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Logistic Approach to the Dependence of Efficiency of Scientific-and-Technical Projects on Resources

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Abstract The purpose of this work is to study the possibility to realize logistic approach to the process of scientific investigations and creation of innovation products. In the logistic equation, for the first time it has been offered the parameter r – the level of creativity inherent to a scientific team, which depends on the whole set of factors, namely: scientific level and experience of the leader and co-workers, their medium age and ambitions, and work conditions as well, including psychological climate and using the promising methods for stimulation to achieve high results. When resources are limited, at the initial stages of performing investigations it is expedient to determine the most promising and efficient direction for development and concentrate all the resources for its realization. It has been ascertained that the break in financing prevents efficient using the supplied resources.

Keywords: *logistic model, efficiency of project, innovation, resources*

1. Introduction

The notion of the word “logistics” was known as early as times of Ancient Greece where “logistike” meant “skill of calculation” or “skill of reasoning”. In the first millennium, namely, in times of Byzantine Emperor Leo VI (866–912 years), logistics was defined as the skill to provision the army and administer its resources, including preparation of every military campaign. Due to military affair, logistics grew up to the level of science. It is commonly adopted to consider the French war specialist of the early XIX century baron A. Jomini (1779–1869) as a creator of the first treatises in logistics. He defined logistics as science of administering and planning the resources, carrying and provision of troop.

In recent years, logistics mainly considers the issues of rational transportation and stock placing the materials and products [1], but the most wide conception of this scientific direction is defined as planning, administering and controlling the usage of resources to reach the maximum efficiency of a social action (optimization of manufacture) [1,2].

This work is aimed at studying the possibility to realize logistic approach to the process of scientific investigations.

2. Main Part

In 1838, in the work [3] P.F. Verhulst offered his logistic equation that was further “repeatedly discovered” by R. Pearl and L. I. Reed [4]. Considered in the Verhulst-Pearl equation is the growth of the population size under conditions of definite limitations and competitive conflict inside the population.

$$\frac{dN}{dT} = rN - \frac{r}{K}N^2 \qquad (1)$$

where N is the population size, t - resource, K - maximum result, r - birthrate.

The solution of this equation can be plotted as a curve resembling the Latin letter S with the slope to the right (Figure 1).

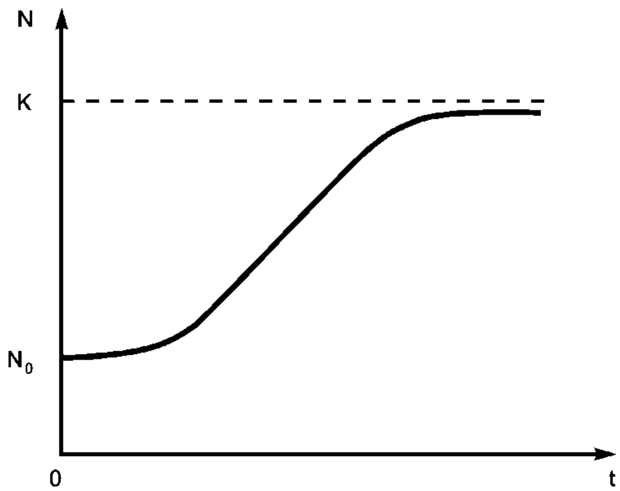

Figure 1. Dependence of the population growth on time under conditions of some limitations (competitition)

Let us consider this logistic approach to the possibility of estimating the efficiency of scientific-and-technical developments. In the paper [5], the processes of innovation development and technical progress are illustrated with the same s-like curve, but the authors did not make any detailed analysis of this dependence. Besides, there are logic mistakes in their consideration (see Figure 2).

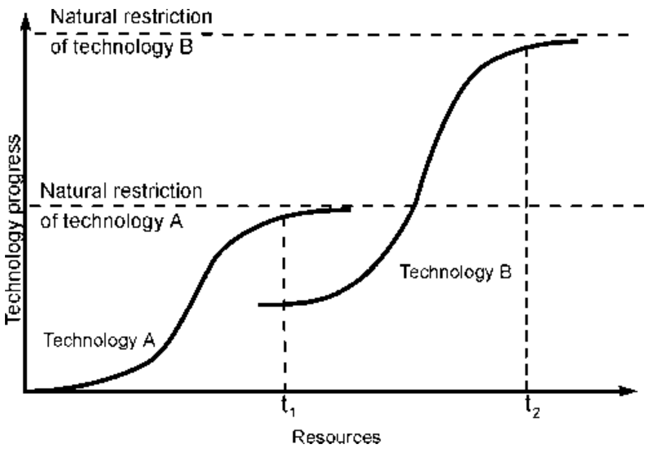

Figure 2. Exchange of technologies (technical progress)

There are several lacks of the above plot, namely:

1. Each technology does not begin from a zero position but has its analogs and prototypes. Therefore, the technology curve A should not start from the zero value of parameter.

2. Obviously, technology B should begin with parameter equal or higher than the parameter for technology A. It is known that the resource for development is extended to more promising technology that possesses competitive initial indexes.

3. The corrected plot describing technological progress, which corresponds to known scientific-and-technical as well as industrial practice, is depicted in Figure 3.

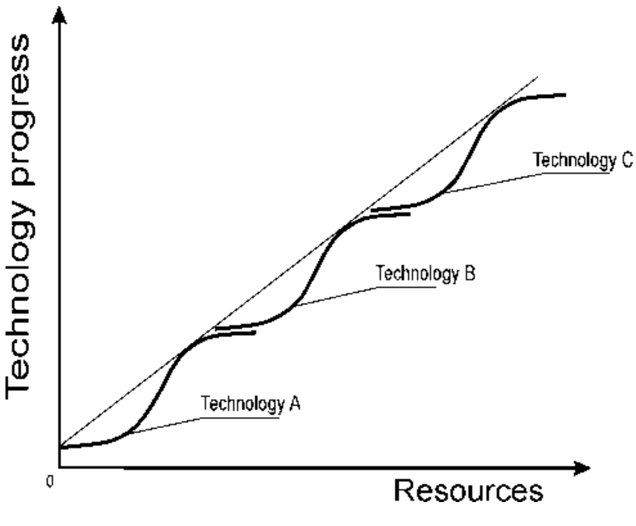

Figure 3. Technical progress in development of technologies from A to B

If we use the logical constructions that enabled to deduce the Verhulst-Pearl equation, then in the case of "scientific-and-technical production" via N we shall designate the amount of scientific results, via t – resource (time, funding), K - maximum result that corresponds to physical limitation of the chosen scientific-technical idea. In Equation (1), r corresponds to the index of birthrate in the given population. In the scientific-technical work, the factor r can describe the level of creativity in the team work when elaborating the scientific solutions and new innovation products.

What can influence on this factor? One can formulate the following reasons:

1. Education, qualification and scientific-technical level of team members. The team should have its leader of high scientific-practical level, which corresponds to qualification of doctor of sciences or professor, while the main part of team members should have the maximum possible educational level and try to increase it, for instance, via the post-graduate study. The level of previous achievements of this team can be estimated using the amount of publications in professional journals, monographs, via citation index and taking participation in and respective awards of international exhibitions, etc.

2. Age and numerical composition of the team, in which the medium age of scientific co-workers (in accord with my observations) should be equal to 30…35 years. It means that the team should be composed from persons both with a large scientific-and-practical experience (of declining years) and alongside with them co-workers of younger and medium ages with a lower experience. As a rule, young investigators have stronger motivation to reach high scientific-technical results for their career growth.

3. Availability of modern equipment (testing, measuring, technological, etc.) to perform the work at a high level.

4. Availability of dataware for this work.

5. Labor conditions and psychological climate in the team. Members of the team should be united and operate as one team aimed at reaching the set purpose. There should be realized progressive financial and non-financial measures to motivate members for achieving the high results.

Taking the above reasons into account, let us follow the analogy with logics of solving the Equation (1), namely:

$$\frac{dN}{dt} = rN\frac{K-N}{K} \quad K \to N_{\max} \tag{2}$$

$$\frac{K \cdot dN}{N(K-N)} = rdt \tag{3}$$

$$\frac{1}{N(K-N)} = \frac{1}{KN} + \frac{1}{K(K-N)} \tag{4}$$

$$\left(\frac{1}{N} + \frac{1}{K-N}\right)dN = rdt \tag{5}$$

after integration

$$\int\left(\frac{1}{N} + \frac{1}{K-N}\right)dN = \int rdt + A \tag{6}$$

$$\ln N - \ln(K-N) = \mathrm{rt} + \ln a \quad \ln a = A \tag{7}$$

$$\frac{N}{K-N} = ae^{rt} \quad \mathrm{t} = \mathrm{t}_0;\ \mathrm{N} = \mathrm{N}_0;\ a = \frac{N_0}{K-N_0} \tag{8}$$

$$N_t = \frac{aKe^{rt}}{1+ae^{rt}};\ N_0 = \frac{aK}{a+e^{-rt_0}} \tag{9}$$

$$N(t) = \frac{K}{1+\exp(b-rt)};\ b = \ln\frac{1}{a} = \ln\frac{K-N_0}{N_0} \tag{10}$$

Thus, the efficiency of the scientific-technical work versus resources corresponds to the logistic dependence that can be plotted as the following curve (Figure 4):

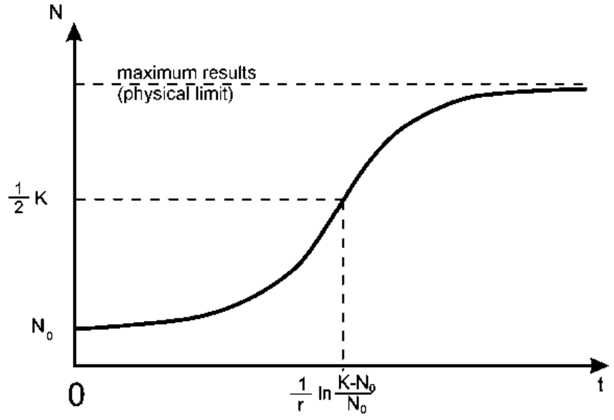

Figure 4. Dependence of the efficiency of a scientific work on resources

Using Equatoin (10), one can find that the result $\frac{1}{2}K$ (half of the possible maximum) will be reached at the resource value $\frac{1}{r}\ln\frac{K-N_0}{N_0}$, while for higher r values the result $\frac{1}{2}K$ can be reached for a lower resource value.

Let us analyze this conclusion. Opposite to Equation (1) describing the growth of the population strength under conditions of some limitations and competition inside the population, in our case the limiting factor is r that depends on the educational level and other marks, which were adduced above. Here, we can state that this limitation is determined by such competitive factors as: level of knowledge, experience, motivation, ambitions, quality of equipment. It means that if two competitive teams work to solve the same scientific-technical task, then the initial N0 value for both teams will be different and proportional to r factor. Respectively, the result K achieved by each team will correspond not only to physical limitations in this technical branch (the team can not reach maximum results) but, in the first approximation, will be in proportional dependence on r.

As to resources necessary to reach the result, in accord with Figure 4, the team with higher r will reach this result earlier than the team with lower r. In the case of identical resources, this team will reach a higher result. Being based on the above considerations, the logistic equation for the dependence of the efficiency of scientific-technical elaboration on resources can be written as follows:

$$\frac{dN(r,t)}{dT} = rN(r,t) - \frac{r}{K(r,t)}N^2(r,t) \qquad (11)$$

The offered logistic approach to the analysis of the scientific result efficiency shows that at the first stage (Figure 5a) the work efficiency is low.

The first stage comprises formulation of purposes, setting the problems, search for information, patent-and-information investigations, choosing the methods, etc.

The second stage is the most efficient. Just here the augmentation of results per each unity of resources reaches its maximum. At the third stage, to obtain new results needs to essentially increase the supplied resources. Therefore, it is the second stage that is the most advantageous period to create start-up companies.

It is noteworthy that any discontinuity (break) in financial support to this work for some period with further renewal and prolonging the initiated investigations (Figure 5b) leads to the necessity to repeat the new first stage (Figure 5a) of information searches, of a critical analysis of methods with account of new data obtained by other competitive teams. This situation results in non-efficient using the resources and can even cause the loss of leading positions at the innovation market. In this case, all the delivered resources can be lost, since the possibility to return the means in the form of profit when making and selling the innovation products is lost, too. Therefore, when resources are limited, at the initial stages of performing investigations it is expedient to determine the most promising and efficient direction for development and concentrate all the resources for its realization.

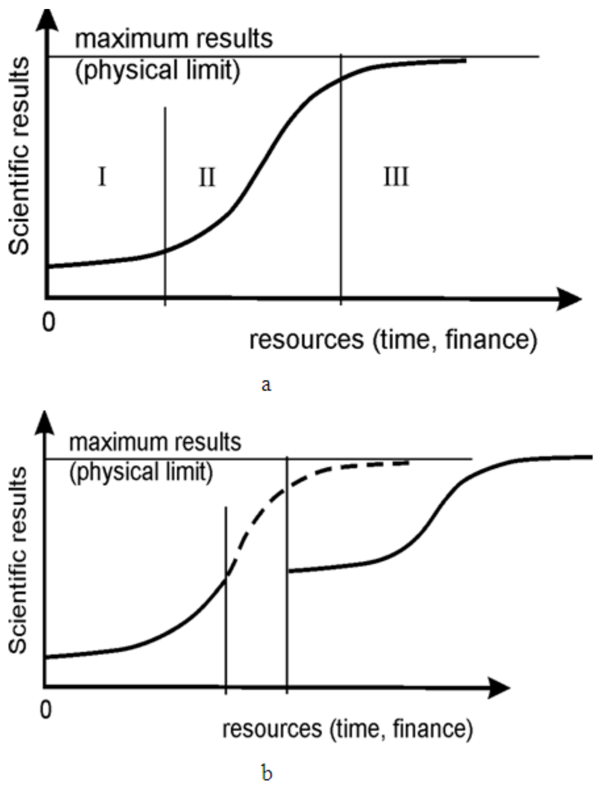

Figure 5. Stages of the efficiency of fulfilling the innovation projects (a) and losses of the efficiency caused by interruptions in financing (b)

If financial resources are provided continuously, regularly and in required volumes, then technical progress has an advancing character (Figure 3). But under the other conditions – for instance, intensive financing or, contrary, scanty one - this progress can be accelerated or decelerated, respectively (Figure 6).

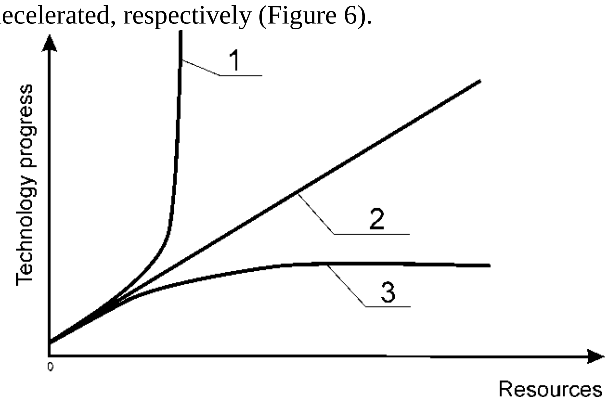

Figure 6. Influence of financing on the rate of technical progress: 1 - accelerated or rapid development; 2 -stable development; 3 - decelerated one

World experience of developed countries shows that for accelerated technical development it is necessary to provide financing the science in the volume 2% of the gross domestic product (GDP). When providing 1% of GDP, development has a stable character, but this level is a critical limit of necessary financing the scientific investigations. Financing at lower values results in deceleration of technical progress, which means that the scientific-technical potential of this country develops with lag.

3. Conclusions

1. For the first time, offered in this work is the logistic model for planning, controlling and evaluating the results of scientific projects.

2. The main factors that influence, except resources, on the efficiency of scientific projects are as follows: scientific level, experience of the leader and co-workers, their medium age and ambitions, potential, healthy ambitions, and psychological climate in the team-developer. The higher the level of creativity, the lower financial resource is necessary to reach the needed scientific results.

3. When resources are limited, at the initial stages of performing investigations it seems reasonable to determine the most promising and efficient direction for development and concentrate all the resources for its realization.

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