ECONOMIC EFFICIENCY OF AGRICULTURAL R & D

ROUMEN G. DENTCHEV (*) - HRABRIN Y. BASHEV (**)

Abstract

The present paper presents some ideas related to science peculiarties as an object of economic study, to the mechanism of realization and estimation of agricultural research efficiency. It also determines the economic efficiency of wheat selection in Bulgaria.

Résumé

Dans ce travail les auteurs illustrent des concepts sur les particularités de la science en tant qu'objet d'étude économique, sur le mécanisme de réalisation et d'estimation de la rentabilité de la recherche agricole. Ils déterminent aussi la rentabilité économique de la sélection du blé en Bulgarie.

The problem of science economic dimensions is one of the mostly treated by economics during the last 3 decades and a half (2, 4, 11, 15). Over 6000 publications appeared on the assessment of research results, at least several hundred formulae were proposed to measure the efficiency of research workers, research institutions and of science as a whole (16). The different aspects of research activity participation in the realization of society relations have been cleared to a greater or less extent. However, at an overall estimate, the economic theory of research efficiency is still at the stage of its formation (5).

The studies on agricultural research efficiency increased together with its share in the economy growth of society and with the size of resources allocated for agricultural production development on a scientific basis, see (7, 10, 12).

During the last decades a considerable progress was done in clarifying the approach for estimation of research projects efficiency in agriculture (1, 6), in revealing the mechanism of agricultural economic science effect formation (3, 13) and of the factors of efficiency growth of research studies and the innovation processes in the branch (9, 13).

Science as an object of economic research

Scientific system is a large combination of activities determined by its specific product (the new scientific knowledge) as one of types of society intellectual production. The information character of the specific for science interdependent inner links is their main peculiarity. Their enlargement does not depend on the form and movement of the ideal by nature products of the research process. This conditions the «universal» character of production and consumption links in the research process to differentiate from the strictly determined by means of materialized products of labour links in the material production process. This character of links in the field of research is realized in synchronic and diachronic aspect simultaneously (i.e. in time) and in space (the international character of research process). The scientific production process is not a reproductive one but of accumulation of scientific knowledge. It is not proportional to the investments and does not depend on the degree of knowledge use. Hence, its dynamics could be only intensive. As every creative process the research process has unique and difficult to be defined characteristics of development and effectiveness. In that way,due to its specific determination science is related to the other structures in society. In the process of this interaction the complex «logic» of science development is being formed.

The beares of economic links in science are the product flows outcoming from the production system that reproduce and enlarge science material infrastructure and ensure the labour force reproduction of the research employees. In this connection specific economic relation have been formed in relation to the most effective use of the resources outgoing from the economic system into the field of research. This does not exhaust the economic dimensions of science. At the present stage of development research investigations turn in their great part into immediate part of the total productive (in the economic sense of the word) labour of the society. This is related to the participation of the employed in research activities in the formation and changes of economic relations in the material process of reproduction. This links enrich with new characteristics the process of reproduction and condition new regularities in its development. Research efficiency for example, specially in its fundamental part reveals unlimited possibilities for intensive economic dynamics.

The investment (long-term) character of the research process and the non-material character of its products make impossible the use of market as a mechanism for their establishment and management. In this field the role of public recognition is played by decisions which accept the financing of research projects in the process of research direct coordination on a national and international level. Without dropping out the necessity of value quantity realization and movement it ceases to be an essential characteristic of the research economic effectiveness. A specific form in which the effectiveness of research investigations development finds expression from society view point becomes the science economic potential. It characterizes the possibilities already created in the research process for increase of the economic efficiency of reproduction. The quantity of economic potential is formed and developed together with the development of productive and research potential of society and in the process of their interaction.

Essence of research efficiency

To express the essence of research process efficiency it is necessary to differentiate 2 types of links typical of the research process:

First: Endogeneous links and relations in the process of realization of productive existence of the employed in research activities. From this point of view efficiency characterizes effectiveness in the processes of creation and increase of scientific information - the advisable useful character of the activity in the field of research, as a special kind of society intellectual production.

The relation between material factors expended on research process and the effect of their combining, consisting of one or another invention, is not an important characteristic of their efficiency (as for example it is for the inner links on the system of material production). The very efficien-

(*) Senior Researcher, Bulgarian Agricultural Academy, He is currently Associate/Guest Professor at the University of Padua, Institute of Agricultural Economics and Policy.

(**) Senior Researcher, Bulgarian Agricultural Academy, Institute of Agricultural Economics, Sofia.

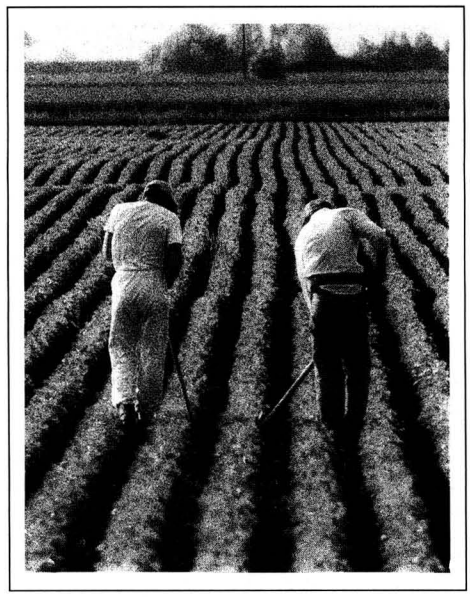
cy (fundamentality) of research process is determined by the variety and intensiveness of links in which the obtained scientific result is able to participate. Another more efficient way to measure (co-measure) the qualitative different new scientific knowledge and processes in whichthey have been created besides this important their characteristic, science and practice had not found yet.

Second : Exogeneous links, in the process of use of the products outcomung from the research field by the other social systems (political, economic, demographic e.t.c.).They determine the efficiency of research activities through the various useful effects when introducing the research results in practice. The immediate science efficiency is only a basis for realization of the outher technological, economic, political, psychologic, ecological, informative and other applied effects from the development of research potential of society. Research efficiency in this sense is socially determined, synthetizing characteristic of multi-side effectiveness of science development as a subsystem in society structure. It finds expressed in the functioning (effect) of other systems for which the final research results are defined. This efficiency in the long run conditions the social meaning and importance of research investigations development as an activity organized on a social scale and makes it economically possible.

Research expenditure is not directly an economically effective expenditure. It turns into one in the objectively carried out process of scientific information materializing. In the process of R & D *additional economic potential for the production* has been created and it is effectively realized in the process of research results introducing. The additional economic effect obtained of the applying a result in the production is the degree of scientific potential economic realization. It expresses the share of its joint effect with labour using research achievements corresponding to the research expenditures. Therefore, its size characterizes the influence of research factor on the changes of final economic results and science share in the gross economic effect of society.

Under the present conditions efficiency is a function of reproduction process development as a whole and a result of the realization of economic links of diachronic character on a wide temporal horizon. Its limits are determined by the period of creating and applying of scientific and technical achievements. On this scale the economic effect becomes an expression not only of current economy (effectiveness) of production costs but also of the maximum effectiveness realized, of the total expenditures in dynamics.

Research costs are additional social costs for increasing the efficiency of reproduction - *expenditure for non-material accumulation*. The determining of its size is a subject to a long term economic strategy through



which the economic links between research and economic spheres have been carried out. For given participators in the research process this size finds concrete economic expression in the admissible (marginal) investments for research to increase the efficiency of reproduction.

Research costs differ considerably from the traditional capital and current costs and could not be compared (compete) with them when determining efficiency. These costs require different time horizon for the realization of their effectiveness, they have different targets and play different functions in the reproduction process.

The possibilities for additional growth of economic effect on the account of an increase in the research costs, usually are limited only by the available arsenal, which the fundamental science possesses at the given stage of development. For every concrete production process theoretically they are unlimited. Yet, these abstract possibilities meet economic limits conditioned by the time lag between the investment in research and their final effect on the one side and the society resources limited at every stage for accumulation (for research and investment) and for the realization of additional effect. The admissible (marginal) research costs for effect growth show this social price, that at the given stage of development it is possible to allocate only for non-material accumulation volume, there will be more research achievements but investments and time (labour force) for science potential use will not be enough. As a result of this the rate of production current effect will decrease and consequently the dynamics of final consumption. The opposite : if the research costs will be considerably decreased and investments increased at a closer look we'll have higher rate of current effect but dynamics as a whole will decrease due to the lack of research achievements. The economic effect of research activities is realized in the process of research product participation in the formation and changing of total expenditures (and consequently effectiveness) on the product. It finds expression in the differential earning profitability of scientificated labour compared to the traditional (base) level and in the growth of the results of the process of development on a scientific basis that could not be achieved in the conditions of lack of scientific achievements. The size of the effect of research results applying is determined by their qualities, by the scale and speed of their spreading, by the economic and psychological conditions under which the applying is carried out, by the scale of moral depreciation (obsolences) and the available funds for investments, by the possiblities for realizing of parallel effect in the interrelated branches and activities, by the creation and implantation of more perfrct research achievements. The quantity of additional economic effect of the applying is determined by the qualities of research results and by the conditions under which the applying is carried out as well. The process of realization of efficiency of concrete research projects is characterized by strict specifity, while the links between the quantity of economic effect and production efficiency are rarely of a functional type.

The economic effect of research achievements applying could be manifested in the following three forms : in the national income growth (additive value), in the size of prevented losses, in the increase of non-productive (free) time of society. Most often it is formed in sizes overgrowng the limits of economically differentiated units of the economy system. This conditions the necessity for the economic importance of research investigations to judge not by the local effect in the separate units of the cycle science - applying but by the importance for the national economy.

Determining of agricultural R & D economic efficiency

As a criterion for identifying of research activities in agriculture, in the large area of science, we use their object. This is a combination of research works in science branches and subbrances with different object of investigation which final results are directly intended for agriculture. This area includes different fields of fundamental research specified by their final applying orientation - agricultural production. In this way we provisionally differentiate the upper end of agricultural research from the «pure» fundamental science. Dropped out of it are these applied studies that realize its effect in agriculture but are directly implanted in branches related to agricultural reproduction process. In that way we differentiate agricultural science from the applied studies in the field of agricultural machine construction, agricultural chemistry e.t.c.

The transition of research potential into an economic one in agriculture is through its

concrete existence as *biotechnological potential of research achievements*. Its quantity is considerably differentiated in the concrete climatic conditions during the different years (seasons) and in the corresponding agrooecological regions (subregions) of the country. This conditions the use of agrooecological approach in the organizing of research, in testing, applying and when estimating the efficiency of their achievements.

The determining of the economic efficiency of a given research projects is the basis for estimating of science efficiency. At the higher levels (research programmes, institutes, fields e.t.c.) the efficiency is a generalization as a results of its components encriching with new elements of expenditures and of effect.

In the economic analysis of science efficiency it is necessary to use *a system of indices* to characterize different aspects of research effectiveness. *The comparative efficiency* of research investigations shows the additional economic effect realized in the field of science from the economy of current and capital expenditures for research as a result of the choice of the mostly economical variant for given research problem solving. *The absolute efficiency* of research is efficiency of growth as a result of research achievements applying compared to the base variant of production development. It is expressed by the indices : economic effect of research results applying and of the unit of cultivated area (animal); efficiency of the expenditures and research resources; research workers labour productivity; efficiency of the expenditures and resources for the applying of research achievements; efficiency of the total expenditures for creating and applying of research achievements (for science and technical progress).

The period of research economic effect estimate is determined by the term of realization of research economic potential of achievements. It continues either till a new level of socially necessary effectiveness is formed, when on the basis of a given research achievement the predominant quantity of a given production is produced or till they grow old morally (obsolences) as a result of new research achievements applying.

When the efficiency of different research projects is calculated the estimation is made on the basis of adequate relating of research costs to the economic effect conditioned by them. In generalized assessments, estimates of research costs efficiency in given research institutes, fields or science as a whole the annual effects of the realization of economic potential are related to the corresponding annual costs. A more complete idea of efficiency during the period of analysis is obtained through estimation of the total current return of the created economic potential to the total research costs during the period. The most accurate idea of the research total costs level of efficiency is obtained by rendering of the time lag, determined by the average duration of research activities and the average period for their effect realization in the corresponding field of research, research unit or science area.

When estimating the resources efficiency in the research process it is necessary to consider a second lag conditioned by the period of their setting up and preparation for exploitation. An account of the effect of the resources is given in terms corresponding to the average period of obsolences of the research equipment and the average period for increasing the quality level of the employed in the field of research.

The economic effect of agricultural science achievements applying is realized on the account of cost reduction, quality increase, increase of production and economy of capital expenditures per unit of area (animal) in agriculture, of the effect realized in the interrelated branches and activities and the effect of foreign trade operations with research product and (or) with products produced on the basis of research achievements.

When determining the share of research investigations in the effect of science achievements implantation it is necessary to render additionally the expenditures on enlarged reproduction (additional investments for science and technical progress applying) through the minimum level of return of investment during the period (oopportunity costs). This is the effect that must be realized by any means by the additionally accrued capital in production and this effect could be considered as investment share when forming the efficiency of production. On condition of capital intensive enlargement of production this quantity expresses the effect of additional capital investments in reproduction of traditional way and it is necessary that it should be substracted from the economic enlargement of production it expresses the economy of investments comeasureed with the current cost (capitalized) as a result of scientific achievements applying. In this case it should be added to the quantity of the effect realized.

An estimation of efficiency level of research studies in the field of wheat selection in Bulgaria

Till the middle of the 80's the wheat production in Bulgaria was based mainly on the achievements of the foreign selection. During the period 1976-1989 35 new varieties of wheat, our selection, were created, established and distributed by region for production. They are bearers of the newly created selection economic potential and their applying determined the science and technical level of production during the period.

When estmating the economic effect of new varieties applying we use the results of their annual, year-to-year, agrooecological testing in the system of State variety testing (in 30 experimental stations) and statistical information for applying volume by main agrooecological regions in the country.

When testing the new varieties we use optimum for its type technology in the corresponding agrooecological regions. Compared to the control (base) they do not realize an economic effect of the change of production costs per unit, since they are grown under similar technological conditions. A representative samples of the corresponding types and groups of wheat are used for comparison of the grain quality. The complete comparability providing for of all factors allows to differentiate the annual economic potential created by selection. Under these conditions it finds expression in the rate (or change) of incomes per unit of area as a result of increase in productivity and quality of the new varieties compared to the basic ones.

As a result of the implantation of the achievements of Bulgarian selection during the period the variety structure of wheat production changes. From 16% in 1975 now the Bulgarian varieties of wheat almost cover all the areas in the country after 1983. The speed of realization of economic potential is different for the different varieties: from 1-2 years to 7-9 years for the simple wheat, 3-4 years for the strong wheat and 2-4 years for the hard wheat. The scale of implantation for the different varieties has different dynamics. Their share in the total volume of production is also different when the economic potential is exhausted and during the whole period of effective use. The percentage of the wheat implantation in more than 10% of the area under wheat for the different years is 19%, for the strong and hard wheat their percentage is 100%. The importance of the different varieties is also different when improving the variety structure of wheat production. The share of the new varieties soft wheat, implantated over 0.1 mln ha is 50%. Their area is 90.7% of the total volume of areas under the new varieties during the period.

Generally during the period the economic potential is realized on 22.5% of the areas under new wheat vatieties. This percentage shows really the share of distribution scale, bearer of selection effect. It gives an idea for the total quantity of lands necessary to realize the efficiency of science and technical progress in the field of wheat selection during the period of analysis.

The new varieties to a different extent take part in the formation of variety structure in the corresponding agroecological regions and subregions. Their share is the biggest in the total wheat production in Danube-Dobruja region and in the Central Northern Bulgarian region, and they surpass the percentages of innovation in the country as a whole with about 10-12% and 6-8%. In Danube-Dobruja region the percentage and absolute scale of variety innovation is the biggest. Over 50% (64% for the period 1976-1980) of the total size of the new var-

Table 1 ***Economic effect of new wheat varieties implantation in Bulgaria during the period 1976-1989*** *(in thousand levas).*

New varieties	1976-1980	1981-1985	1986-1989	1976-1989
1. Wheat	12491	−9034	44035	47492
a) positive effect	21679	15359	46125	83163
b) negative effect	9188	24293	2090	35671
2. Strong Wheat	5191	173	−2616	2748
a) positive effect	5191	289	6	5486
b) negative effect	0	116	2622	2738
3. Hard Wheat	0	654	1275	1929
a) positive effect	0	654	1275	1929
4. New varieties Total	17682	−8207	42694	52169
a) positive effect	26870	16302	47406	89578
b) negative effect	9188	24509	4712	38409

Table 2 ***Efficiency of production and wheat selection in Bulgaria*** *(percent).*

Average Yield (a)	Labour productivity (b)	Profitability of production (c)	Economic effect of varieties implantation (d)
100	100	100	0
110.5	123	108.2	176.82
113.2	157	53.4	−72.07
113.1	159	25.5	416.95

ieties area during the period are implanted in it. The distribution of the new varieties total production in the different agrooecological regions and subregions gives idea of the regionalization of newly created varieties. It is a basis for eonomic potential territorial redistribution of which this varieties are bearers.

The sum economic potential effect of wheat new varieties implantation during the period 1976-1989 is 52169913 levas (**Table 1**). The degree of the factual economic potential realization of the new varieties in the conditions of mass practice in Bulgaria according to experimental data is 60-70% (14). Consequently the economic effect of the implantation of new varieties during the period is within the limits of 31302 thousand levas and 36519 thousand levas.

The dynamics of the total economic effect of implantationof new varieties is quite various for the different years of the period. The rate in the quantity of economic effect is characterized periodically by sharp drops as a result of the economic losses of new varieties implantation realized during the different years.

The economic effect of the implantation of new varieties is with different dynamics, share of the total size and absolute level during the different years of potential realization and for the period as a whole. Only as an exception the changes and the levels of these indices coincide with the indices for production volume by varieties.

The total effect of 37.5% of the new varieties is negative for the period of implantation as a whole. The economic effect of the implantation of four varieties (13% of varieties number) at the same time amounts to 88% of the size of its total quantity for the period. This means that real economic profit of improving of variety structure during the period has been realized only for 13.2% of the total new varieties areas.

The level of the current efficiency of research costs in the selection during the period is 3.33 levas/lv, incl. 3.83 levas/lv soft wheat and 0.76 levas/lv hard wheat. It allows the return of the total expenditures for selection of the current effect when implanting new varieties in the year of new varieties implantation (for less than 4 months). During the first five years of the period the level of efficiency of expenditures is higher - correspondingly for total expenditures with 0.76 and for soft wheat selection with 0.77 levas. The increasing of biological and economic production potential is therefore achieved under increasing investments of public funds for research in the field of selection. Production efficiency dynamics during the period had been provided on the account of increased investments in science per unit of additional economic effect.

The additional economic effect of unit of cultivated land for new varieties economic potential realization is 1.19 levas/0.1 Ha. Compared to the first five years of the period its quantity has increased by 330%. This means that the implantation of selection achievements has brought about increase in efficiency off he use of land resources during the period.

The economic of every research worker and employed in the field of research selection is 1169 thousand levas and 223 thousand levas correspondingly during the period. It has increased compared to the first five-year period by 145% and 140% correspondingly. In this the increasing efficiency of labour of the employed in this field of research finds expression for periods necessary for the improving of their qualification level. The level of efficiency of fixed assets used in research process during the period is 10.94 levas/lv, incl. on the basis of their active part - 26.51 levas/lv. Compared to the first five years it has increased 227% and 203%. This expresses the increased return on fixed assets in research field.

During the period 1976-1989 the size of the economic effect from the implantation of new varieties of wheat amounts to 1.34% of the size of the net product of the subbranch during the period. **Table 2** expresses the dynamics of the main indices for wheat production efficiency - (a) average yield; (b) labour productivity; (c) profitability of production which is varies for the different years of the period and does not correspond to the dynamics in the economic effect of varieties implantation (d). The realization of efficiency of the development of variety structure during the period has been carried out under the conditions of stronger influence of the rest of wheat production efficiency factors. The direct influence of the economic effects of selection development on the total efficiency level of production is comparatively small. ●

References

(1) Arnon, I. (1968): *Organization and Administration of Agricultural Research*, Elsevier Publ. Comp. Ltd, New York.

(2) Braunstein, Y. et al. (1980): *The Economics of R & D*, Management Science, 15.

(3) Capablo, B. et al. (1988): *Agricultural Productivity Measurement and Explanation*, Wash. Resources for the Future.

(4) Dobrov, G. (1978): *Upravlenie na efectivnosta na nauchnata deinost*, Naukowa Dumka, Kiev.

(5) Funsfeld, H. et al. (1984): *Understanding R & D Productivity*, Pergamon Press; New York.

(6) Griliches, Z. (1958): *Research costs and social returns: Hibrid corn and related innovations*, Journal of Political Economy, 66.

(7) Griliches, Z. (1963): *The Sources of Measured Productivity Growth: US Agriculture 1940-60*, Journal of Political Economy, vol. 21, No 4.

(8) Holton, G. (1978): *«Can Science Be Measured»* in Yehunda Elkana et al., Editors, Toward a Metric of Science: The adyent of Science Indicators, New York.

(9) Jones, G. (1963): *The Diffusion of Agricultural Innovations*, Journal of Agricultural Economics, vol. 15.

(10) Latimer, R. et al. (1965): Geographic Distribution of Research Costs and Benefits, Journal of Farm Economics, vol. 47, No 2.

(11) Mansfield, E. (1968): Industrial Research and Technological Innovation, W. W. Norton, New York.

(12) Matthews, R. (1964): *Some aspects of Post-War Growtb* in the British Economy in Relation to Historical Experience, Transactions of Manchester Statistical Society, 132nd Session.

(13) Metcalf, D. (1970): *The Economics of Agriculture*, Penguin Education, London.

(14) Panayotov, I. (1987): *Postijenia na Selektsiata na pshenitsata i triticale v IPS «Dobruja» prez izminalite 25 godini*, Selskostopanska Nauka, 6.

(15) Twiss, B. (1986): *Managing Technological Innovation*, London.

(16) Zavlin, P. (1980): *Nauchnia Trud v Usloviata na Nauchnotechniches-kata Revolutsia*, Ikonomika, Moskva.

(17) Zuckerman, M. et al. (1980): *«Indicators of Science: Notes and Queries»*, in Science Indicators: Implications for Research and Policy, Amsterdam.

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