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The Law of Diminishing Marginal Productivity in the Model of Pure Discounted Income of Innovations

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ABSTRACT

An econometric model of the law of diminishing marginal productivity is proposed in the phase of the commercialization of innovative projects. It is based on the functional dependence of the volume of production of innovative products on the factors of production: capital, labor, innovation and inflationary discounting. By deducting investments in innovative projects, an economic-mathematical model of net cash income from innovative projects was obtained. Considering the diminishing marginal productivity in the phases of the life cycle of innovations, as well as the effect of market saturation with innovative products, increase the accuracy of assessing the economic efficiency of innovation activity.

Keywords: Innovations, law of diminishing marginal productivity, income, discounting, project, efficiency.

1. INTRODUCTION

A vector for innovative development is currently a priority for Russia. This is evidenced by many venture, scientific, innovative funds created since 2000. Their financing is largely done by government [1]. The strategy of innovation development is implemented by specific innovative projects. In addition, the result of such activity in terms of efficiency is predetermined by the innovative potential of projects. As a result of implementation of a large number of projects over the past 10-15 years, returns have not been achieved commensurate with the average level of Europe, America and Japan. Consequently, the selection of innovative projects for investment has been proved as ineffective.

Taking into account the above problems, an urgent task is to refine the economic and mathematical models of innovative potential of projects [2]. This work is devoted to solving this problem.

2. MATERIALS AND METHODS

In order to describe the decreasing marginal productivity in the model of pure discounted innovation income we have to note that innovations are characterized by a variety of private metrics [3, 4], each of which reflects the merits and opportunities of project commercialization, its scientific and technological level, the possibility of practical implementation, taking into account available resources, the potential of employees participating in the project, etc.

Traditionally, such a set of metrics m_i, $i = 1, 2, \ldots, N$ is summarized taking into account the weight (significance in the project implementation) to obtain the value of the integral indicator P, allowing to perform a comparison of projects and to rank them on the basis of preferences when choosing an investor [5]:

$$P = \sum_{i=1}^{N} k_i \cdot m_i , \tag{1}$$

where, m_i is a value of the i-th metric of the innovation project;

k_i is weight coefficient.

The following model is more developed:

$$P = \sum_{j=1}^{N_j} \left(k_j \cdot \sum_{i=1}^{N_i} x_{i,j} \right) \tag{2}$$

In this model homogeneous indicators ($j - e$) are grouped, for example, by the stages of the innovation process [6].

These traditional models of a linear kind (1), (2) are based on representation about extensiveness of innovative activity results by a principle "the more, the better". In reality, practice denies this idea of correlation between costs and results of innovation activities [7]. The proof is, for example, the analysis of the ratio of costs of personnel having the scientific degrees of candidates of sciences, and the number of innovative products produced by such personnel – Figure 1. This dependence reflects data on the universities of the Russian Federation (the database of reporting data of universities with a rating evaluation). Markers are actual data, lines are polynomial approximations [12].

Analysis of dependence of results of innovation activity on the costs of resources used in innovation processes: equipment (Figure 2), premises, materials, etc., gives similar results. Markers are actual data, lines are polynomial approximations [12].

In order to determine the trend of dependence of R & D work results on the resources used, the experimental data (marked in Figures 1 and 2 by markers) is approximated by polynomials of the second order:

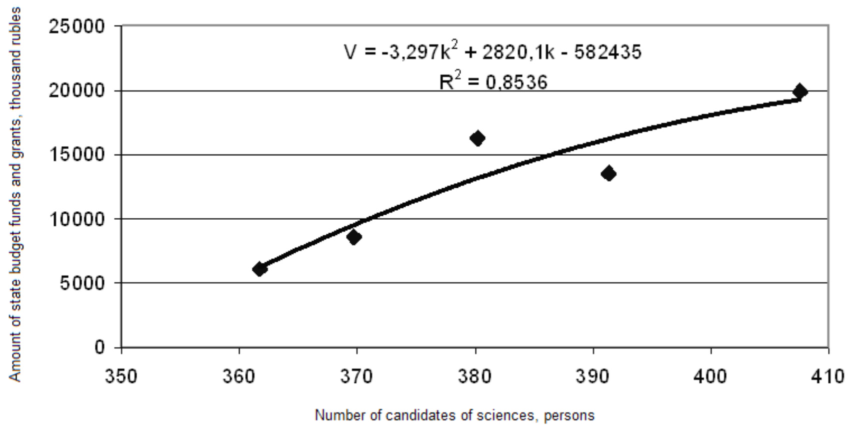

Figure 1: Dependence of volume of grants and scientific-research works implementation financed by state budget from the number of candidates of science

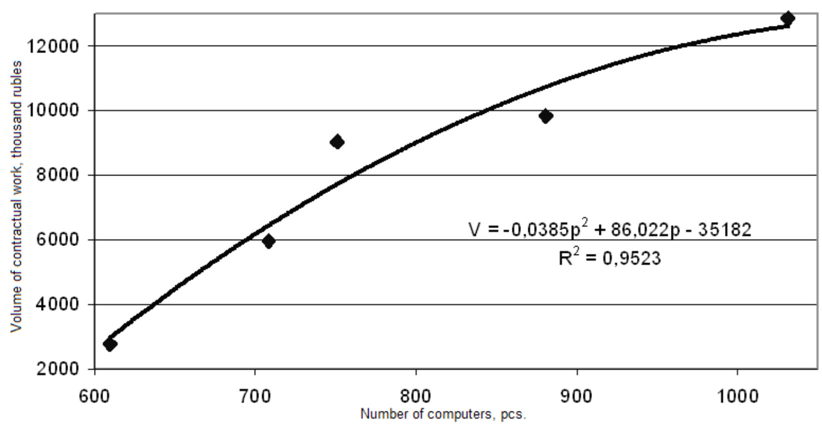

Figure 2: Dependence of the volume of R & D work on the contractual topics from the computer equipment

$$V(k) = -3{,}297 \cdot k^2 + 2820{,}1 \cdot k - 582435, \tag{3}$$

$$V(p) = -0{,}0385 \cdot p^2 + 86{,}022 \cdot p - 35182, \tag{4}$$

It is important to note that both dependences (3) and (4) have a high correlation with the experimental data, which indicates the tightness of the connection with them:

$$R^2 = 0{,}8536, \tag{5}$$

$$R^2 = 0{,}9523, \tag{6}$$

Polynomial series show that as the cost of innovation resources increases, the rate of increase in its efficiency in monetary terms decreases. To quantify such changes in the rates, we determine the numerical values of the derivatives (indicated rates):

$$dV/dk = -3{,}297 \cdot 2 \cdot k + 2820{,}1, \tag{7}$$

$$dV/dk = -0{,}0385 \cdot 2 \cdot p + 86{,}022, \tag{8}$$

In quantitative terms, the dependences (7) and (8) are reflected in Figure 3 and Figure 4.

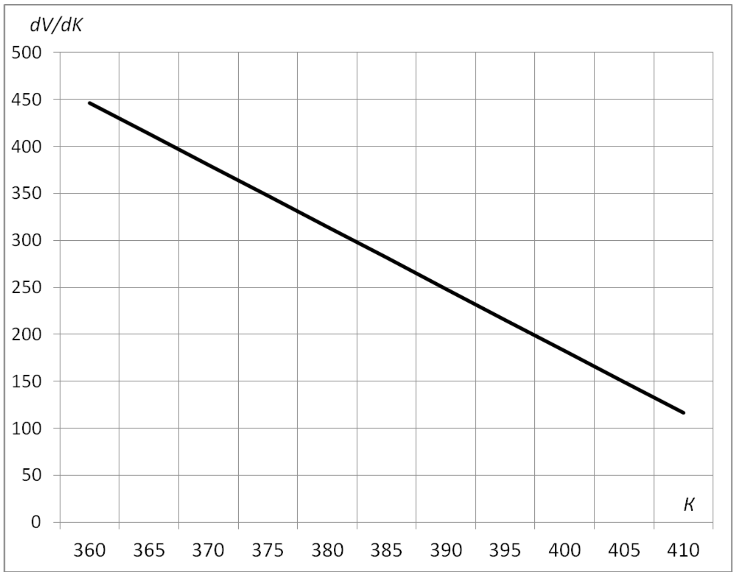

Figure 3: Dynamics of decrease in rates of R & D work от from the number of candidates of science

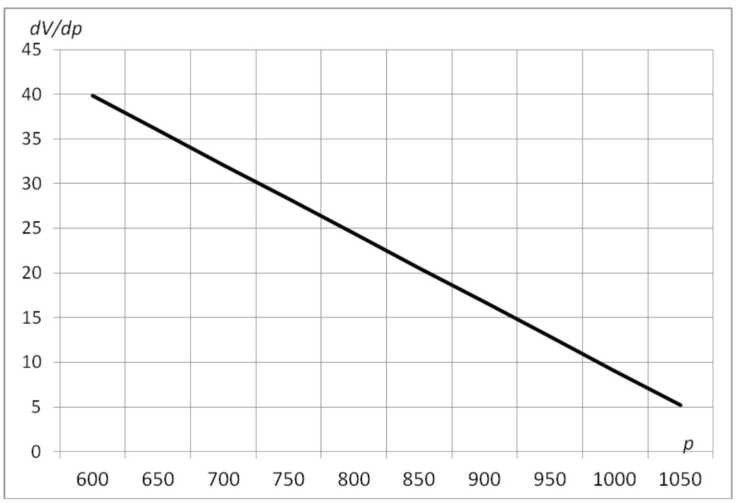

Figure 4: Dynamics of decrease in rates of R & D work from the computer equipment

The results shown on Figure 3 and Figure 4 indicate that the rate of decrease (the first derivative) of marginal productivity is very significant. For the dependence on human capital (the level of candidates of sciences), the decrease is 73.88% (3.829 times), and 87% (7.7 times) of the computer hardware used.

These quantitative indicators of the decrease in productivity of the phase of scientific activity in the life cycle of innovations show how important is verification of the economic and mathematical model that reflects the dependence of innovation activity on used resources.

3. MODEL

Authors propose to take into account the law of diminishing marginal productivity when obtaining an integral evaluation of innovative projects and their portfolios. This law reflects the fact of a relative and even absolute decrease in the results in the growth of any of production factors.

For this we will use the economic-mathematical model proposed by Cobb and Douglas:

$$V = A \cdot K^{\alpha} \cdot L^{\beta} \cdot e^{\gamma \cdot t}, \tag{9}$$

where, A is a scale of an innovative project or portfolio;

V is a volume of manufactured innovative products;

K is amount of invested capital;

L is work spent on the project;

α is the capital elasticity;

β is the labor lasticity;

$e = 2.71828$;

γ is the speed of saturation with innovative products;

t is the time.

We will express the result of an innovative project in the cash flow taking into account the price of each innovative product P_i:

$$S_i = V_i \cdot P_i \tag{10}$$

Now the revenue from the innovative product implementation is numerically equal to the positive cash flow, and the costs to the negative. Net present value will be the following:

$$NPV = \sum_{i=1}^{M}\left(\sum_{j=1}^{F1}\frac{S_i(t_j)}{(1+r)^j} - \sum_{j=1}^{F1}\frac{I(t_j)}{(1+r)^j}\right) \tag{11}$$

where, S_i is a cost of innovative products;

$I(t_j)$ are costs of innovative production;

M is the number of time periods taking into account while calculating NPV;

r is discount coefficient;

F_1 is the number of accounting periods for innovation project implementation that correspond to the accrual of discount rate r.

Taking into account the Cobb-Douglas function (9) and price function (10), we obtain (11) in the modernized form:

$$NPV_{INN} = \sum_{i=1}^{M}\left(\sum_{j=1}^{F1}\frac{P_i(t_j)\cdot A_i \cdot K_i^{\alpha}(t_j)\cdot L_i^{\beta}(t_j)\cdot e^{\gamma \cdot t}}{(1+r)^j} - \sum_{j=1}^{F1}\frac{I_i(t_j)}{(1+r)^j}\right) \tag{12}$$

Net present value, obtained with allowance for decreasing marginal productivity, is an indicator of commercial efficiency of an innovative project or portfolio.

4. RESULTS AND DISCUSSION

An improved representation of net discounted cash income of innovative products portfolio is obtained, which is characterized by taking into account the law of diminishing marginal productivity. The model expression of the diminishing productivity is reflected by the Cobb-Douglas production function. Such an economic and mathematical model of innovative products cash flow makes it possible to carry out a comprehensive account of the full life cycle phases of innovations: from scientific activity to commercialization [10].

Fundamentally important in the obtained economic-mathematical model of net discounted income is the dependence of innovative products volumes on the costs of the resources necessary to obtain it [11]. Therefore, this model is applicable for solving problems of optimization of innovation activity. In this formulation of the problem, the solution of innovation management tasks is excluded, for example, during crisis periods, by sequestering the project budget, as evidenced by the revenue side of the model.

5. CONCLUSION

Taking into account the law of diminishing marginal productivity in the discounted cash flow allows, thus, to obtain a more adequate economic and mathematical model of the innovation portfolio. Particularly important is the area of revenue reduction from innovative products in the saturation zone of market. Such a zone of ratio of costs and revenues is critical for enterprises carrying out innovative activities. And for the preservation of competitive positions in such a range of costs, it is advisable to switch to the utilization of product, or its modernization. The transfer of costs to create the next version or generation of innovative products provides an increase in income elasticity in costs. Accordingly, the results of modeling more accurately reflect the potential of economic efficiency of portfolio implementation.

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