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IMPACT OF TECHNOLOGICAL INNOVATIONS ON LABOR PRODUCTIVITY IN CROP PRODUCTION

ӨСІМДІК ШАРУАШЫЛЫҒЫНДАҒЫ ЕҢБЕК ӨНІМДІЛІГІНЕ ТЕХНОЛОГИЯЛЫҚ ИННОВАЦИЯЛАРДЫҢ ӘСЕРІ

ВЛИЯНИЕ ТЕХНОЛОГИЧЕСКИХ ИННОВАЦИЙ НА ПРОИЗВОДИТЕЛЬНОСТЬ ТРУДА В РАСТЕНИЕВОДСТВЕ

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Abstract. An important element in managing the economic results of economic entities is the search for reserves to increase labor productivity. *The goal* is to improve the methodology for calculating the impact of adaptive farming technologies on intensification of labor activity in grain production. *Methods* – statistical: data on technical solutions, machine systems, types of fertilizers, hydrothermal conditions, yields and areas of wheat crops, the number of workers employed in grain subcomplex-steppe zone of Northern Kazakhstan for 1961-2020. To assess the impact of specific components on the level of working productivity, the methods of regression and index analysis were used. The impact of production factors, including technological innovations, on the change in the criterion of beneficial effect in agricultural sector is quite accurately calculated by the proposed methods and procedures. *Results* – it has been determined that adaptive opportunities for obtaining agricultural products have a positive effect on increasing profitability and profitability in agro-industrial complex. The expansion of the range of indicators and the tasks set makes it possible to make calculations with even greater reliability and accuracy. However, it should be borne in mind that the system of statistical accounting in countries with transit economies is at the stage of improvement. *Conclusions* – since the sixties, labor productivity in grain industry has undergone significant changes. Its growth rates differed in different time periods. Until the end of the last century, the indicator changed relatively slowly. A jump-like growth of more than two times was observed in the 2000s, due to a number of reasons, primarily the use of resource-saving mechanisms adapted to real external conditions and high-performance machines.

Аңдатпа. Шаруашылық жүргізуші субъектілердің экономикалық нәтижелерін басқарудағы маңызды элемент – еңбек өнімділігін арттыру үшін резервтерді іздеу. *Мақсаты* – ауыл шаруашылығын жүргізудің бейімделгіш технологияларының астық өндіру кезіндегі еңбек қызметін қарқындатуға әсерін есептеу әдіснамасын жетілдіру. *Әдістері* – статистикалық: 1961-2020 жылдардағы Солтүстік Қазақстанның дала аймағының астық кіші кешенінде жұмыс істейтін қызметкерлердің саны, техникалық шешімдер туралы мәліметтер, машина

жүйелері, гидротермиялық жағдайлардағы тыңайтқыш түрлері, бидай егісінің өнімділігі мен алаңдары туралы деректер. Жеке компоненттердің жұмыс өнімділігі деңгейіне әсерін бағалау үшін регрессиялық және индекстік талдау әдістері қолданылған. Технологиялық инновацияларды қоса алғанда, өндірістік факторлардың аграрлық сектордағы пайдалы әсер өлшемінің өзгеруіне әсері ұсынылған әдістермен және рәсімдермен жеткілікті дәл есептеледі. *Нәтижелері* – ауыл шаруашылығы өнімін алудың бейімдеу мүмкіндіктері АӨК-дегі рентабельділік пен кірістілікті арттыруға оң әсер ететіні анықталған. Көрсеткіштер мен міндеттер шеңберін кеңейту есептеулерді одан да сенімді және дәл жүргізуге мүмкіндік береді. Алайда, транзиттік экономикасы бар елдердегі статистикалық есеп жүйесі жетілдіру сатысында екенін есте ұстаған жөн. *Қорытындылар* – алпысыншы жылдардан бастап астық саласындағы еңбек өнімділігі айтарлықтай өзгерістерге ұшыраған. Оның өсу қарқыны әртүрлі уақыт кезеңдерінде ерекшеленген. Өткен ғасырдың соңына дейін көрсеткіш салыстырмалы түрде баяу өзгерген. 2000 жылдары секірмелі өсу екі еседен астам байқалған, бұл бірқатар себептерге байланысты, ең алдымен нақты сыртқы жағдайларға бейімделген ресурстарды үнемдейтін механизмдерді және өнімділігі жоғары машиналарды қолдану.

Аннотация. Важный элемент в управлении экономическими результатами хозяйствующих субъектов – поиск резервов для повышения производительности труда. *Цель* – совершенствование методологии расчета влияния адаптивных технологий ведения сельского хозяйства на интенсификацию трудовой деятельности при производстве зерна. *Методы* – статистический: данные о технических решениях, системах машин, видах удобрений, гидротермических условиях, урожайности и площадях посевов пшеницы, численности работников, занятых в зерновом подкомплексе степной зоны Северного Казахстана за 1961-2020 годы. Для оценки воздействия отдельных составляющих на уровень рабочей продуктивности использованы приемы регрессионного и индексного анализа. Влияние производственных факторов, включая технологические инновации, на изменение критерия полезного эффекта в аграрном секторе достаточно точно рассчитывается предложенными методами и процедурами. *Результаты* – установлено, что адапционные возможности получения сельскохозяйственной продукции позитивно влияют на повышение рентабельности и доходности в АПК. Расширение круга показателей и поставленных задач позволяет производить расчеты с еще большей надежностью и точностью. Однако следует иметь в виду, что система статистического учета в странах с транзитной экономикой находится на стадии совершенствования. *Выводы* – с шестидесятых годов производительность труда в зерновой отрасли претерпела значительные изменения. Темпы ее роста отличались в разные временные периоды. До конца прошлого века показатель менялся относительно медленно. Скачкообразный рост более, чем в два раза наблюдался в 2000-е годы, связанный с рядом причин, в первую очередь – использованием ресурсосберегающих механизмов, приспособленных к реальным внешним условиям и высокопроизводительных машин.

Key words: agricultural sector, grain subcomplex, labor productivity, regression model, index method, production factors, adaptive technologies.

Түйінді сөздер: аграрлық сектор, астық кішікешені, еңбек өнімділігі, регрессиялық модель, индекстік әдіс, өндірістік факторлар, бейімделген технологиялар.

Ключевые слова: аграрный сектор, зерновой подкомплекс, производительность труда, регрессионная модель, индексный метод, производственные факторы, адаптивные технологии.

Introduction. The dynamics of labor productivity can be analyzed taking into account changes in three main components: yield, acreage, labor expenses using index analysis methods. The influence of acreage on labor productivity is manifested through the scale effect. Labor expenses change due to the use of technologies and new agriculture machines systems. However, it should be borne in mind that these two components are interrelated, and it is impossible to separately calculate the impact of technologies and new machines on the level of labor expenses.

The calculation of the influence of individual factors of interest in the total set of factors is still debatable, requires its own understanding and further research. The problems of material and technical equipment of agriculture from the position of its impact on the competitiveness of the industry and ensuring food security are considered in some works of Kazakhstani authors [1,2]. In some publications it is emphasized that a comprehensive assessment of labor productivity is a necessary condition for improving the efficiency of its management [3,4]. Methodological aspects of measuring labor productivity without reference to the sectoral characteristics of agriculture are reflected in some publications [5,6]. Some works emphasize the role of technology as one of the key factors of economic growth [7].

There are a number of works devoted to the analysis of changes in labor productivity in agriculture in the conditions of the Russian economy [8,9]. Common to all currently available works is that they consider the impact on labor productivity of various factors in comparison with each other. In our study, we raise the question of changes in labor productivity due to changes in the technological equipment of production. That is, the question is raised about the change in labor productivity when one technology is replaced by another. And it should be noted that there is a practical lack of research in this particular vein.

Material and methods of research. The most important feature and difficulty of solving the problem is that in modern socio-economic conditions it is almost impossible to set up a direct production experiment for a comparative assessment of the effectiveness of different farming technologies. It is also difficult to find enterprises comparable in terms of their conditions, in one of which an exceptionally intensive technology would be used, in another - simplified, in the third - resource-saving, etc. Therefore, it is necessary to conduct a comparative analysis in the conditions of one enterprise using retrospective historical data for a fairly long period of time: the 60s-70s (when non-fallow soil protection technology was used), the 80s (intensive technology), the 90s and early 2000s (simplified technology) and since the early 2000s to the present (adaptive technology).

From the set of surveyed enterprises, Rodina LLP of Akmola oblast was selected as the object of study and subsequent testing of the methodology for measuring the influence of production factors as the enterprise with the most complete and reliable database for research. We used data on the technologies used, machine systems, the use of fertilizers, hydrothermal conditions, yields and areas of wheat crops, the number of people employed in wheat production for 1961 to 2020.

Weather hydrothermal production conditions have a decisive influence on the formation of yields. However, the nature of humidification and temperature regime have undergone significant changes over the past decades - the most important fact that should be taken into account in the analysis.

Results and their discussion. Evaluation of the relationship between wheat yield and temperature regime in different months of vegetation gives the following results: yield-temperature in May - there is practically no relationship (correlation coefficient – 0,08); yield-temperature in June – the relationship is inverse and quite noticeable (-0,43); yield-temperature in July - the relationship is weak (-0,24); yield -temperature in August - there is practically no relationship (0,04). Thus, as a temperature factor, it makes sense to include the average air temperature in June in the model.

A significant factor in increasing the yield of wheat and, consequently, labor productivity in grain production, in principle, is the level of use of fertilizers, including mineral fertilizers. However, the correlation between crop yield and the amount of fertilizers used in the object of study is very insignificant, the correlation coefficient is only 0,24. This conclusion is consistent with the conclusions of other researchers that in the conditions of arid steppe zone, the effect of fertilizers on increasing yields is severely limited [10]. Therefore, this factor is excluded from further analysis.

In addition to quantifiable factors, the behavior of the process under study is also influenced by qualitative parameters: the varieties used, technology, machine system. They can be included in the model in the form of so-called categorical variables, which take the value 1 if used, and 0 if not used in certain segments of the studied time period. However, the varieties Saratov 29, Virgin, Jubilee were used in the studied object up to the beginning of the 90s; and only in the last 15-20 years other varieties began to be used: Omsk 28, Omsk 31, Astana. The system of machines used on the farm underwent a radical change only with the introduction of minimal technology, when sowing complexes began to be used.

Thus, the following variables are included as the main factors in the numerical model of the relationship between wheat yield and production factors in the object of study: quantitative variables - the amount of precipitation in October-July, the temperature regime; from categorical variables, the technology of culture cultivation is included in the analysis.

In modern econometrics, many different statistical tools are used, but linear regression is still the most frequently used starting point for an analysis. The multiple linear regression model is basically a basic econometric tool [11].

Formally, the communication model used in the analysis looks like this:

$$Y = b_0 + \sum b_i X_i + \sum b_j T_j \qquad (1)$$

where $Y-$ crop yield, c/ha; X_j- quantitative variables for natural conditions and resource costs (precipitation, temperature regime); T_j- categorical variables (agricultural technologies used); b_0, b_i, b_j- parameters (coefficients) of the model.

The parameters b_i for quantitative variables X_i show the magnitude of the change in wheat yield Y when the values of the corresponding factors change by one. The parameters b_j for variables T_j indicate the magnitude of the change in wheat yield Y when using the appropriate wheat production technology.

Based on the model (1), calculations were carried out to assess the impact of individual production factors, including farming technology, on wheat yield in the conditions of “Rodina” LLP.

Next, we turn to the analysis of labor expenses during the periods of use of different technologies. The labor productivity is the ratio of production volume to labor expenses. The volume of production in crop production depends not only on the yield, but also on the area of sowing. In the studied farm, different areas of arable land were allocated for wheat in different years. Therefore, the analysis of the labor productivity dynamics should be carried out taking into account changes in yield, acreage, labor expenses. To calculate the impact of these components individually on the level of labor productivity (when switching from one agricultural technology to another), we use the methods of index analysis.

For the analysis we will use the following relations:

$$ПТ_0 = \frac{Y_0 \times П_0}{ЗТ_0} \qquad (2)$$

$$ПТ_1 = \frac{Y_1 \times П_1}{ЗТ_1} \qquad (3)$$

where $ПТ_0-$labor productivity, c/person, Y_0- wheat yield during the period of using the old technology, c/ha, $П_0-$ crop area, thousand hectares, $ЗТ_0-$ labor expenses during the period of using the old technology; $ПТ_1$, Y_1, $П_1$, $ЗТ_1$ - respective indicators during the period of use of the new technology.

Then the value

$$\Delta ПТ_П = \frac{Y_0 \times П_1}{ЗТ_0} - \frac{Y_0 \times П_0}{ЗТ_0} \qquad (4)$$

represents an increase in labor productivity due to changes in the crop area;
the value

$$\Delta ПТ_{ЗТ} = \frac{Y_0 \times П_1}{ЗТ_1} - \frac{Y_0 \times П_1}{ЗТ_0} \qquad (5)$$

shows an increase in labor productivity due to changes in the volume of labor costs;
the value

$$\Delta ПТ_Y = \frac{Y_1 \times П_1}{ЗТ_1} - \frac{Y_0 \times П_1}{ЗТ_1} \qquad (6)$$

shows an increase in labor productivity due to changes in crop yields from the use of new technology.

However, the yield Y_1 during the period of using the new technology consists of the yield when using the old technology and the yield changes due to the use of the new technology and the increase due to other factors, including hydrometeorological conditions, that is $Y_1 = Y_0 + \Delta Y_{technology} + \Delta Y_{others}$.

Therefore, formulas (2) and (5) can be rewritten as follows, respectively:

$$ПТ_1 = \frac{(Y_0 - \Delta Y_{technology} + \Delta Y_{others}) \times П_1}{ЗТ_1} \qquad (7)$$

$$\Delta ПТ_Y = \frac{(Y_0 + \Delta Y_{technology} + \Delta Y_{others}) \times П_1}{ЗТ_1} - \frac{Y_0 \times П_1}{ЗТ_1} \qquad (8)$$

It follows from formulas (6) and (7) that

$$\frac{\Delta Y_{technology} \times П_1}{ЗТ_1} = ПТ_1 - \frac{(Y_0 + \Delta Y_{others}) \times П_1}{ЗТ_1} \qquad (9)$$

$$\frac{\Delta Y_{technology} \times П_1}{ЗТ_1} = \Delta ПТ_Y - \frac{(Y_0 + \Delta Y_{others}) \times П_1}{ЗТ_1} + \frac{Y_0 \times П_1}{ЗТ_1} \qquad (10)$$

Then, using any of the formulas (9) and (10) allows us to calculate the impact of technology on the level of labor productivity through a change in yield.

Formula (5) allows us to calculate the increase in labor productivity due to the total changes in labor costs caused by the use of new technology and agricultural machines with qualitatively different characteristics. At the same time, it is not possible to single out separately the impact on labor productivity of changes in labor costs associated with new technology and labor costs associated with the use of more productive machines. In practice, both of these factors are interrelated. Table 1 shows the parameters of the model (1) calculated on the data of “Rodina” LLP.

Table 1 - Parameters of the model of the relationship between productivity and production factors in “Rodina” LLP (the basic technology is traditional)

No.	Factor	Parameter value
1	Hydrothermal production conditions:	
1.1	Precipitation (October-July)	0,03
1.2	Temperature (June)	-0,77
2	Production technology:	
2.1	Intensive	1,34
2.2	Simplified	2,83
2.3	Minimum	3,77

The results shown in table 1 indicate the following: an increase in the total amount of precipitation in October-July by one millimeter from its average level contributes to an increase in yield by 0,03 c/ha; an increase in air temperature in June by one degree from its monthly average value leads to a decrease in yield by 0,8 c/ha; the transition to the intensive technology in the early eighties led to an increase in yield by 1,3 c/ha compared to the traditional; the simplified technology led to an increase in yield by 2,8 c/ha compared to the traditional; replacing the traditional technology with the minimum increases the output of products by 3,8 c/ha. The influence of various factors on the formation of wheat yield in the conditions of the studied object is shown in table 2.

Table 2 - The influence of production factors on wheat yield during the change of cultivation technologies in “Rodina” LLP (1961 - 2020)

New/old technologies	Yield increase, c/ha, due to changes in:			Total increase	Yield with new/ old technology, c/ha
	precipitation	temperature	technology		
Intensive/ traditional	0,6	-0,7	1,3	1,3	10,3/9,1
Simplified/ intensive	-0,2	0,6	1,5	1,9	12,2/10,3
Minimum/simplified	0,9	-0,4	0,9	1,5	13,7/12,2

It follows from table 2 that due to an increase in the average annual precipitation during the use of intensive technology, wheat yield increased by 0,6 c/ha compared to the period of application of non-fallow technology; at the same time, there was a decrease in yield due to a less favorable temperature regime (- 0,7 c/ha), which was offset by an increase in productivity due to the introduction of a more progressive technology (1,3 c/ha); the total increase was 1,3 c/ha; average yield during the intensification period increased to 10,3 c/ha. With the non-dumping technology, the yield was 9,1 c/ha.

During the transition from intensive technology to simplified, there was a decrease in yield by 0,2 c/ha due to less precipitation during the use of simplified technology, an increase in yield by 0,6 c/ha due to a more favorable temperature regime in June, the use of the simplified technology itself contributed to an increase in yield by 1,5 c/ha; the total increase in yield was 1,9 c/ha; the average yield during the use of simplified technology was 12,2 c/ha. During the period of using the minimum technology, there was an increase in wheat yield by 0,9 c/ha due to more precipitation, a decrease in yield due to less favorable temperature conditions (-0,4 c/ha), the new technology contributed to an increase in productivity by only 0,9 c/ha; the total increase was 1,5 c/ha. The average annual yield during the period of using the minimum technology in the farm was 13,7 kg/ha.

Table 3 shows wheat yield, yield increase, average area of wheat crops and average annual labor costs in the periods corresponding to each successive pair of technologies. Data on the increase in yield from the introduction of a new technology are taken from table 2.

Table 3 - Yield, yield increase, area of crops, labor costs in wheat production in "Rodina" LLP (1961-2020)

Indicator	Wheat growing technologies		
	intensive/traditional	simplified/ intensive	minimum/simplified
Yield, c/ha	10,3/9,1	12,2/10,3	13,7/12,2
Total yield increase, c/ha, including:	1,3	1,9	1,5
- due to technology	1,3	1,5	0,9
- due to other factors	-0,1	0,4	0,5
Average annual acreage area, ha	14 726/20 955	17 098/14 726	21 843/17 098
Labor expenses, person-days	4 621/8 033	406 779/4 621	2 490/4 067

The growth rates of labor productivity were different in different periods. In the period from the beginning of the 60s to the end of the 90s, labor productivity grew at a rather slow pace: for more than 30 years, labor productivity increased by less than 40%. A jump-like increase in labor productivity (more than twice) was observed in the 2000s, associated with a number of reasons, primarily with the use of minimal technology and high-performance machines, and to a lesser extent with an increase in production volumes.

During the period of using intensive technology, labor productivity increased by 9,2 c/person-day compared to the period of using non-waste technology (38,9%). However, the impact of the intensive technology itself (through a change in productivity) on the level of labor productivity is expressed in the growth of the latter by only 4,3 c/ person-day, that is, 18,1%. Slightly less favorable weather conditions during the intensification of agricultural production contributed to a slight decrease in labor productivity (by 0,3 c/person-day, that is, by 1,3%).

The change in labor costs (due to the peculiarities of the new technology and the use of more productive machines) led to an increase in labor productivity by 12,3 c/person-day, that is, by 51,9%. On the contrary, a significant reduction in the area of sowing for wheat (by almost 30%) in the 80s in the economy led to a decrease in labor productivity in wheat production by 7,0 c/person-day, that is, by 29,8% (negative scale effect).

During the period of using simplified technology, labor productivity increased by 18,3 c/person-day compared to the period of using intensive technology, that is, by 55,7%. However, the impact of the simplified technology itself (through a change in productivity) on the level of labor productivity is expressed in the growth of the latter by only 6,2 c/person-day, that is, 19,0%. Due to slightly more favorable weather conditions, there was an increase in productivity by 1,6 c/person-day, that is, by 4,8%). The change in labor costs (mainly due to the features of the new technology) led to an increase in labor productivity by 5,2 c/person-day, that is, by 15,8%. An increase in the area of sowing for wheat (by 16%) in the 90s in the economy led to an increase in labor productivity in wheat production by 5,3 c/person-day, that is, by 16,1% (positive scale effect).

During the period of using the minimum technology, labor productivity increased by 68,6 c/person-day compared to the period of using the simplified technology, that is, by 134,2%. However, the impact of the actual minimum technology (through a change in productivity) on the level of labor productivity is expressed in the growth of the latter by only 8,3 c/person-day, that is, 16,2%. The influence of weather factors on labor productivity through changes in wheat yield during the specified period was positive: the increase in labor productivity amounted to 4,8 c/person-day, that is, 9,3%.

The change in labor costs (mainly due to the use of high-performance machines) led to an increase in labor productivity by 41,4 c/person-day, that is, by 80,9%. The increase in the area of sowing for wheat in the 2000s in the economy led to an increase in labor productivity in wheat production by 14,2 c/person-day, that is, by 27,8% (positive scale effect).

Conclusions

1. The results obtained indicate that in the last 60 years – since the 60s of the last century - labor productivity in the grain industry has undergone significant changes. However, the growth rates of labor productivity were different in different periods. In the period up to the end of the 90s, labor productivity grew at a rather slow pace: for more than 30 years, the indicator level has increased by

less than 40%. A jump-like increase in labor productivity (more than twice) was observed in the 2000s, associated with a number of reasons, primarily with the use of minimal technology and high-performance machines, and to a lesser extent with an increase in production volumes.

2. For an objective assessment of the impact of farming technology on the level of labor productivity in agriculture, calculations should be carried out not on the basis of experimental stations, but in real production conditions. Since the main factor – productivity - in experimental fields, as a rule, is higher than in commercial fields by almost a third.

3. The use of adaptive systems and resource-saving technologies of crop cultivation, of course, has a positive impact on the growth of labor productivity in the industry. For a more accurate assessment of the impact of innovations, including technological ones, on the productivity of labor in agriculture, it is necessary to involve as wide a range of indicators as possible in the analysis. However, there is currently a shortage of reliable data in countries with transit economies for a scientifically based assessment of the effectiveness of new technologies and other innovations in agriculture. There is an urgent need to organize a specialized system for collecting and recording primary data of agricultural production and the agricultural market.

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