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Economic Efficiency of Applicative Research and Development Work

"That who cultivates the science is rewarded because its ideals give him a purpose in life."

W. I. Beveridge

Scientific research exerts a powerful influence on the rhythm of industrial production and on economic development in general. The continuous qualitative and quantitative development of the means for scientific research requires an analysis of the efficiency of research activity in the national economy, especially in industry.

Any fabrication process in an industrial enterprise is preceded by a study of the product and of the respective technological process and by their experimental application. It is only in the enterprise that the conception of the product or technology can be materialized and one can experiment and pass on to the stage of production.

In the present stage, the activity of a research collective is estimated both according to the scientific results obtained and according to the effective contribution of these results to the economic, social and cultural development of the country and to the prosperity of society.

To obtain an ever higher efficiency, it is imperatively necessary to concentrate the forces of research towards essential problems and to improve the profile and structure of the research institutes and centres. The documents of the Tenth Congress of the Romanian Communist Party underline that: "the new tasks facing research require the concentration of the forces towards essential problems, the liquidation of the present dispersion of the subject-matter which wastes forces and reduces the efficiency of research. At the same time, the present crumbling of the research unit network should be solved by an adequate grouping of the research institutes and centres and by the improvement of their profile and structure". [1]

A complex of factors among which are the situation of the material basis for research, the scientific value of the results of research and their applicability in the material production or unproductive sphere, the technical desiging and development activity following research, should be taken into consideration in estimating the efficiency of scientific researches.

As in the conditions of the present technical and scientific progress, a country, especially middle-sized or small, can no longer carry out thorough studies in all branches of activity, naturally, it is necessary that the main forces should be concentrated towards certain domains and problems. Obviously, the selection of the research domains should be made very judiciously, taking into consideration the requirements of the national economy so that this should lead to a corresponding, harmonious development of all branches of production and to a most rapid economic growth.

1. THE CONTENT AND WAY OF EXPRESSION OF EFFICIENCY

At present, the advance of society is conditioned by the increase of economic efficiency in all fields of activity. In approaching this problem, a distinction between technical and economic efficiency should be made at the beginning. From the technical point of view, a certain machine can be efficient through the fact that it has an increased production capacity in relation to its weight, power, etc. without this should necessarily imply the economic efficiency of the machine. Besides a technical efficiency, a favourable relation between the social labour expenditure occasioned by the designing, building, installation and upkeep of the machine, the specific consumptions of raw materials, materials, etc., on the one hand, and the value of the production obtained with the aid of the respective machine, on the other, should result from the utilization of the machine in production.

Considered at the level of the national economy, economic efficiency in all fields of activity of the sphere of material production reflects in essence the productivity of social labour, namely the direct expression of the relation between the expenditure of live and materialized labour and the mass of the use values created with these expenses.

The problem of the economic efficiency of an activity should be directly examined within a branch, subbranch or enterprise. Its comparing to labour productivity on the national economy as a whole is not conclusive for its concrete valuation. The term of comparison should be the indicators reflecting the average productivity of the respective branch or subbranch.

Directly, the criterion for the concrete analyses of economic efficiency is not social labour productivity but only the objective pursued in choosing the most efficient solution; the direct objective of the increase of economic efficiency is the improvement of the average relation, on branch or subbranch, between the live and materialized labour expenditure and the volume of production obtained, that is the reduction of the socially necessary labour expenditure for the respective products.

In socialism, economic efficiency is one of the main criteria of the repartition on branches and fields of activity of the material means and labour in

the national economy. The economic efficiency calculations are playing an important part in choosing the concrete solution and the best variant from the economic point of view, respectively that which in the existing conditions contributes, to the greatest extent, to the increase of labour productivity at the level of the branch and national economy.

The category of economic efficiency is characterized by a double relativity: firstly, it appears as a relation between the effort made and the economic effects obtained and, secondly, the economic appreciation of this relation can be done only relatively, on the basis of comparisons.

The economic effects forming the object of the efficiency analyses can be grouped into value, material and social effects.

The value effects are synthetically expressed with the aid of indicators, such as: the volume of production, the cost price of production, respectively the volume of accumulations of money and the volume of investments.

The material effects are expressed with the aid of a multitude of indicators in a physical expression, reflecting the use values, the technical and functional parameters, etc. The correctness of the appreciation of this initial aspect of economic efficiency has a special significance in the present stage, when particular stress is laid on the increase of the quality of production.

The social effects refer to the improvement of working and service conditions, the increase in the degree of employment of man power, the attraction of natural resources into the active economic circuit, the development of localities, etc.

Essential in the determination of economic efficiency is the approach to problems in the light of the economic interests both of the enterprise, branch and of the whole country.

The elaboration of the best solutions at the level of enterprises or branches should take into consideration their implications for the connected branches, that is the analysis of all significant economic implications and effects.

In the case of scientific research, the concept of economic efficiency has, more strikingly than in other fields of activity, a double significance: economic and social. [6]. The researches with an economic efficiency cause most obvious social effects, just as the researches with a social efficiency influence the economic activity of research. The separation between economic and social efficiency depends, to a great extent, on the present limits of the methods of calculation and appreciation of the results obtained in the scientific research work.

A delimitation between applicative and fundamental research work is necessary for appreciating the economic efficiency of research and development work. If the application of criteria of economic efficiency is necessary in the case of applicative and development researches, appreciations of scientific value and of future efficiency are used in case of fundamental researches instead of calculations.

The establishment and permanent maintenance of the necessary proportions in the development of science should be taken into consideration in the appreciation of the economic efficiency of research work. Certain proportions among the research levels should be established for each period: between fundamental research work, on the one hand, which aims at the disco-

very of the secrets of nature, the knowledge of various phenomena, the creation of a new technical basis (all this being a reserve of subsequent studies) and the applicative and development research work, on the other hand, with a practical character and purpose, accumulating laboratory and organizational work for the application of the results supplied by fundamental research.

It is also necessary to grant special attention to the proportions among various scientific branches and within the branch itself among various research domains.

In our country, particular attention is paid to the development and orientation of scientific activity in keeping with the programme of social and economic development of the country: "the promotion of technical progress requires the intensification of scientific research activity and the wide-scale turning to account in production of the achievements of contemporary science and technology. The important role science has to play in the development of economy and culture, in the whole work of socialist construction, is well known. To fulfil this role, both fundamental and applicative scientific research must start from a thorough knowledge of the directions of our country's economic and social development and of the general tendencies of development of society" [2].

2. THE MAIN FACTORS CONDITIONING THE LEVEL OF EFFICIENCY

The directions of research promoted in various branches and domains of science can be divergent or complementary, they may mark parallelisms or leave unsolved problems of major significance in keeping with the general needs of the country. The full consideration of the national research effort is a very important element.

One of the main factors conditioning the level of economic and social efficiency of research work can be considered the orientation and co-ordination of the scientific research activity on a national scale. This is achieved on the basis of a large comprehension of the mission of research work in social life and of the observance of the internal laws of the development of science and of the characteristic features of planning within this field of activity. A rigorously substantiated research program, in dialectical unity with the requirements of economic development may have important effects on the economic efficiency of research work.

The progress of science is inconceivable without fundamental researches which broaden the theoretical horizon and force of comprehension of society. Therefore, the organic and harmonious blending of fundamental with applicative research work is necessary. The translation of this requirement into deed implies various methods of blending the two research categories, leading to the obtaining of particular achievements.

A transformation of science into a direct force of production is taking place in our epoch. In the socialist countries and consequently in our country, this transformation is not achieved automatically and spontaneously, but in the conditions of a planned economy. The blending of research work with the problems of technical progress is expressed by an adequate research

subject-matter, based on social order, a fact implying the co-operation of all cadres in economy. The organizational basis of co-operation between research and economy, beginning with the working out of the subject-matter and ending with the practical application of the results of research work in production is playing a particular role in raising the economic and social efficiency of scientific research.

Another important factor influencing the economic and social efficiency of research is the specialization of the research institutes and centres. The specialization of the institutes and the concentration of the scientific forces on certain priority domains have positive repercussions on the profoundness of solutions, on their practical values, on the speed of solution and application.

Yet, the specialization of the institutes does not exclude the possibility of the existence of institutes for complex scientific domains, rallying specialists from various branches of activity.

An important role is played by the rational territorial repartition of the research institutes and centres in keeping with the requirements of production and the approach to the productive units for which the respective researches are being carried out.

The material basis including the research building, the apparatus and equipment of a high technical level, the complete and systematic scientific information exerts a considerable influence on the economic efficiency of research.

The characteristic features of the development of science in the contemporary epoch determine increased needs for precision and laboratory apparatus of big proportions, which is leading to the continuous increase of expenditure for ensuring the material basis. Huge funds for research and development investments are earmarked in the industrially developed countries. In 1966 and 1967, for example, about 4% of the national revenue was spent to this purpose in the Soviet Union and the United States, 2.8% in Great Britain, 2% in France, etc.

Serious problems with economic implications necessitate the organization of independent centres which are unfolding their activity, on the basis of orders, at scientific institutions, education institutes, big enterprises, etc.

The problem of scientific organization, information and documentation in various fields of activity, at documentary and information centres is ever more insistently raised on an international plane.

The material incentive and moral stimulation of scientific workers, the level of organization of scientific work and the personality of the heads of school constitute another factor of the efficiency of research work. The composition of a research collective, the unfolding of research work on stages influence the level of the economic efficiency of research work. Indisputably, the level of qualification of the research cadres influences, to the greatest extent, the level of the economic efficiency of research.

A defining tendency of the contemporary scientific research is the ever more powerful affirmation of the related sciences and of the interdisciplinary and multidisciplinary researches. As such, particular attention should be given to the selection of cadres, the research collective including research workers of various age and speciality.

In the ensemble of scientific work, the turning to account of the results of research is one of the most important factors influencing the level of economic efficiency. The degree of materialization in economic and social practice of research work is pertaining to the social mechanism, to the inter-relations created between the research workers, on the one hand, and the beneficiary, on the other hand, and to the intermediate links in the process of materialization designer, builder and authority organs.

These factors conditioning the economic efficiency of research work exert particular influence on the progress of science in general and of applicative research, in particular.

3. EFFICIENCY CALCULATION AND VALUATION METHODS

Applicative and development research program should be directed in such a way that the application of its results in practice should enable a rapid and objective establishment of the concrete economic effects.

The calculation methods of the economic efficiency of research programs are different according to the character of the research theme. A number of methods, based especially on two synthetic indicators, for the determination of the economic efficiency of research have been used so far:

a) the relation between the economic effects and the expenditure for scientific research;

b) the decreasing of production, administrative and other expenditure through the ammendments brought.

There is no satisfactory methodology so far for the valuation of the economic efficiency of scientific research work and of the influence of science on production.

Generally, a periodization, based on the influence of the results of science on production and on the economic development in general, should first be made for the valuation of the economic efficiency of scientific research and secondly, the requirements of research should be established.

The works of speciality [7] are trying to make a periodization of scientific research, from the incipient stage to the introduction in fabrication of the product or technological process, a periodization which comprises four stages:

1. Theoretical and fundamental research is being carried out only for knowing the theoretical basis of the process or of the respective technological method.

2. The incubation of the scientific idea establishes the possibility of the technical achievement of the scientific idea, the necessary investments for application and the expected economic effect.

3. The turning to account of the scientific results, a period which starts with the perception of the possible economic effect and ends with the first introduction in fabrication of the new product or technological process. This

period of time also includes the necessary time for preparatory work linked to the introduction in fabrication.

4. The propagation of a new product or technological method includes the period of time in which the potential economic effect of scientific research is turned into real effect. With this period of time ends the process of the turning

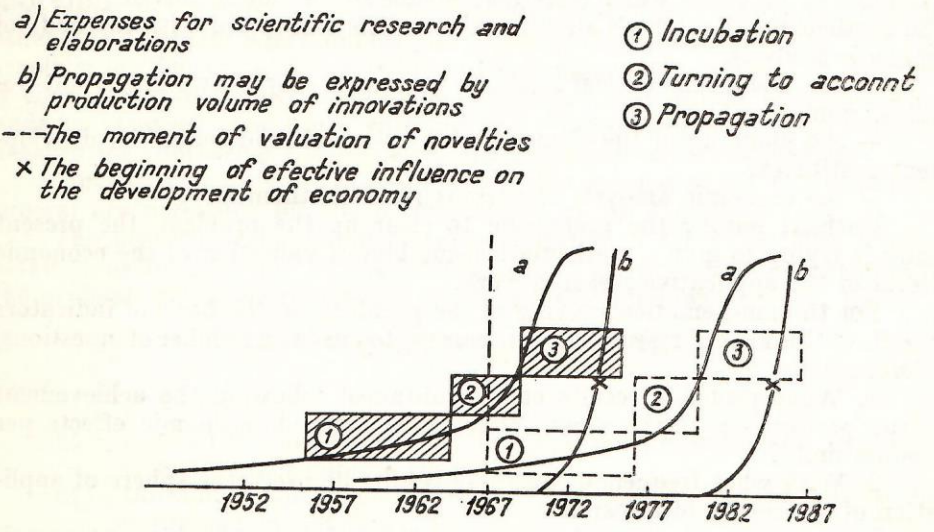

Figure 1

to account of research both for the research workers and the beneficiaries. The volume of production of a new product may serve as indicator of the rhythm of propagation of the scientific idea.

As regards this last period, many works of speciality [7] approach the problem of the evolution of expenditure on phases of research and the application of the results of scientific research. Thus, one can see in (figure 1) [7] that after the expenditure for scientific work attains the maximum value, several years, on an average, are passing until the influence of the novelties brought on the economic development is felt.

Consequently, particular attention should be given to the shortening of the length of conveyance in practice of the scientific idea, especially in the conditions of the contemporary technical progress.

As regards the establishment of the necessary conditions for research, these may be synthetized according to the following criteria:

a) before the beginning of any research, the analysis of all the occuring novelties, even of those in the form of licence proposals, etc. in order not to rediscover what is already known;

b) the orientation of research work in keeping with the consumers requirements resulting through the prospection of the market, especially when the research work is orientated towards an extremely important product;

c) the establishment of the technological research program sa art of which the aim of the research, the necessary research staff and laboratory installations, the unfolding of the research work in time,the time for the possible introduction in fabrication are defined.

Generally, the economic efficiency of scientific research work may be determined through various mathematical methods with the aid of which a number of problems which were inaccessible so far can be solved. [3][4][5]. The mathematical methods should, however, be completed with methods of economic analysis.

So far, the mathematical methods were used only in two important domains, namely:

— the planning of the themes for the research and industrial development institutes;

— the economic analysis of various research themes.

Without having the pretension to clear up the problem, the present study is trying to give a mathematical method of valuation of the economic effects of the applicative research work.

For the mathematical solving of the problem, on the basis of indicators specific of this kind of research, it is necessary to answer a number of questions, beforehand:

1. What probable results can be obtained following the achievement of the product or of the new technological method (economic effects per product unit)?

2. With what frequency can these results be used (the sphere of application of the results of research)?

3. On what period can the results of research be used taking into consideration the moral wear (the length of economic life of the research work)?

4. What is the cost of research from the beginning to the introduction of the results in production?

5. What is the total expenditure for the introduction of the results in production?

6. What are the necessary investments for the introduction of the results of the research work?

If the answers to these questions are known, the probable technical and economic results for the national economy as a result of the application of the results of research can be calculated as follows [4]:

$$E_e = E_c \cdot c \cdot n - [Q_i + I_i \cdot c \cdot n + Q_c + M_i]$$

where:

E_e — represents the probable economic results;

E_c — the savings per product unit resulting after the application of research, for an established period (for example, one year);

c — the demands established in the respective period;

n — the period of application of the results of research;

Q_i — the expenditure occuring in the industrial application per product and time units (without investments);

I_i — the investments necessary on the industrial introduction of the results of research per product and time unit.

Q_c — the research expenditure until the finalization of the theme;
M_i — the material means (in lei) immobilized after the carrying out of research work until the introduction of the research in production.

A number of auxiliary calculations are used for defining each factor separately. For example, the factor E_c, representing the savings obtained following the application of the results of the research work requires calculations based on a number of technical considerations. These savings can appear either with the plant which applies the results of the research work or with the beneficiaries. The calculations should be made on product unit and on a period of time determined according to the calendar. The relations should also be made in identical conditions, with the same factors and the same units of measure for comparing the precalculated efficiency with the real one.

Forecast calculations (the sounding of the opinion of the potential consumers) are necessary for the determination of the factor.

The problem is becoming more complicated in the event that foreign installations are necessary for the introduction of a new product or technology. The probable economic results can be calculated as follows [4]:

$$E_e^s = E_c^s - [P_s^s + Q_a^s + Q_f^s + M_i^s]$$

where:

E_e^s — represents the probable economic results obtained on the basis of installation imports (in lei);
E_c^s — the additional production (in lei) obtained with the aid of the purchased installation;
P_s^s — the purchasing price of the installation (in lei);
Q_a^s — the expenditure for adapting the foreign installation to the producer's requirements (in lei);
Q_f^s — the expenditure for the commissioning of the installation (in lei);
M_i^s — the material means (in lei) immobilized from the purchasing of the installation until its commissioning.

If the problem is raised to purchase licences for certain products or technologies, a research of our own being no longer necessary, only a thorough study of the problem, the economic efficiency of research may be calculated in keeping with the probable economic effects through licence purchase, so that [4]:

$$E_e^L = E_c^L - [Q^L + I_f^L + Q_f^L + M_i^L]$$

where:

E_e^L — represents the economic effects obtained through the purchase of licences;
E_c^L — the additional production obtained through the application of licences (in lei);
Q^L — the cost of the licence;
I_f^L — the fabrication expenditure of the installation on the licence basis;
Q_f^L — the cost of the commissioning of the installation manufactured on the basis of the licence;

M_i^L — the material means (in lei) immobilized from the purchase of the licence to the commissioning of the installation.

An important role in the valuation of the economic efficiency of research is played by the determination of purely economic effects, that is of the coefficient of the economic efficiency of research, a determination which can be made with the aid of the formula [4]:

$$K = \frac{(Q - P_p) \cdot T}{P_c + P_{cf}}$$

where:

K — represents the coefficient of economic efficiency;

Q — the annual production in the prices on the world market after the planned capacity has been attained;

P_p — the annual fabrication expenditure;

T — the best period for the sale of products on the market (beginning with the fabrication of the production and ending with the attainment of the planned parameters);

P_c — research and development expenditure;

P_{cf} — the expenditure for the introduction of the research in fabrication.

An important role in the determination of economic efficiency is also played by the indicators of the recuperation time (in years) of the research, development and introduction in fabrication, which give an image of the period of time in which the research expenditure can be recuperated. The recuperation coefficient of research expenditure from the profit can be calculated with the aid of the formula:

$$t_r = \frac{P_c + P_{cf}}{Q - P_p}$$

where the notations are identical as above.

Another indicator of the recuperation of research expenditure can be calculated after the formula [4]:

$$R = \frac{Q_i^i + P^i cf \cdot c^i + P_c^i + M_i^i}{B_c^i \cdot c^i}$$

where:

Q_i^i — represents the expenditure occuring in the industrial application of the results of research calculated on production unit and on a determined period of time (without investment expenditure);

P_{cx}^i — the necessary investments on the introduction of the results of research work per product;

c^i — the demands for products for an established period of time;

P_c^i — the research expenditure estimated for the respective period of time;

M_i^t — the material means (in lei) immobilized during the research work;

B_c^t — the profit estimated per product on the application of the results of research work.

For the calculation of the economic efficiency of research, the utilization of the mathematical means is more necessary as the problems occuring are more complex.

4. THE TURNING TO ACCOUNT OF RESEARCH, THE MAIN FACTOR INFLUENCING THE LEVEL OF EFFICIENCY

The economic and social efficiency of research is given by the possibility and degree of application into practice and by the turning to account of the results obtained.

The turning to account of the scientific results, the valuation of economic effects require the active collaboration of the research units, on the one hand, and the beneficiaries of the results, on the other. This collaboration should exist already on the drawing up of the research subjects and continue during the studies for clearing up the problems specific of the beneficiaries and for solving all the problems cropping up. Collaboration between science and practice should be based on the plans of research subjects and the turning to account of the scientific results.

The basic criterion of the introduction of a theme in the scientific research programme — except for fundamental research is the possibility of turning to account the results obtained, taking into consideration their necessity and opportuneness. Each theme of the research programme must have its correspondent in the turning to account programme, estimating from the very beginning the necessary time for the turning to account and the advantages which can be obtained.

The main forms of collaboration between science and practice can be synthetized as follows:

— the setting up of mixed collectives made up of scientists and specialists of enterprises which should periodically analyse the stage of research work, the prospects of turning to account and the new problems arising in the way.

— the temporary attachment of specialists from industry to scientific research institutes or of research workers to the beneficiary units.

— a system of material and moral incentive for research workers and specialists participating in these actions.

The main criterion of estimation of the results obtained from the research activity is the contribution of the researchers or research collective to obtaining concrete economic effects in the process of turning to account.

One of the indicators expressing an aspect of the efficiency of scientific work can be considered the relation between the sum of research expenditure for the applicative themes turned to account and the sum of research expendi-

ture for the completed applicative themes. The coefficient of turning to account may be calculated with the aid of the formula:

$$\varepsilon = \frac{Q_v}{Q_i} \leqslant 1$$

where:

Q_i — represents the sum of research expenditure for finished applicative themes;

Q_v — the sum of the research expenditure for the themes turned to account.

A favourable estimation of scientific research work can be made only when besides the other indicators of the economic efficiency of scientific research work, the coefficient of the turning to account is close to 1, that is when most of the research themes have been turned to account. Thus, when:

$$0{,}9 < \varepsilon \leqslant 1$$

The research contract is playing an important role in the intensification of the scientific research work, especially in the turning to account of research, in the case of applicative and development research. The judicious use of the research contract allows the achievement of a close connection between science and production and is leading to a more rapid application into practice of the results of science, to the increase of the realistic character of scientific preoccupations and to the increase of their economic and social efficiency.

Each research is concluded only after the scientific results have been turned to account, only when through the application of the results of the research work into practice, the expected economic, social and cultural effects are obtained. The generalization of the results of scientific research is the basic condition for obtaining a high efficiency in economy. That is why the research worker or the research collective has the important task to follow the product until the envisaged technical and economic parameters are obtained and to grant technical assistance during the whole period.

The immediate turning to account of the scientific results respectively the passing from the scientific idea to the practical achievement, to its materialization, is one of the organizational secrets of modern scientific research.

The requirements of the economic efficiency of research correspond to the present tendencies of international development of the means of production and of scientific research and of the objective development of society. Joint efforts, a close collaboration between science and practice, a sustained activity of specialists in production and of those guiding and carrying out research are necessary for the achievement of these requirements.

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L'EFFICIENCE ECONOMIQUE DE LA RECHERCHE APPLICATIVE ET DE TRAVAUX DE DEVELOPPEMENT

L'auteur étudie le rapport entre la recherche applicative et la production, l'efficience économique des travaux de recherche applicative et de développement, les facteurs qui conditionnent cette efficience.

Un accent particulier est mis sur la necesité d'établir des méthodes mathématiques pour aprécier les effets économiques des travaux de recherche applicative, utilisant certains indicateurs spécifiques, dont le coefficient d'efficience économique, déterminé par formule:

$$K = \frac{(Q - P_p) \cdot T}{P_c + P_{cf}}$$

a une importance particulière.

ЭКОНОМИЧЕСКАЯ ЭФФЕКТИВНОСТЬ ИССЛЕДОВАТЕЛЬСКИХ РАБОТ ПО ПРИМЕНЕНИЮ И РАЗВИТИЮ

В статье анализируется вопрос взаимосвязи между прикладным исследованием и производством, вопрос экономической эффективности работ в отношении прикладного исследования и развития исследования, факторов, обусловливающих это развитие.

Особое внимание уделяется необходимости установления математических методов оценки экономических эффектов работ по прикладному исследованию на основе специфических показателей; важную роль играет коэффициент экономической эффективности, определенный по следующей формуле:

$$K = \frac{(Q - P_p) \cdot T}{P_c + P_{cf}} .$$