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SIMULATION MODELING: ANALYZING THE IMPACT OF GOVERNMENT SUPPORT ON AGRICULTURAL PRODUCTION EFFICIENCY

Since the forecasting of general economic income in diversified industries has a number of peculiarities associated with the presence and nature of the stochastic relationship of production and economic indicators, as well as the uncertainty of production and market conditions of the planning year, to calculate the forecast values of marginal income in this article is used the method of forecasting, which uses the principles of expert judgment in combination with probabilistic analysis of historical data and assumes the correction of historical data The model was tested on the materials of agrarian production of one of the largest agricultural regions of the country - North-Kazakhstan region.

To calculate the forecast values of marginal income of agricultural crops of commercial crop production of the North-Kazakhstan region, historical data on yields, variable costs and prices of realization of agricultural products of the region were used. In general, the development of such models, their testing and practical application are justified in solving the problems of forecasting and analysis of consequences from the implementation of regional and national agricultural economic programs.

Keywords: yields, crop production, variable costs, marginal revenue, inflation, subsidies, simulation model, forecasting

Introduction

In Kazakhstan, with its vast agricultural lands and very harsh natural and climatic conditions, the development and application of tools for analyzing and planning agricultural production taking into account uncertainty and risk has been completely neglected until today. It is only in the last two decades that the academic circles of the Central Asian region have shown a growing interest in the problem of risk analysis in agriculture (e.g., [1, p. 82; 2, p.2458; 3, p.176]). At the same time, the scientific community of countries and regions with developed agrarian economies has accumulated quite a lot of experience in researching various aspects of developing effective solutions using the methods of system analysis. Particular attention should be paid to the classic work by Hardacker, Huirne, Anderson, and Lien [4, p. 276], which summarizes various approaches to the analysis and management decision-making in agroecosystems under conditions of risk and uncertainty.

In agriculture in developing and transit economies, biodiversification is the most commonly used tool to counter risk [5, p.86]. Measures that rely on the use of agricultural biodiversity in response to abrupt changes in climate and economic environment can be divided into two broad categories: growing more species and diversifying farms in general; introducing or scaling up more adapted crops and varieties, as well as livestock and livestock breeds. Livestock development is also seen as a diversification strategy in response to climate change [6, p.1968; 7, p.128]. Over the past three decades, in many arid regions of Kazakhstan, farmers have reduced their investments in crops or even stopped planting and instead focused on livestock management.

Different species and breeds of animals vary greatly in their ability to tolerate extreme climatic conditions. In the arid regions of Kazakhstan, there is a return to breeding traditional animals for commercial purposes, such as camels, sheep and horse breeding, which are more adaptable to changing climatic conditions. Such trends are observed almost everywhere. For example, the expansion of the range of one-humped camels further into southern Africa has been observed to displace cattle because of their better drought tolerance [8, p.690]. Crop diversification and crop-livestock integration are often combined with adjustments in farming practices and the adoption of low-cost methods to improve soil fertility, water conservation and weed control. The replacement of traditional varieties with improved, early maturing varieties has also been observed as part of adaptation strategies in locations subject to sudden increases or decreases in temperature and rainfall [9, p.225; 10, p.748]. The opposite is also observed: farmers stick to growing traditional varieties because of their ability to respond and adapt to new climatic conditions [11, p.19563].

The main conclusion from the analysis of available publications on the topic under consideration is that the effective and adequate application of system analysis methods for forecasting the economic development of agro-ecosystems is possible only with careful consideration of specific local natural and economic conditions and peculiarities of entrepreneurs' behavior under the uncertainty of the economic environment. The process of formation and selection of strategic decisions can be modeled in different variants using different criteria of rationality of the decision. In the academic environment, the standard approach is to use the utility function and risk aversion coefficients to analyze and forecast decisions. However, it should be noted that due to the complexity of the problem structure and the uncertainty factor in it, the construction of appropriate models requires a very thorough study of the problem, which in turn predetermines the need to attract significant resources: intellectual, financial, and time [12, p.124].

The development of such models, their testing and practical application are justified when solving the tasks of forecasting and analyzing the consequences of the implementation of regional and national agricultural economic programs. The time and resources spent on thorough elaboration of the problem are quite justified and dictated by the scale, public importance and long-term effect of such programs.

Materials and methods

The results of numerous experiments and empirical evidence indicate that the most appropriate functions are those that allow reflecting the behavioral property of most individuals in the decision-making process: relative risk aversion does not increase with the expansion of wealth. In other words, the percentage of funds invested in risky assets (risky activities) remains constant or is growing. The persistence or decrease in relative risk aversion means that as wealth increases, the desire of entrepreneurs to invest money (in absolute terms) in risky industries also increases. That is, the absolute risk aversion decreases, and the investor has a greater desire to invest money in risky assets. Both of these considerations are quite consistent with common sense and observations. Therefore, as a utility function, it is recommended to use a power function of the formula $U = \left(\frac{1}{1-r}\right) z^{1-r}$ where z the total value of assets, r the relative risk aversion index. The greater the value r is, an entrepreneur is less susceptible to make risky decisions, that is, he/she is less likely to invest money in risky activities. This function is very convenient in practical use. If $r=0$, the function takes a linear form $U=z$; the linear function corresponds to the case when the entrepreneur's attitude to risk is neutral. If $r=1$ z, the power function turns into a logarithmic one. The empirical studies and calculations show that a relative risk aversion index, equal to 1, is typical for the majority of entrepreneurs and investors. Since the risk aversion index in the model is estimated at marginal income (not the total value of agricultural assets),

it is necessary to calculate the index of relative risk aversion for marginal income. To do this, a formula is used that links the risk aversion indices for wealth and income, that is $r = r(z) = (z / W)r(W)$, where z is the average annual income; W is the average annual total value of the company's assets.

The developed simulation model links together the main sub-sectors of agriculture – crop and livestock – at the regional level, and allows to analyze the industry in the system.

Results and discussion

To calculate the forecast values of the marginal income of agricultural crops of commercial crop production in the North Kazakhstan region, historical data on yields, variable costs and sales prices of agricultural products of the region, shown in tables 1-3, have been used.

Table 1 – Crop yield of the North Kazakhstan region in 2017-2023, hundredweight/ha

Years	Wheat	Barley	Oats	Leguminous crops	Oil crop
2017	16.7	18.6	17.3	10.9	9.8
2018	15.4	17.5	18.9	10.8	9.6
2019	14.2	15.1	17.4	11.4	9.9
2020	14.4	14.2	12.2	11.3	10.0
2021	11.6	11.8	10.0	9.3	7.3
2022	14.7	16.1	13.0	12.3	8.3
2023	11.4	11.2	8.6	9.5	6.8

Table 2 – Prices for the sale of crop production in the North Kazakhstan region in 2017-2023, tenge/hundredweight

Years	Wheat	Barley	Oats	Leguminous crops	Oil crop
2017	3.827	3.039	2.275	5.401	9.385
2018	4.009	3.449	2.536	4.331	8.936
2019	6.159	4.781	3.118	6.056	11.760
2020	7.813	5.635	4.186	10.568	16.295
2021	9.875	7.872	5.204	17.053	24.545
2022	11.708	8.863	6.023	19.877	27.372
2023	8.908	6.465	5.464	13.887	16.564

Table 3 – Estimated amounts of variable costs for crops in the year under planning, tenge/ha

Crop	Wheat	Barley	Oats	Leguminous crops	Oil crop
Cost amount	54.442	47.881	33.500	70.426	61.097

The calculation of the forecast values of marginal income has been carried out in two ways: 1) excluding subsidies; 2) taking into account the amount of subsidies granted in 2023 (Table 4). The outcomes are understood as the production and market conditions of the corresponding year: 2017 – outcome 1; 2018 – outcome 2, …, 2023 – outcome 7. To take into account the probability of occurrence of conditions similar to those in previous years, an equally probable distribution is used, that is, each year of observations corresponds to a probability level equal to 0.143. The year 2023 is taken as the base year to reflect inflation.

Table 4 – Forecast values of marginal income in the North Kazakhstan region, tenge/ha

Outcome	Wheat	Barley	Oats	Leguminous crops	Oil crop
Marginal income excluding subsidies					
1	90.902	62.543	51.181	81.556	93.037
2	83.216	60.009	56.680	78.699	90.136
3	85.809	57.949	52.935	85.949	95.323
4	92.576	57.095	37.513	90.429	99.925
5	79.339	55.097	31.187	78.459	79.973
6	99.452	73.083	40.993	105.848	88.177
7	66.774	37.677	24.911	73.185	66.073
Expected MI	85.438	57.636	42.200	84.875	87.521
Standard deviation	48.334	38.497	25.461	49.666	43.551
Variability, %	56.6	66.8	60.3	58.5	49.8
Marginal income including subsidies in 2023					
1	98.994	70.635	59.273	89.648	101.129
2	91.308	68.101	64.772	86.791	98.228
3	93.901	66.041	61.027	94.041	103.415

4	100.668	65.187	45.605	98.521	108.017
5	87.431	63.189	39.279	86.551	88.065
6	107.544	81.175	49.085	113.940	96.269
7	74.866	45.769	33.003	81.277	74.165
Expected MI	93.530	65.728	50.292	92.967	95.613
Standard deviation	48.334	38.497	25.461	49.666	43.551
Variability, %	51.7	58.6	50.6	53.4	45.5

The forecast values of marginal income are subsequently used to analyze the impact of government support measures for the industry on the location, structure, output, and efficiency of agricultural production in the North Kazakhstan region based on the formula given above.

When solving the problem, the following conditions have been set: 1) the total area of tilled land in the region is limited by the size of the acreage of commodity crop production in 2023 - 4097 thousand hectares; 2) the share of oilseed crops in the amount of no more than 25% in the total structure of crops is related to the technological characteristics of oilseed cultivation; 3) restrictions on the supply of barley (not less than 79 thousand tons) and oats (not less than 33 thousand tons) is due to calculations of the need for these crops in the production of formulated feeds for livestock of agricultural animals of the region.

The results of calculations based on the model are shown in Table 5.

Table 5 – Results of solving the problem based on the model

Solution option	The disposition of crops, %					Marginal income, thousand tenge/ha
	wheat	barley	oats	leguminous crops	oil crop	
Including subsidies	73.1	1.3	0.6	0.0	25.0	85.3
Excluding subsidies	73.1	1.3	0.6	0.0	25.0	93.4

The results of solving the problem indicate that the presence or absence of subsidies in the available volumes does not affect the composition of crops and their structure. Meanwhile, in both cases, leguminous crops turn out to be relatively unprofitable in the conditions of the North Kazakhstan region (in comparison with other crops).

The crop acreage under barley, oats, and oilseeds is determined by restrictive conditions (agrotechnical, market). In general, the expected marginal income for

crop production in the region per hectare will optimally amount to 85.3 thousand tenge (option without subsidies) and 93.4 thousand tenge (option with subsidies).

In general, the results obtained suggest that government subsidies in the available amounts in the context of crops do not have an impact on decisions on the location and optimization of crops disposition.

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Conclusions

The developed simulation model links together the main sub-industries of agriculture – crop production and animal husbandry – at the regional level, and allows to analyze the industry in the system. The economic category of utility is taken as an economic attribute for analyzing decisions. Utility of the decision in the model is expressed through a stepped function of a special kind, where the attitude of entrepreneurs to risk is quantitatively represented by the coefficient of relative risk aversion. The mentioned coefficient very accurately reflects the behavioral property of the majority of individuals in the process of risky decision making. By simulating the parameters of internal (endogenous) and external (exogenous) variables (factors) it is possible to forecast and analyze possible shifts in the location of production and its structure at the regional level depending on the measures taken by the state to support the industry. The model reflects all the most important and determining economic relations inherent in the agricultural system of the regional level.

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ИМИТАЦИЯЛЫҚ МОДЕЛЬДЕУ: АУЫЛ ШАРУАШЫЛЫҒЫ ӨНДІРІСІНІҢ ТИІМДІЛІГІНЕ МЕМЛЕКЕТТІК ҚОЛДАУ ШАРАЛАРЫНЫҢ ӘСЕРІН ТАЛДАУ

Әр тараптандырылған өндірістердегі жалпы экономикалық кірісті болжау өндірістік-экономикалық көрсеткіштердің стохастикалық байланысының болуы мен сипатына, сондай-ақ жоспарланған жылдың өндірістік-нарықтық жағдайларының белгісіздігіне байланысты бірқатар ерекшеліктерге ие болғандықтан, маржалық кірістің болжамды шамаларын есептеу үшін осы мақалада тарихи деректерді ықтималдық талдаумен бірге сараптамалық бағалау принциптері бар болжау әдісі қолданылады және тарихи деректерді тренд пен инфляцияға түзету көзделеді. Модельді

тестілеу (тексеру) еліміздің ірі ауыл шаруашылығы өңірлерінің бірі - Солтүстік Қазақстан облысының аграрлық өндіріс материалдарында жүргізілді. Солтүстік Қазақстан облысының тауарлық өсімдік шаруашылығының ауыл шаруашылығы дақылдарының маржиналды табысының болжамды шамаларын есептеу үшін облыстың ауыл шаруашылығы өнімінің өнімділігі, айнымалы шығыстары және өткізу бағасы бойынша тарихи деректер пайдаланылды. Жалпы, мұндай модельдерді әзірлеу, оларды тестілеу және тәжірибе жүзінде қолдану аймақтық және ұлттық ауылшаруашылық экономикалық бағдарламаларын іске асырудың салдарын болжау және талдау міндеттерін шешу кезінде ақталады.

Кілтті сөздер: өнімділік, өсімдік шаруашылығы, өзгермелі шығындар, шекті табыс, инфляция, субсидиялар, модельдеу моделі, болжам

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ИМИТАЦИОННОЕ МОДЕЛИРОВАНИЕ: АНАЛИЗ ВЛИЯНИЯ МЕР ГОСУДАРСТВЕННОЙ ПОДДЕРЖКИ НА ЭФФЕКТИВНОСТЬ СЕЛЬСКОХОЗЯЙСТВЕННОГО ПРОИЗВОДСТВА

Поскольку прогнозирование общехозяйственного дохода в диверсифицированных производствах имеет ряд особенностей, связанных с наличием и характером стохастической связи производственно-экономических показателей, а также неопределенностью производственно-рыночных условий планового года, для расчета прогнозных величин маржинального дохода в данной статье применяется метод прогнозирования, в котором используются принципы экспертной оценки в сочетании с вероятностным анализом исторических данных и предполагается корректировка исторических данных на тренд и инфляцию.

Тестирование модели проводилось на материалах аграрного производства одного из крупнейших сельскохозяйственных регионов страны - Северо-Казахстанской области.

Для вычисления прогнозных величин маржинального дохода сельскохозяйственных культур товарного растениеводства Северо-Казахстанской области использовали исторические данные по урожайности, переменным расходам и ценам реализации сельскохозяйственной продукции области. В целом, разработка таких моделей, их тестирование и практическое применение оправдано при решении задач прогнозирования и анализа последствий от реализации региональных и национальных сельскохозяйственных экономических программ.

Ключевые слова: урожайность, сельскохозяйственные культуры, переменные расходы, маржинальный доход, инфляция, субсидий, имитационная модель, прогноз

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