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Criteria for Evaluation and Planning of Science Foundation Activity

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ABSTRACT

The growing role of S&T funds as one of the important mechanisms for financing science results in necessity to improve methods for evaluating and planning activities of such funds. In this paper we identified some indicators of scientific activity based on statistical data analysis. On our opinion these indicators should be taken into account for evaluation and planning of R&D activities, in particular, regarding S&T funds. One of the key indicator, which determines pace of scientific development is GERD per one researcher. Accelerated development of science, which manifests itself in a significant increase in its effectiveness. At the same time, it is sufficient to keep the magnitude in order to achieve high values of performance and efficiency of scientific activity if management of financial flows is enough efficient. If each researcher publishes approximately 1 work in 2 years, it will be enough to ensure the quality and relevance of scientific publications.

Keywords: Corrector, Moderator, Tutor, Subject Teacher, Meta-competence
JEL Classifications: I22, I20, I23

1. INTRODUCTION

Significant financial resources are spent in different countries to ensure accelerated development of science. That's why it is desirable to permanently improve mechanisms for their distribution and use. Grants are one of such mechanisms, which are widely used by government agencies and private organizations. Among organizations - Funders first of all science foundations must first be noted. Their field of activity in various countries is very extensive as well as ever-increasing volumes of financing of research projects and programs. For example the budget of the National Science Foundation (NSF) of the USA in 2013 reached nearly $ 7 billion (US National Science Foundation, 2013) or about 1.6% of GERD. The budget of the Deutschen Forschungsgemeinschaft (DFG) in the same year was around € 2.6 billion. (DFG, 2013) (3% of GERD) and was increased almost 2 times in comparison with 2005 (Hotopp, 2005).

Due to the significant amount of financial resources science funds support many scientific programs and projects, groups and individual researchers. Only in 2013 the NSF financed 233,000 projects and personally 179400 researchers (US National Science Foundation, 2013). German Science Foundation in the same year funded 954 programs and 29,817 projects (DFG, 2013).

The trend towards increasing the role of research funds in the financing of science is also observed in Russia. Thus, according State program of the Russian Federation, the 2020 budgets (State Program of the Russian Federation "The Development of Science and Technology for 2013-2020 years," 2012) of the Russian

Foundation for Basic Research and the Russian Humanitarian Foundation will increase several times and reach 45 and 20 billion Rubles, respectively.

2. METHODS

The growing role of S&T funds as one of the important mechanisms for financing science leads to need to improve methods for evaluating and planning activity of such funds. Methods of evaluation mechanisms for financing research activities have been developed and described in many papers and reviews (Carpon, 1992; Coccia, 1999; Ruegg and Jordan, 2007; Barczynski and Rek, 2011; Molnar, 2011). However, these methods cannot efficiently provide answers to some of the practical issues that are important for the evaluation and planning of activity of scientific funds.

Among these issues, first of all, it should allocate the question of the minimum amount of financial resources, above which the efficiency and effectiveness of scientific activity begins to increase at an accelerated pace. Secondly, it is important to know how fast and to what extent, under certain conditions, scientific activity can develop in excess of this minimum amount of financial resources. Finally, it is interesting to know how quantitative indicators of scientific activities match the quality of obtained results.

Answers to these questions can be obtained to a certain extent based on an analysis of available statistical data of (OECD, 2012). In particular, it was shown in Glisin et al., 2013) that dramatic exponential increase of receipts R, obtained by the technology balance of payments, per one researcher $r = R/N$ for the G7 occurs when the condition is satisfied:

$$v = \frac{V}{N} > v_{min} \cong 100000 \frac{\text{current dollars}}{\text{researcher year}} \quad (1)$$

Here V - Value of GERD, and N is total number of researchers.

3. RESULTS

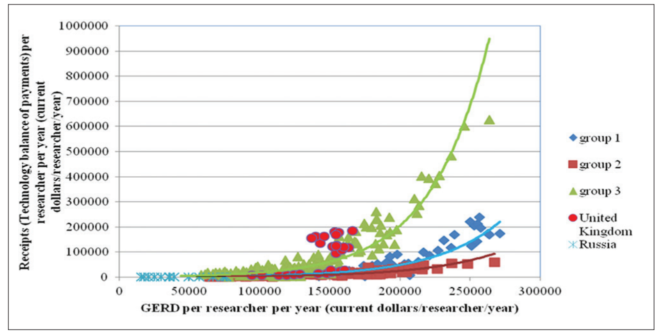
Detailed analysis of (Glisin and Kalyuzhnyi, 2014) showed that (1) is prerequisite condition for exponential growth of r not only in the G7, but also in many other countries (Figure 1).

Figure 1 shows that in all studied countries when the condition (1) is satisfied, there is an exponential increase in the value of r[1]. Numerical difference of values r in different countries at the same value of is due to the peculiarities of the infrastructure, in particular, due to differences in the management and distribution of finances.

Figure 1 shows that the maximal pace of change of $r(v)$ is for countries of Group 3 (Belgium, Greece, Czech Republic, Denmark,

1 In the UK, when (1) is satisfied an increase in r is stronger than exponential.

Figure 1: Dependence $r_i = r_i(v_i)$ for different groups of countries (Glisin and Kalyuzhnyi, 2014)



Finland, Netherlands, Portugal, Spain). Among these countries maximal values of r were achieved in Netherlands. The minimal pace of change of is for countries of Group 3 (France, Japan, USA, South Korea, and Australia). The maximal value of r in countries of Group 1 was achieved in Germany.

Group 1: Canada, Germany, Austria

Group 2: France, Japan, USA, South Korea, Australia

Group 3: Belgium, Greece, Czech Republic, Denmark, Finland, Netherlands, Portugal, Spain.

In Russia, the condition (1) is not satisfied. Therefore, as one would expect, the r values remain low. Figure 1 results show that only increase of GERD does not necessarily lead to an equivalent increase in specific performance indicators of science, such as the value of r. The improvement of the management and allocation of financial resources for R&D is equally important. For example higher values of r in Germany and the UK compared with other countries of G7 are explained in (Glisin et al., 2013) that financial management is carried out directly scientific communities. From this point of view, S&T funds, where in the distribution of grants directly involved expert scientific councils, are one of the most effective mechanisms to control the scientific activity.

Figure 2 shows that the condition (1) it is also necessary to ensure the increase in the total number of patents (triadic patents and patent cooperation treaty [PCT]) per one researcher. Finland leads on this indicator, when changes in the range from 100,000 to 150,000 $\frac{\text{current dollars}}{\text{researcher year}}$. The best values of this indicator at v>150,000 $\frac{\text{current dollars}}{\text{researcher year}}$ were achieved in Germany and Sweden. With regard to Russia, as seen in Figure 2, the number of domestic patents per researcher significantly exceeds total number of triadic and PCT patents per researcher. This indicator, calculated by the number of domestic patents, is comparable with the values for Germany, Sweden and Finland. It is possible that this situation is due to the relatively high cost of triadic and PCT patenting compared with domestic patenting, as well as with comparatively low capabilities for Russian researchers to use their patents abroad.

Figure 2: Number of patents per researcher versus GERD per researcher (Glisin and Kalyuzhnyi, 2014)

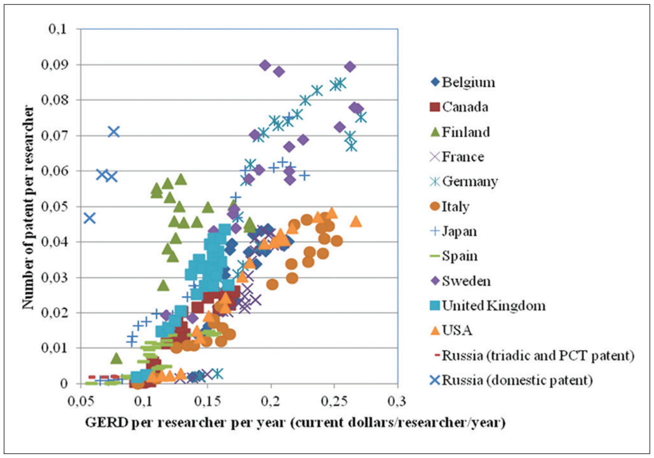


Figure 3: Number of publications (SCOPUS) per researcher versus GERD per researcher for G7

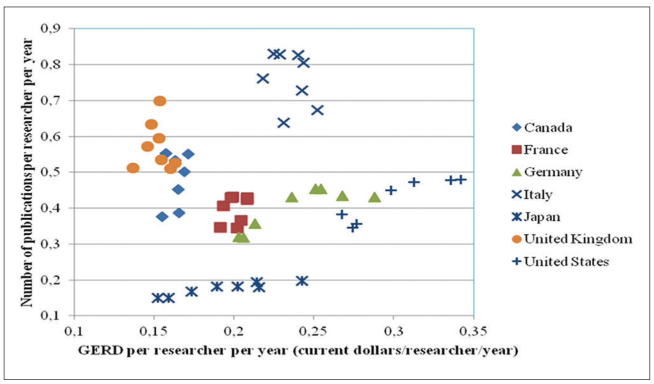
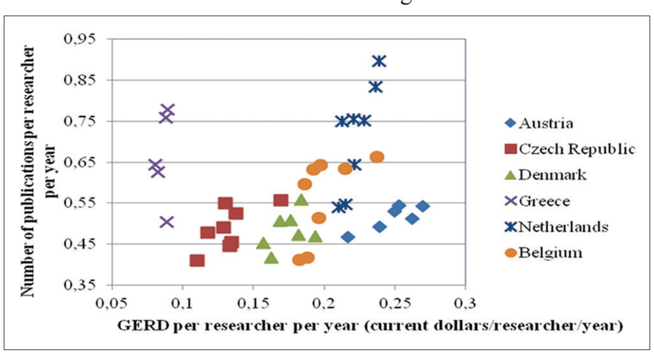


Figure 4: Number of publications (SCOPUS) per researcher versus GERD per researcher for Austria, Czech Republic, Denmark, Greece, Netherlands and Belgium



Figures 3 and 4 show the number of publications per researcher as function of *v*. Data on the number of publications were taken from SCOPUS for the period 2000-2014.

It is seen, that when increases, the rising trend in the number of publications less pronounced than for the total number of patents per one researcher. Moreover, in some countries (UK, Canada, Italy and Greece) an increase in the number of publications takes place at the same value v. However, in all cases, increase the number of publications occurs when $v>v_{min}$, i.e. condition (1) is satisfied.

As can be seen in Figures 3 and 4 in all countries the number of publications per researcher per year is <1, i.e. on average, one researcher publishes not more than one article per year, regardless of the value of GERD per researcher *v*.

Figures 1-5 presents quantitative indicators of scientific activity. However in evaluating and planning R&D activities qualitative indicators sometimes have even more importance than quantitative ones. One of the indicators, which to some extent can characterize the quality of scientific results, is the impact factor. Figures 5 and 6 shows how the impact factor depends on the number of publications per one researcher. The data presented in Figures 5 and 6 were obtained using a database SCOPUS.

As it is seen on Figures 5 and 6 for all countries studied the dependence of the impact factor of the number of publications per researcher has a maximum, which is reached when the number of publications per researcher is in the range of 0.4-0.6. The maximum value of the impact factor in most cases is in the range of about 20-35. The only exception is Czech Republic, where the maximum value of the impact factor is 15. Thus, judging by the magnitude of the impact factor, we can say that results of interest to the scientific community publish an average of about one every 2 years. It appears that such publication activity is optimal.

Still another indicator of the efficiency of scientific activity is the ratio of expenditures on science and received receipts as measured by technology balance of payments. This indicator to some extent characterizes the profitability of science and determined using expression:

$$\eta = \frac{R}{V+P} \tag{2}$$

In the expression (2) *R* and *P* - receipts and payments are determined by the balance of payments technology (OECD, 2012), V - GERD. Figures 7 and 8 show dependence of η on *v*.

Figures 7 and 8 show that in all cases any appreciable quantities of indicator η is reached at *v*, satisfying the condition (1). Moreover, among the G7 countries the maximum value $\eta \approx 80\%$ achieved in the UK with relatively low values $v \approx 150000 \frac{\text{current dollars}}{\text{researcher year}}$. On the contrary, in the United States even at the highest among all the countries studied values $v \approx 350000 \frac{\text{current dollars}}{\text{researcher year}}$ η values do not exceed 20%.

Comparison of the data presented in Figures 7 and 8 show that in countries studied, non-G7, science develops more efficiently from an economic point of view. Indeed, if in the G7 (except UK) in Germany maximum $\eta \approx 45\text{-}50\%$ is achieved at high values $v \approx 300000 \frac{\text{current dollars}}{\text{researcher year}}$, in Austria and Holland η values are 60 % and 90%, respectively, at $v \approx 250000 \frac{\text{current dollars}}{\text{researcher year}}$. When $v \approx 200000 \frac{\text{current dollars}}{\text{researcher year}}$ in G7 countries the value of η does not

Figure 5: Impact-factor versus number of publications per researcher for G7

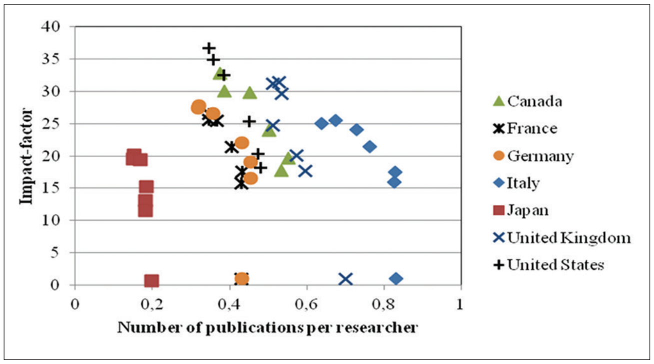
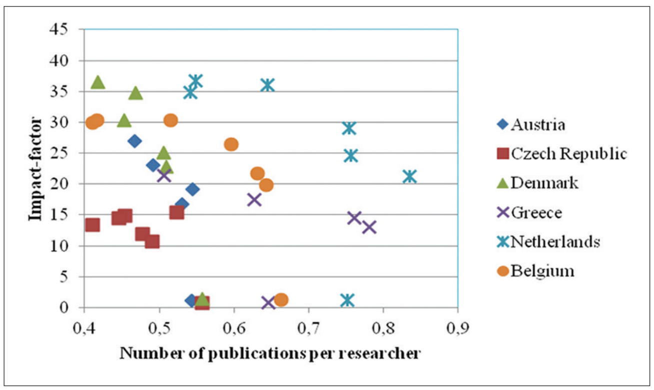


Figure 6: Impact-factor versus number of publications per researcher for Austria, Czech Republic, Denmark, Greece, Netherlands and Belgium



exceed 20%, while in countries outside the G7, it is much larger and ranges from 30% to 60%.

4. DISCUSSION AND CONCLUSION

Thus, these results indicate that one of the key indicators that determine the pace of scientific development is GERD per one researcher *v*. The accelerated development of science, which manifests itself in a significant increase in its effectiveness, starts at $v > 100{,}000\ \frac{\text{current dollars}}{\text{researcher year}}$. At the same time, with the effective management of financial flows in order to achieve high values of performance and efficiency of scientific activity it is sufficient magnitude $v \leq 250{,}000\ \frac{\text{current dollars}}{\text{researcher year}}$. Exceeding these values is not always appropriate, since it may not lead to an equivalent increase in the productivity and efficiency of science. This is well illustrated by the example of the United States.

It is also not necessarily aspire to excessive increase in the number of scientific publications. As the analysis of data in the database SCOPUS shows, to ensure the quality and relevance of scientific publications it is enough each researcher to average published approximately 1 work in 2 years.

Figure 7: Dependence of η on v for G7

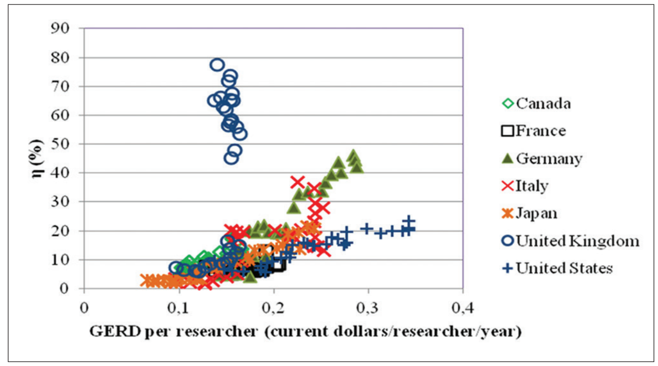
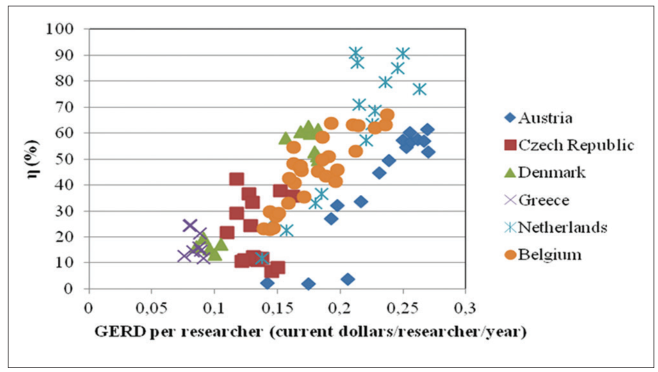


Figure 8: Dependence of η on υ for Austria, Czech Republic, Denmark, Greece, Netherlands and Belgium



Since the scientific foundations are one of the mechanisms to control the financing of science, then it is advisable to take into account the above criteria for the evaluation and planning of their activities.

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