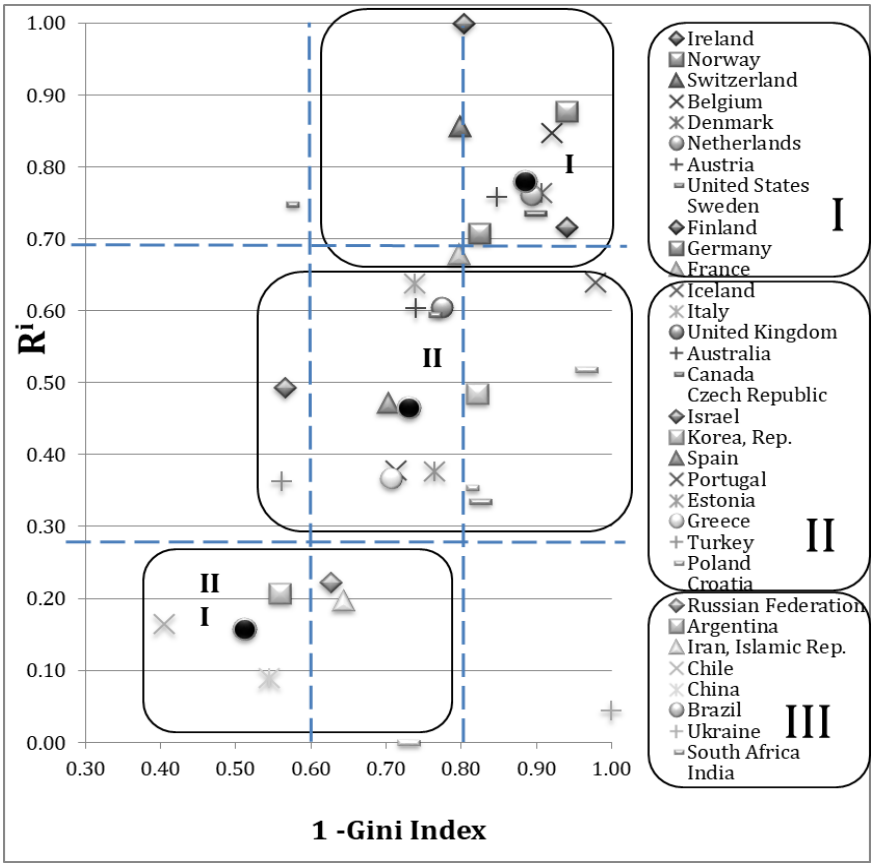

Fig. 3. Distribution of countries by inequality index (Gini index)

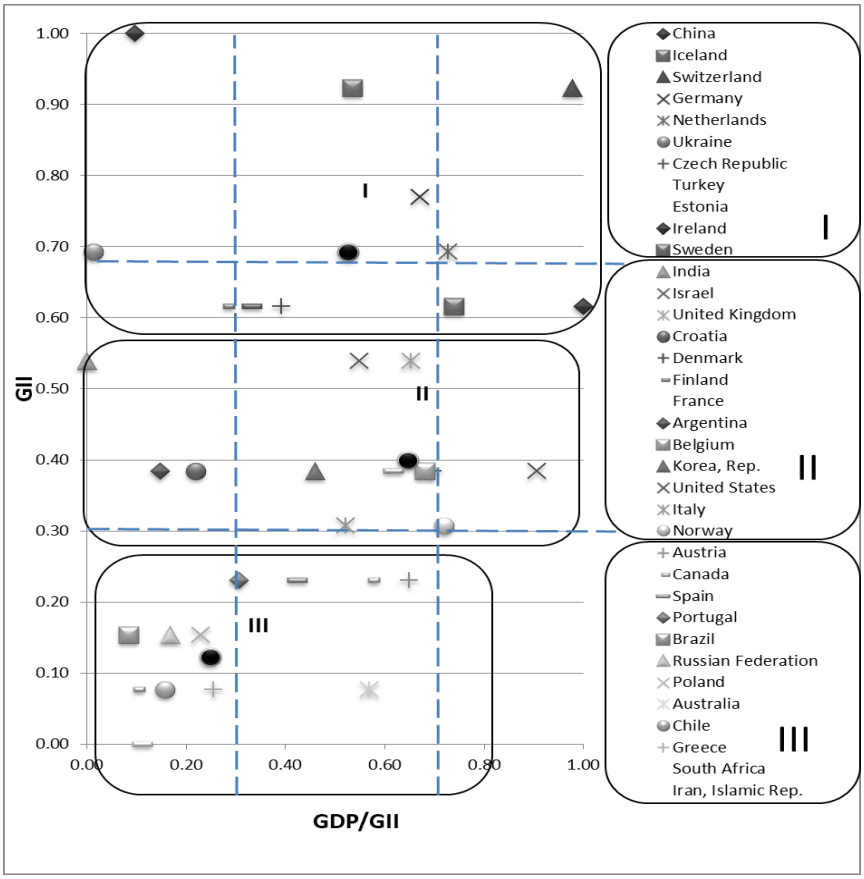

Fig. 4. Distribution of countries by GDP / GII value

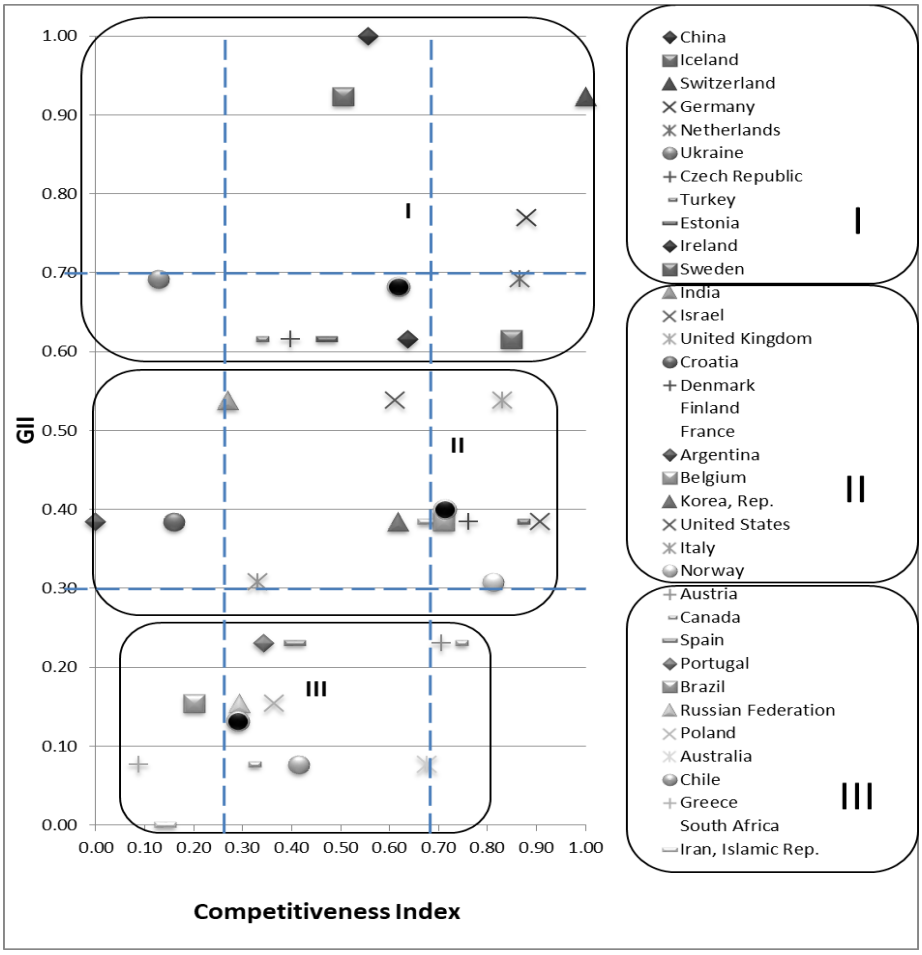

Fig. 3. Distribution of countries by competitiveness indicator

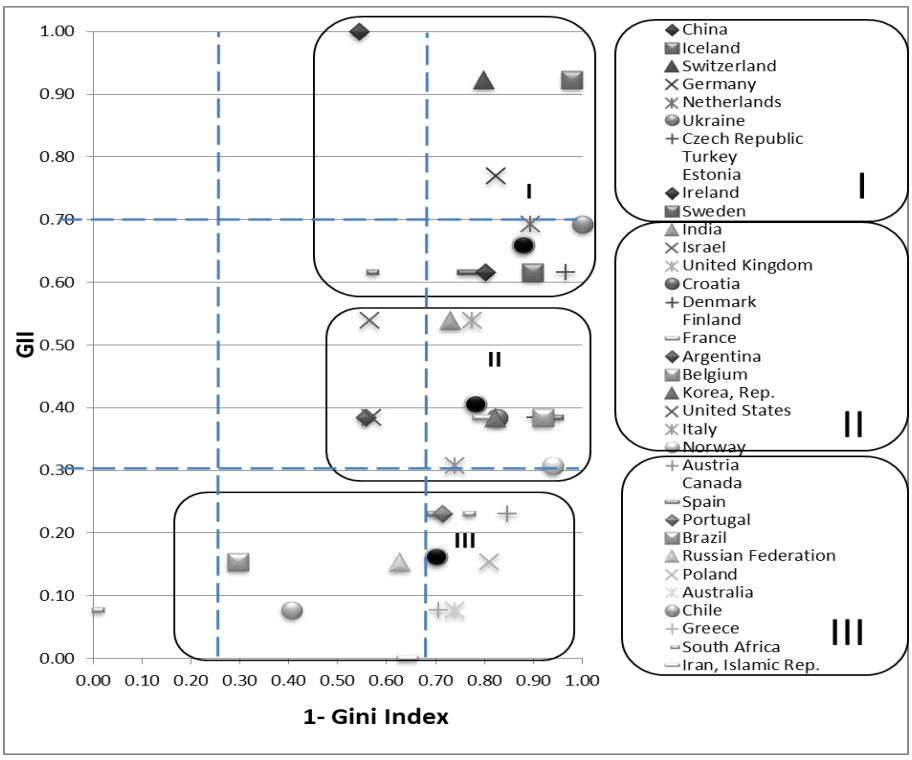

Fig. 4. Distribution of countries by inequality indicator (Gini index)

The analysis of the calculation results shows that the efficiency of innovation activity in Ri confirms the regularity of the existence of a close relationship with the countries

development level on GDP/GII, competitiveness and income inequality. Thus, countries of the 1st group on all the charts are mainly in the upper right quadrant with high values of the indicators, of the 2nd group – in the middle, of the 3rd group in the lower left corner, whereas the evaluation of effectiveness on GII of these countries are scattered across all segments, thereby demonstrating the lack of correlation between the data.

The absence of correlation or weak correlation in this case is an indicator of the discrepancy of the assessment to common sense. This is most clearly seen when comparing countries such as Ukraine and the Netherlands, which, with the same relative importance of innovation efficiency (0.69), have competitiveness indices of 0.13 and 0.87 and GDP/GII values of 0.01 and 0.73, respectively. Argentina and the United States also at the same efficiency value (0.38) have competitiveness indices of 0.00 and 0.91 and GDP/GII of 0.15 and 0.91, respectively. It is difficult to assume that, with the same efficiency of innovation activity, the results achieved by it differ so much. Returning to the position that the assessment on the GII reflects potency, but not the results achieved, assessment of the effectiveness by this method in principle cannot be interpreted even as a potential indicator because the efficiency expresses the cost optimality when the actual result and the result in the calculation of efficiency in the GII does not appear, since neither the patents nor the article relate to it, because they are not the result of innovation. But even if we assume this result in the future, for example, for Ukraine, which occupies the 5th place in the rating (note, its rating is higher than such countries as England, Sweden or the United States), it is difficult to assume that in the coming years it will really overtake these countries in terms of competitiveness or GDP/GII. The same can be attributed to Argentina, in the case where it is difficult to assume that in the foreseeable future on the index of competitiveness or GDP/GII it gets closer to the USA, where the efficiency value is estimated in the same way or Argentina will surpass in these indicators Norway, for which efficiency is evaluated less.

There are also cases of uncorrelated data in the distribution of countries to assess the effectiveness of Ri, but more often non-compliance with the general laws is due to objective reasons. For example, the low value of the Gini index for the United States is indeed contrary to the accepted logic of reasoning, but this is an exceptional case, which is confirmed by the perception of it as a serious problem [27, 28]. The low value of the normalized value of GDP in China is due to the large population, and the high level of competitiveness – a large number of technological industries, which employ a relatively small part of the working-age population. In general, the values of Ri performance indicators are consistent with the values of all the considered indicators, confirming their close linkage with each other.

IV. CONCLUSION

Thus, the distribution of countries by the innovation performance rating by the Ri indicator is consistent with the rating of indicators that determine the achieved level of their socio-economic development, which logically reflects the relationship of innovation with the welfare of the country's population, since for the latter improvement, the innovative activities are conducted, respectively, the assessment of the effectiveness of which should be determined taking into account the achieved level of socioeconomic development. On the example of comparison with the widespread GII it is shown that the proposed method of evaluating the effectiveness of innovation determines it more objectively both from a methodological point of view, and the result obtained. From a practical point of view, the proposed alternative methodology for assessing the effectiveness of innovation allows us to consider and evaluate innovations in the country not as a weighted sum of a disparate set of indicators, which does not take into account the systemic factor of their combination, leading to a positive effect, but on the basis of an integrated assessment of the result of their activities, where all factors are taken into account.

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