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Method of Forecasting the Price of Agricultural Machines

One cannot speak about prognosis without mathematics.

The mechanization of agricultural work is one of the essential elements of the progress of techniques and technologies in agriculture, a point of interference between the development of agriculture and of the machine-building industry.

In drawing up the prognosis for the coming decades, one sets out, on the one hand, from the necessity of complete mechanization of work both in the cultivation of plants and zootechnics and, on the other hand, from the continuous improvement of the installations used. In this way, an increase in the agricultural labour productivity is going to be ensured, which should allow a reduction of the share of the population employed in agriculture from about 50% at present to only 10—15%, until 1990, under the conditions of a 2—3 times in the volume of overall agricultural output.

The evolution in the improvement of the mechanization of agriculture requires the guided development of technics, taking into consideration the general requirements of economic growth and, first and foremost, the requirements of the improved economic efficiency of mechanization and, the new means should be introduced in the order of priority imposed by their efficiency.

To ensure mechanization and technical endowment, those installations will have to be introduced which ensure the reduction of production expenses in the conditions of the continuous increase in the incomes of those employed in agriculture and in mechanizing enterprises. Accordingly, a number of general principles will have to lie at the basis of the development of mechanization, namely:

— the total reduction of the costs of agricultural work;

— the constant maintenance of the price of delivery, of liquidation expenses and of the repair of technical means; their possible rise should be based on

the qualitative improvement of machinery, the diversification of work carried out with them, etc. in view of obtaining an increased productivity.

* * *

The expenses on mechanical works (C_m) per work unit (ha, t) are calculated with the aid of relation:

$$C_m = \frac{A}{W_a} + \frac{R}{W_a} + \frac{S}{W_z} + C$$

where:

A represents the average annual payment of the tractors and agricultural machines;

R — the average annual expenses on the maintenance and repair of the tractors and agricultural machines;

W_a — the annual working capacity of the tractors and machines in ha, t;

S — the daily wages of the workers serving the aggregate;

W_z — the average daily working capacity of the aggregate in ha, t;

C — the expenses on materials, fuel and lubricants per work unit.

On the introduction of new technics and on comparing two successive stages, mechanization will be efficient only if the sum of expenses (C_m) in the future stage is more reduced than that in the present stage, in other words, if the agricultural enterprises obtain some economies (B) in the expenses on mechanical works by introducing new installations or by improving the existing ones.

In the present calculations, the expenses on materials and fuel (C) were considered as constant in the analysed periods, being given their reduced variation in time. The expenses for maintenance and repair (R) vary in the same way with those for the payment of the equipment.

In these conditions, it results that the development of technics influences, in fact, only the following factors:

— the level of payment — A — thus, of the delivery prices of the machines;

— the level of the workers' wages in exploiting the machine — S;

— labour productivity reflected in the working capacity — W_a and W_z;

— the level of the economies obtained in the expenses on mechanical works — B.

The most mobile element in this relation, determining the level of the others, is the increase of labour productivity. That is why, the prognosis of the development of mechanization in the next stages consists in establishing the growth of labour productivity based on the improvement of the working capacity of the installations, which should ensure both the covering of the increase of the wages of the workers employed in agriculture and the possible rise in the delivery prices of the equipment, under the conditions of obtaining in each period, a growing profitableness by the agricultural units.

The object of the present study is the very establishment of the correlation which has to be achieved between the specified economic factors,

under the conditions of the continuous development of the mechanization of work in agriculture.

For the technical progress to bring an economic contribution, it is necessary that the increase of the working capacity of the new aggregates should always be higher than the increase in wages. As the evolution of the wages increase has been established for the next five-year plans the evolution of the other indicators, for each five-year plan, can be established and taken into calculation, on this basis, so that the expected economic parameters should be obtained. In this way, one can draw up a concrete programme for the researchers, designers and builders of machines as regards the level of the working capacities which is to be compulsorily attained in the next stages.

This correlation between the increase of the working capacity of the machines and the recommended wages increase will allow the knowing of the admissible limits of the increase in the prices of the machines to be introduced in the endowment, under the conditions of obtaining an increased economic efficiency.

The present stage of technics has been considered as a starting point for establishing this dynamic correlation, setting out from the payments, working capacities and present wages for the carrying out of a given work.

The dynamic correlation was established in keeping with the direct expenses at the work unit. For this, the following notations were used:

$A(t)$ — the average annual payment of the machine of installation at stage t;

$R(t)$ — annual expenses for machine repairs;

$S(t)$ — the average daily wages of a worker;

$N(t)$ — the number of workers participating in the respective work;

$C(t)$ — the expenses on materials, fuel, lubricants, etc. per work unit;

$W_a(t)$ — the annual working capacity of the machine;

$W_z(t)$ — the daily working capacity of the machine;

$B(t)$ — the reduction of expenses per work unit from a stage $(t-1)$ to the next stage (t);

Z — the number of days of a year as long as the machine is working;

σ — the share of increase of the wages;

$P(t)$ — the value of the crop losses per work unit, due to the utilization of the machines (for example: lei/ha for wheat harvest — the equivalent of the grains not harvested or lost on the ground, etc.)

ω — the share of increase of the working capacity for a stage;

$\mathcal{P}(t)$ — the price of the machine in stage t;

β — the reduction share of the expenses for carrying out the mechanized work per work unit.

Noting with t_0 the reference stage (the current year, the present five-year plan, etc.) and with t a certain stage considered in the future, the evolution of wages and of the working capacity of a machine is calculated after the formulas:

— evolution of the wages:

$$S(t) = (1 + \sigma)^{t-t_0} \cdot S(t_0) \tag{1}$$

the formula results from iteration

$$S(t) = S(t-1) + \sigma S(t-1) = (1 + \sigma)S(t-1);$$

— the evolution of the working capacity:

$$W_z(t) = (1 + w)^{t-t_0} \cdot W_z(t_0) \tag{2}$$

the formula results from iteration:

$$W_z(t) = W_z(t-1) + \omega W_z(t-1) = (1 + w)W_z(t-1).$$

To establish the average annual payment and repairs at stage t, compared to the reference stage t_0, the iterative relation is used:

$$\frac{A(t) + R(t)}{W_a(t)} + \frac{N(t) \cdot S(t)}{W_z(t)} + C(t) + P(t) + B(t) =$$

$$= \frac{A(t-1) + R(t-1)}{W_a(t-1)} + \frac{S(t-1) \cdot N(t-1)}{W_z(t-1)} + C(t-1) + P(t-1). \tag{3}$$

Taking into consideration that:

$$B(t) = \beta\left[\frac{A(t-1) + R(t-1)}{W_a(t-1)} + \frac{S(t-1)\,N(t-1)}{W_z\,(t-1)} + \right.$$

$$\left. + C(t-1) + P(t-1)\right]$$

relation (3) becomes:

$$\frac{A(t) + R(t)}{W_a(t)} + \frac{N(t) \cdot S(t)}{W_z(t)} + C(t) + P(t) =$$

$$= (1 - \beta)\left[\frac{A(t-1) + R(t-1)}{W_a(t-1)} + \frac{S(t-1) \cdot N(t-1)}{W_z(t-1)} + \right.$$

$$\left. + C(t-1) + P(t-1)\right].$$

Using this iterative relation and taking into consideration also formulas (1) and (2), a correlation is obtained between the values of the considered stage (t) and those of the reference stage (t_0).

$$\frac{A(t) + R(t)}{Z \cdot W_z(t_0)\,(1 + w)^{t-t_0}} + \frac{N(t) \cdot S(t_0)(1 + \sigma)^{t-t_0}}{W_z(t_0)(1 + w)^{t-t_0}} + C(t) + P(t) =$$

$$= (1-\beta)^{t-t_0}\left[\frac{A(t_0) + R(t_0)}{ZW_z(t_0)} + \frac{S(t_0)\,N(t_0)}{W_z(t_0)} + C(t_0) + P(t_0)\right].$$

Considering the reference stage $t_0 = 0$ and noting:

$$A(t_0) = A_0 \qquad W_z\,(t_0) = W_0$$

$$R(t_0) = R_0 \qquad C(t_0) = C_0$$

$$N(t_0) = N_0 \qquad P(t_0) = P_0$$

$$S(t_0) = S_0$$

relation (3') is written:

$$\frac{A(t)+R(t)}{ZW_0(1+w)^t}+\frac{N(t)\,S_0(1+\sigma)^t}{W_0(1+w)^t}+C(t)+P(t)=$$

$$=(1-\beta)^t\left(\frac{(A_0+R_0}{ZW_0}+\frac{S_0N_0}{W_0}+C_0+P_0\right). \qquad (4)$$

If we consider that the reduction of losses is made according to a decreasing exponential function (the Weibull law) of the type:

$$P(t)=P_0e^{-\psi t^\alpha}$$

where α and ψ are parameters established by extrapolating the evolution of the losses in the previous stages and that, generally $C(t)=C_0=C$ (that is the expenses on fuel consumption are maintained somehow constant per work unit), then relation (4) becomes:

$$A(t)+R(t)=(1-\beta)^t\,(1+\omega)^t\,(A_0+R_0+S_0N_0Z+$$
$$+C_0ZW_0+P_0ZW_0)-$$
$$-C_0ZW_0(1+\omega)^t-P_0ZW_0(1+\omega)^t\,e^{-\psi t^\alpha}-$$
$$-ZS_0(1+\sigma)^t\,N(t). \qquad (5)$$

As ratio $\frac{R(t)}{A(t)}=\frac{R_0}{A_0}=\varphi$ is maintained constant, relation (5) allows the forecasting of the price of the machines.

It results from relation (5) that the only element which has also to be foreseen is the evolution of the number of workers $N(t)$. To express $N(t)$ in keeping with N_0 two cases are taken into consideration:

a) The machines are working stationary (installations and machines used in zootechnics, in the conditioning of products, motorpumps, etc.). In this case, the process of mechanization and automation is expected to develop quite rapidly, manpower being permanently reduced. For this reason, for this category of equipment, it may be considered that number of workers $N(t)$ is given by the expression

$$N(t)=N_0e^{-\mu t} \qquad (6)$$

where parameter μ is established by extrapolating the variation of manpower in the stages prior to the reference stage, for each work in part.

b) The machines are working by shifting, as is the case with most installations used in agricultural work, both for the growing and harvesting of produces and for their transport.

In this situation, the process of automation is developing at a lower pace and the number of workers used cannot be reduced beyond any limit, because each aggregate will always require at least one mechanic.

For this reason, the following function is proposed for this group of installations:

$$N(t) = 1 + (N_0 - 1)\, e^{-\mu_1 t} \tag{7}$$

where parameter μ_1 is also established by extrapolating the evolution of manpower in the previous stages.

Carrying out the replacements in relation (5), in the event that $N(t)$ is given by expression (7) (a most frequent case in agriculture), the calculus relation of the annual payments and repairs of the machines in the envisaged stages is obtained, in the form:

$$\begin{aligned} A(t) + R(t) = (1-\beta)^t (1+\omega)^t (A_0 + R_0 + S_0 N_0 Z + C_0 Z W_0 + \\ + P_0 Z W_0) - C_0 Z W_0 (1+\omega)^t - P_0 Z W_0 (1+\omega)^t e^{-\psi t^\alpha} - \\ - Z S_0 (1+\sigma)^t [1 + (N_0 - 1)\, e^{-\mu_1 t}]; \end{aligned} \tag{8}$$

or, grouping according to the categories of expenses, we obtain:

$$\begin{aligned} A(t) + R(t) = (A_0 + R_0)(1-\beta)^t (1+\omega)^t + S_0 Z [N_0 (1-\beta)^t (1+\omega)^t - \\ - (1+\sigma)^t - (1+\sigma)^t \cdot (N_0 - 1) e^{-\mu_1 t}] + C_0 Z W_0 (1+\omega)^t [(1-\beta)^t - \\ - 1] + P_0 Z W_0 [(1-\beta)^t - (1+\omega)^t e^{-\psi t^\alpha}]. \end{aligned} \tag{9}$$

The length of service T (in years) of the machines, used for establishing the prices in the envisaged stages was considered to be a constant value established by state norms. For the installations at which the state norms do not establish the length of service, it can be calculated by economic considerations, with the aid of reliability.

Knowing the evolution of the payment and the length of service, the evolution of the price of the machines can be established with the aid of formula:

$$\begin{aligned} \mathcal{P}(t) = A(t) \cdot T = \mathcal{P}_0 (1-\beta)^t (1+\omega)^t + \\ + \frac{T S_0 Z}{1+\rho} [N_0 (1-\beta)^t (1+\omega)^t - (1+\sigma)^t - (1+\sigma)^t (N_0 - 1) e^{-\mu_1 t}] + \\ + \frac{T C_0 Z N_0}{1+\rho} (1+\omega)^t [(1-\beta)^t - 1] + \frac{T P_0 Z W_0}{1+\rho} [(1-\beta)^t - (1+\omega)^t e^{-\psi t^\alpha}]. \end{aligned} \tag{10}$$

Noting TZ-the length of service of the machine on work days-by V_0, the following final relation, for establishing the evolution of the prices of the machines, is obtained:

$$\begin{aligned} \mathcal{P}(t) = \mathcal{P}_0 (1-\beta)^t (1+\omega)^t + \\ + \frac{V_0}{1+\rho} \{S_0 N_0 [(1-\beta)^t (1+\omega)^t - (1+\sigma)^t] - S_0 (1+\sigma)^t (1 - e^{-\mu_1 t}) + \end{aligned}$$

$$C_0W_0(1+\omega)^t[(1-\beta)^t-1]+P_0W_0[(1-\beta)^t-(1+\omega)^t e^{-\psi t^\alpha}]\}. \quad (11)$$

Formula (11) allows the forecasting of the evolution of the price of the equipment for medium periods (3—5 five-year plans).

For a shorter period (1—2 five-year plans), that is in elaborating short-term prognoses, the formula may be written in a simplified form by neglecting the terms of a higher order resulting from the development of the functions of the form: $(1+x)^t$ where $x \ll 1$, and t is assuming low values.

$$\mathcal{P}(t)=\mathcal{P}_0(1+\omega t-\beta t)+$$

$$+\frac{V_0}{1+\rho}\{S_0N_0t(\omega-\beta-\sigma)-S_0(1+\sigma t)(1-e^{-\mu_1 t})+$$

$$+C_0W_0(\omega t-\beta t)+P_0W_0[1-\beta t-(1+\omega t)e^{-\psi t^\alpha}]\}. \quad (12)$$

Some essential conclusions result from relation (11), the most important of which is that of *the correlation existing between the share of increase of the working capacity of the machine* (ω) *and the shares of increase of the wages* (σ) *and the size of economies* (β).

Indeed, as the price of the machines is, generally, marking an ascending evolution compared to time, so as $\mathcal{P}(t) \geqslant \mathcal{P}_0$, it results that it is necessary that:

$$(1-\beta)^t(1+\omega)^t-(1-\sigma)^t \geqslant 0 \quad (13)$$

because it is the element with the biggest share in ensuring the condition $\mathcal{P}(t) \geqslant \mathcal{P}_0$, most other terms being negative.

In any case, it is necessary that $(1-\beta)^t(1+\omega)^t \geqslant 1$, that is $\omega \geqslant \frac{\beta}{1-\beta} \geqslant \beta$ because otherwise, we would have $\mathcal{P}(t) \ll \mathcal{P}_0$. If $(1-\beta)^t(1+\omega)^t \leqslant 1$, then the first term of the left arm of relation (11) would be lower than $\mathcal{P}_0$, and the other terms would be all negative except, maybe, for that including the losses.

The following condition results from relation (13):

$$\omega \geqslant \frac{\sigma+\beta}{1-\beta}. \quad (14)$$

Obviously that: $\frac{\sigma+\beta}{1-\beta} > \sigma+\beta$

It can be seen from relation (14) that for each $\beta \geqslant 0$, it is necessary that $\omega \geqslant \sigma$ (for $\beta = 0$, or values of β around zero, it results that $\omega \geqslant \sigma$ and, for $\beta \geqslant 0$, it results that $\omega \geqslant \sigma$).

Relation (14) expresses the fact that under the conditions of some wages increases, increases which represent the basic objective of our state's policy in raising living standards, a much higher increase in the working capacity of the agricultural machines is necessary. Thus, if the wages increase in a five-year plan period is $\sigma = 10\%$ and, the economy of expenses in exploiting

a machine: $\beta = 3\%$, then, the increase in the working capacity should be at least:

$$\omega = \frac{0.1 + 0.03}{1 - 0.03} = 0.134 = 13.4\%.$$

Thus, for the increase in the working capacity to be sufficiently high, it should represent, in general, *at least the sum of the share of the wages increase and the share of reduction of expenses for the given stage.*

The efficiency of the introduction of new technics in the next period is also influenced by those qualitative improvements of the machines which lead to the diminishing of production losses. It results from relation (11) that any reduction of harvest losses makes possible an eventual increase in the price of the machines ($\mathcal{P}(t)$), (obviously, only to the extent to which it is justified by their constructive or functional improvements, which, as a matter of fact, is supposed in the event of the diminishing of the losses). In any case, it must lead to an increase in the efficiency of agriculture ($\mathcal{B}$ (t)).

An example of computation for forecasting the maximum admissible delivery price of a machine is presented in the following.

A self-propelled combine presents, in the present stage, the following elements (conventional figure):

$$\begin{aligned}
\mathcal{P}_0 &= 196\,000 \text{ lei} \\
V_0 &= 560 \text{ days} \\
\rho &= 1.4 \\
S_0 &= 108 \text{ lei/day} \\
N_0 &= 1 \\
C_0 &= 100 \text{ lei/ha} \\
W_0 &= 10 \text{ ha/day} \\
P_0 &= 100 \text{ lei/ha.}
\end{aligned}$$

We consider that a five-year plan period, the evolution of the variation shares represents:

$$\begin{aligned}
\omega &= 0.14, \text{ that is } 14\% \\
\sigma &= 0.10, \text{ that is } 10\% \\
\beta &= 0.03, \text{ that is } 3\% \\
\mu_1 &= 0.1 \\
\psi &= 0.8 \\
\alpha &= 1.
\end{aligned}$$

Replacing these values in formula (11), we obtain:

$$\mathcal{P}(t) = 196\,000(1 - 0.03)(1 + 0.14) +$$

$$+ \frac{560}{1 + 1.4}\{108 \times 1[(1 - 0.03)(1 + 0.14) - (1 + 0.1)] - 108(1 + 0.1).$$

$$(1 - e^{-0.1}) + 100 \times 10(1 + 0.14)[(1 - 0.03) - 1] +$$
$$+ 100 \times 10[(1 - 0.03) - (1 + 0.14)\, e^{-0.5}]\} = 208\,600 \text{ lei.}$$

Thus, at the end of five-year plan period, a machine which costs 196 000 lei, at present, by increasing the level of complexity, can reach, at most, a price of 208 600 lei, if one achieves a working capacity $W = (1 + \omega)W_0 = 10(1 + 0.14) = 11.4$ ha/day, reduces the harvest losses from 100 to 84 lei/ha and, a worker's wages reach the value $S = (1 + \sigma)S_0 = (1 + 0.1) \times 108 = 1.1 \times 108 = 119$ lei/day.

Considering the big number of aggregates existing in agriculture, the prognosis of the economic parameters of the development of the number of machines and tractors implies a big volume of calculuses which can be carried out only with the aid of computers. The correlations presented in this material were processed by the Research Institute for the Mechanization of Agriculture, with the aid of an electronic computer IBM 360/30, for the equipment used for all agricultural works in big crops.

The level to be reached by the working capacity of the agricultural equipment for recovering the envisaged increase of wages and for ensuring a certain efficiency of mechanization in agriculture can thus be established as the basic objective of researchers and designers for the next five-year plans.

The maximum purchasing price can also be determined for the installations received under the conditions of achieving the planned working capacity.

On this basis, the parameters of the working bodies of the machines, the form of the working bodies and other details of a constructive character will be established, from the technical point of view, in the second stage, which will ensure the full satisfaction of the economic requirements of the mechanization of agriculture.

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METHODE D'ETUDE PREVISIONNELLE DU PRIX DES MACHINES AGRICOLES

On offre dans cet article une recherche prévisionnelle portant sur les corrélations intervenant dans la mécanisation de l'agriculture, notamment sur les corrélations dynamiques entre l'évolution des capacités de travail des machines, celle de la complexité de ces machines, du

niveau de vie des ouvriers employant ces machines et du niveau des économies (diminution des dépenses) faites lors du remplacement des machines en service par des engins plus perfectionnés.

МЕТОД ПРОГНОЗА ЦЕН СЕЛЬСКОХОЗЯЙСТВЕННЫХ МАШИН

В настоящей статье приводится прогноз соотношений при механизации сельского хозяйства, а именно динамических соотношений, существующих между эволюцией рабочей мощности машин, комплексности этих машин, жизненного уровня работников сельского хозяйства, работающих на этих машинах, и уровня экономии (снижения расходов) при замене имеющихся в данный момент машин более усовершенствованными машинами.