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Original Research

Economic Modeling of Household Farming in the Republic of Uzbekistan

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Abstract

This paper examines an emerging economy in terms of the correlation between poverty and greenhouse development as a tool contributing to higher returns of individual households that can be applied in the socio-economic system as a whole to address underdevelopment. Farming acts both as production and consumption factor. Favorable climatic and technical conditions for conducting this type of economic activity stimulate theoretical and practical scientific interest in the problem. The research target is farming as a type of economic activity, an integral element of a national economic complex. The subject of the study is greenhouse farming as a factor of the socio-economic system that affects living standards of the population. The research methodology is based on universally recognized systems concepts and phenomenological principles of scientific investigation, mathematical calculations and software data processing. The findings of this study demonstrate a high dependence of private subsidiary farms as greenhouses on the country's population employment fluctuations. The paper presents an economic model that reflects the dependence of the unemployment poverty on factors of agricultural production, household structure and total household returns. The conducted research revealed a close relationship between intensified greenhouse farming with the level of poverty in the country.

Keywords: correlation, economic efficiency, econometric model, greenhouse farm, private subsidiary farms

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Introduction

At present, agro-industry of many leading countries of the world is a backbone element of the economy as an area of production, distribution and trade, as well as consumption of goods and services [1-3]. It can be stated that the current context of the agro-industrial development is characterized by an unprecedented aggravation and manifestation of global problems, new risks and challenges.

The relevance of this study is conditioned by the significant contribution of households to the socio-economic development of the country. Currently, the household sector plays an important and at the same time dual role in the agro-industry. On the one hand, this sector owns production factors and provides economic resources. On the other hand, households act as consumers of goods and services. Households continue to be the major constituent of the system of human capital reproduction in the agricultural sector.

Modeling household activity is conditioned by the need for timely adjustment of certain areas of state and municipal policy aimed at maintaining the living standard of the population. The use of econometric modeling methods for designing agricultural activities of households makes it possible to assess their ability to self-development and self-organization. Model developments can determine the activity patterns of households as economic agents for further managerial decision-making in the field of socio-economic policy.

Agricultural business models aimed at better use of production resources at the management level of individual agricultural producers are becoming increasingly popular [4]. Building a digital or an information economy and introducing digital technologies is the basis for innovative sustainable development of agricultural formations. The simulation results are of great importance when using digital and innovative technologies and transferring information from rural territories (large and small farms) to the regional management for scientifically sound decision making.

Sustainable rural development is of strategic importance in the system of modeling the economic sphere of the leading countries of the world and its solution directly consists of the effective use of the total production potential of agricultural producers [5, 6]. Indisputably, agricultural producers can fulfil all their functions with a developed and implemented strategy that provides "growth points" and drivers in rural areas for achieving sustainable development.

Developed economies have created a number of simulation models that enable researchers to effectively design strategic parameters and target indicators for the agricultural sector. There are widely used economic and mathematical models for strategic management of rural areas [7]. The use of model schemes in the EU and the USA is aimed at "simulating" situations and making effective management decisions that are focused on supporting the development of agricultural production, as well as the implementation of import and export operations of agricultural products. The applied methods of economic and mathematical modeling help identify possible consequences of the taken management decisions.

It should be noted that over the past three decades, the Nobel Prizes in Economics have been awarded mainly for scientific developments based on modeling methods. Models designed by researchers are aimed at protecting their own consumers of agri-food products and agricultural producers. One of the main goals of such models is to identify the reaction (response) of rural territorial systems to political and managerial decisions and actions of the external economic environment [8].

It should be noted that there are positive trends in wider application of digital technologies and methods of economic and mathematical modeling by analytical departments of the world's largest companies and enterprises in relation to the management processes in agricultural production. Model designs developed on linear programming are still in demand and used in different industrial and scientific fields.

Modeling the development of the dynamic system "agriculture" is a challenging issue since it requires to link and coordinate different management decisions taken at different levels and having different "aftereffect" periods, that is, decisions made at different management levels and stages. This task can be addressed if the modeling process is continuous and there are control values at every level and time interval. Therefore, modeling should be constant, continuous, and have return coupling with production. In other words, with the change in production conditions, the indicators used in modeling should also change, namely, the input information of the models used.

Agricultural activity, as a type of economic activity, is one of the consumption factors that determines the state of the socio-economic space. Poverty, as a typical characteristic of developing economies, significantly affects the state of the socio-economic system, worsening the social and investment climate of the country. The higher poverty level results in reduced effective demand, lower purchasing power of the population, decreased output and poor conditions for extended reproduction of gross products.

The Republic of Uzbekistan is facing a difficult socio-economic situation, which has significantly reduced the pace of economic growth. According to the State Statistics Committee of the Republic of Uzbekistan the national economic activity declined by 2 percent putting the country ahead of Kazakhstan, Tajikistan and Kyrgyzstan [9].

In 2019, the Government of the Republic of Uzbekistan worked out and approved a greenhouse development program [10]. In 2021 the law on subsidiary farming was approved [11]. Such measures are caused by high unemployment rates in the country and resulting poverty. This research exploits economic modeling as a scientific perception of reality to assess how the development of greenhouse farming in the Republic of Uzbekistan affects the level of poverty in the country.

This research aims to establish a possible relationship between private subsidiary farming (in the form of greenhouses) and changes in the level of poverty in the country. The research set out and solved the following objectives, namely:

– study and review of literary sources in the analyzed subject area;
– descriptive disclosure of the subject area using statistically reliable data;
– presenting the research findings in an accessible and economically justified form.

Literature Review

The authors of the present paper conducted a content analysis of research findings for 2019-2022 on the issue under investigation. The literature review made it possible to identify promising research areas to model the development of agriculture and activities of economic entities in the agricultural sector:

1. Designing a strategy for sustainable agricultural development based on the use of modeling methods.

It should be noted that the agricultural sector of developing countries has great potential for applying mathematical models in the development and implementation of sustainable agricultural development policies. Thus, the agricultural sector in Ethiopia plays a significant role in the economy, and the efficient decision-making regarding the best allocation of agricultural resources determines the strategic importance of model developments in reducing rural poverty and increasing agricultural production [12]. At the same time, the direct impact on management decision-making processes during optimization brings in a higher economic efficiency in using agricultural resources.

Current studies emphasize the importance and relevance of developing an assessment of the water and land resources use based on optimization models to achieve sustainable agricultural development. Sustainable development is for sure the basic concept of present-day agricultural planning. When considering optimum use of agricultural water and land resources (AWLR), foreign experts suggest wider application of stochastic modeling, nonlinear optimization and fuzzy clustering, which, in turn, help determine the internal links between sustainability of agriculture and the AWLR distribution based on alternative scenarios of environmental change [13].

The widespread use of GIS modeling apparatus by Egyptian specialists makes it possible to effectively assess the current state and potential of agricultural sustainability [14]. Evaluating the sustainability of agriculture is definitely important to conserve and improve land resources use. Thus, applying a Designed Sustainable Potential Spatial Model (DSPSM) based on the analysis of five key factors (productivity, security, protection, economic viability and social acceptability) differentiates agricultural industries into several types (classes) of sustainability: class 1, class 2 and class 3.

In turn, an integrated approach based on modeling methods and cluster analysis makes it possible to successfully formulate targeted strategies to restructure rural settlements [15]. The ongoing process of designing target strategies should take into account transformational changes in the spatial structure of farm lands used for rural development. Based on the findings, the researchers identified five types of rural settlements and constructed different scenarios for their spatial restructuring in a heterogeneous rural landscape.

Foreign scientists have developed a forecast model of the economic development for the agricultural sector of the region, which allows identifying priority directions for the long-term operation of agriculture [16]. If it is necessary to adjust the direction of development, alternative scenarios are investigated at the macro level, which are ranked by priorities and may vary in the conditions of uncertainty and possible risks. Scientific substantiation of theoretical, methodological and methodological principles of strategic management is crucial for solving urgent problems of economic development of the agricultural sector of the region in order to balance supply and demand in the agricultural market based on cognitive scenarios. In turn, applying probabilistic modeling technologies makes it possible to identify “growth points” at the regional level, optimize the sectoral structure of the economy, improve the quality and efficiency of the developed and implemented strategies for the agro-industrial production. Thus, the practical value of the study is that it can predict the strategic development of the agricultural sector of the region as a complicated and structured system and its individual areas of functioning based on a systematic approach, analysis and forecasting.

2. Compilation and implementation of models for optimization of land resources used in agriculture.

Foreign researchers emphasize that remote sensing is a powerful tool for analyzing and monitoring spatio-temporal transformations in agriculture [17]. For instance, a hybrid model of logistic regression, being an effective scientific development, can be used to examine land management processes and changes in the parameters of LULC (Land Use Land Cover). The implementation of this model development provides evidence that the modeling of land use processes is the most important component of agricultural planning and management decision-making in the agricultural sector of the economy.

The conducted studies have demonstrated that modeling methods can effectively assess the spatial distribution of unused farm lands with acceptable measurement accuracy [18]. Information about the site and size of unused farm land is of strategic interest for assessing external management impacts on rural development.

The best examples of effective optimization of agricultural industries are model developments applied in the largest agricultural district of Kern County in California (and the USA as a whole) [19]. These models take into account the balanced development goals of agricultural production, the efficient use of underground water reserves for agricultural needs and biodiversity based on certain environmental priorities. It should be emphasized that such optimization models are an integral part of the present-day concept of strategic planning of environmental protection activities. Their practical application contributes to the effective distribution of land-use objects in conditions of water scarcity.

Foreign researchers suggest using BP–ANN and CLUE–S models when optimizing land-use objects in rural areas [20]. Scientists have identified a rural area with an optimal land use scheme when constructing optimization models. The optimal ratio of the land use structure using the BP–ANN model is calculated based on the assessment of the impact of the resulting climatic, social and economic factors. The CLUE-S model can be effectively applied in the spatial distribution of land use for individual rural residents. A prerequisite for implementing the land use optimization process is the expansion of farm lands, taking into account the entire range of ecosystem services provided. It should be noted that the results of quantitative optimization on a scientific basis not only ensure the stable use of cultivated agricultural land, but also allow taking into account such environmental aspects of land use as soil conservation and water purification.

3. Investigating issues of food security and organic agriculture based on economic and mathematical models.

Currently, food security issues can be effectively solved by modeling methods and developed models of agricultural systems. Foreign researchers stipulate the need for wider use of dynamic models of agricultural systems, which should include key parameters reflecting the state of food security, both at the regional and the household levels [21].

In our opinion, one of the promising areas of foreign economic research is modeling consequences of shifting to organic agriculture. A linear programming model proposed by scientists to develop typical farms takes into account such factors as soil condition, precipitation, fodder availability for certain groups of farm animals [22]. The final model results of this study determine a significant reduction in the actual production of wheat and barley, while the production of oats and rye compared to the actual indicators needs to be increased. At the same time, the planned output of vegetables are generally comparable with actual indicators. The research findings suggest that compensating for shifting agriculture in England and Wales to organic farming require significant changes in the diets of cattle and reduced food waste.

Currently, price fluctuations for agri-food products directly affect the results of agricultural production. For adaptive forecasting of price levels, researchers offer a model development that includes the use of time series functions and the establishment of a forecast horizon [23]. In practical terms, the model under consideration is based on twenty-nine time series functions directly applied in the design of prices for agricultural products and the use of current forecasting technologies, namely: artificial neural network (ANN), support vector regression (SVR), and extreme learning machine (ELM).

4. Application of modeling methods in the development of electronic agriculture and rural e-commerce.

The use of modern methods of econometric modeling and, in particular, the construction of regression models makes it possible to effectively assess the opportunities and prospects for the development of rural e-commerce. Thus, the results of heterogeneous analysis conducted by foreign experts revealed the following dependence: rural households located closer to local settlements “benefit” more from introduced e-commerce and trade [24].

The FARMSIM simulation model developed by scientists can assess the potential consequences when introducing new agricultural technologies at the level of individual farms in ex-ante and ex-post conditions [25]. The model is based on the Monte Carlo method. The conducted studies have shown that the use of large amounts of fertilizers by rural producers in combination with optimal irrigation of agricultural fields for growing vegetables provides higher returns compared to the actual development scenario.

The study on evaluating prospects for sustainable development and efficient electronic agriculture conducted on the Malmquist model is of scientific interest [26]. Experts use this model productivity index to improve the management processes of electronic agriculture and ensure a balance between the development of rural society and the state of the environment. Another important advantage of the Malmquist model under consideration is the qualitative analysis of strategic prospects to enhance electronic agricultural infrastructure.

Material and Methods

Table 1 demonstrates the structure of the gross domestic product (GDP) in the Republic of Uzbekistan, according to the National State Statistics Committee.

Fig. 1 shows the implicit dynamics of agriculture, sharing 27 percent of the total GDP of the Republic of Uzbekistan in 2020 while there is no characteristic trend line (growth or decline), there is an implicit trend towards a decrease in agricultural output in the overall structure of the Uzbekistan Republic’s GDP. Comparing the data of the State Statistics Committee of the Uzbekistan Republic on the growth rates of GDP and agriculture over the past four years provides an idea of the current trend in their dynamics.

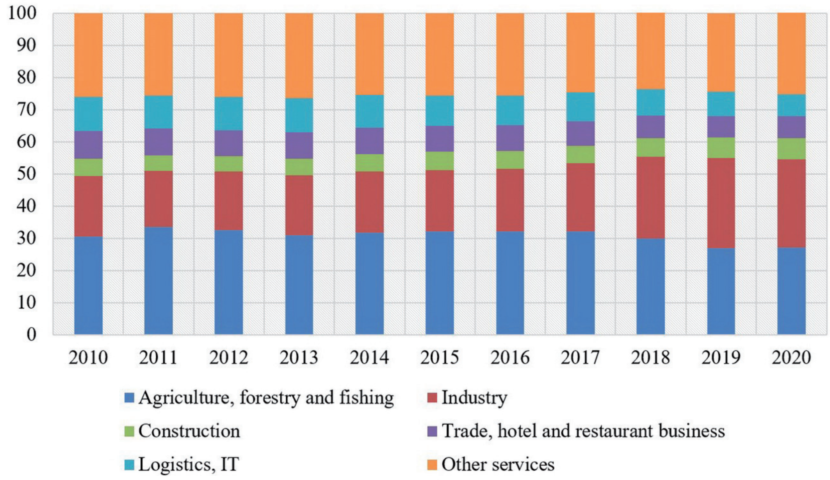

Fig. 1. The GDP structure by types of economic activity in the Republic of Uzbekistan, 2010-2020 (%). Source: [9].

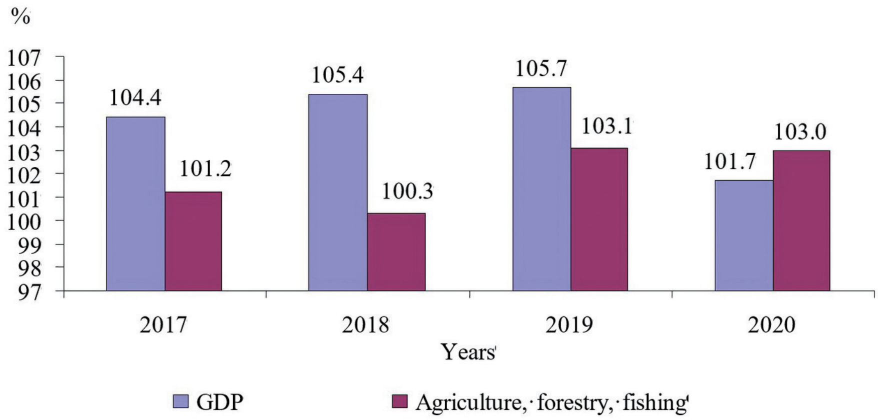

Fig. 2. Changes in GDP and dynamics of agriculture in the GDP structure of the Republic of Uzbekistan. Source: [9].

Fig. 2 confirms the declining trend of agriculture in the structure of GDP. Thus, from 2017 to 2019 inclusive, the GDP of the Uzbekistan Republic changed at a faster pace relative to the growth rate of agriculture. The trend change in 2020 is largely due to the unfavorable macroeconomic situation caused by the COVID-19 Pandemic, when the country's GDP declined sharply as the result of structural shifts in all sectors of the economy. At the same time, the growth rates of agricultural production remained unchanged, indicating the relative stability of the segment to non-systemic external risks.

The study relies on a systematic approach to evaluate the phenomena of the subject area under consideration, using theoretical and heuristic methods of data analysis, based on computational methods of data processing: correlation and regression analysis, data normalization and extrapolation. Paired comparisons of data series are examined to identify mathematically and economically justified dependence of indicators and, if available, the direct elasticity of the evaluation parameters is considered.

Indicator normalizing is used to reduce data series to a single scale of assessment, while the normalization is performed according to the formula of the maximum value from the data series, formula (1) [27]:

$$Nx_i = \frac{x_i}{x_{max}} \tag{1}$$

where Nx_i is a normalized indicator x_i taking a value from [0;1];

x_{max} – the maximum value of x from a series of x values.

Since the calculation results will be extrapolated based on the correlation coefficient more than 0.9 and the confidence coefficient (R^2) more than 0.8, that is, there will be no significant changes in the trend, the following formula (2) [27] can be used after constructing a reliable correlation field:

$$x = \frac{\sum_{i=1}^{n} x_i}{n} \tag{2}$$

where x_i is the i-th value of a random variable;
n is the number of observations.

The elasticity of the indicators is calculated according to the formula (3) [27]:

$$E_{yx} = b\frac{\bar{x}}{\bar{y}} \tag{3}$$

where
E_{yx} – coefficient of elasticity;
$\bar{x}$, $\bar{y}$ – average values of indicators;
b – regression coefficient.

This study relies on the model based on the findings of Berger et al. [28], Castillo et al. [18], and Mugera and Langemeier [29] that use the principles of formal logic and require interrelated factors (elasticity). To do this, the following factors from Table 1 were taken:

– Crop production growth, CPG, %;
– Output growth of private subsidiary farms (greenhouses), PFO, %;
– Unemployment rate of the total workforce, UR %;
– Real growth of total income, RIG, %;
– Household structure by number of members, people;
– Growth rates of agricultural products, APG, %.

The values are normalized using the data processing methods suggested in the study of Khairullin et al. [27], according to formula 1 based on the data in Table 1.

Fig. 2 shows a graphical representation of the normalized values obtained from the analytical Table 2.

Fig. 3 depicts that according to the key factor, the unemployment rate, the linear and exponential trend line has an upward trend, but the accuracy coefficient of the approximation is less than 0.8 (0.65 linear, 0.66 exponential). Hence, it is impossible to extrapolate values by factors and build the elasticity of indicators. Establishing the relationship of factors in the model and assessing the elasticity of indicators require application of stochastic and correlation–regression analysis methods [27]. To do this, a pair comparison of the indicators' relationship strength and correlation field was performed.

Results and Discussion

The conducted study revealed many econometric observations on the factors of agricultural activity in Uzbekistan. Thus, the correlation field of the UR-CRG factors shows the absence of close connections between the factors, which is confirmed by the approximation confidence coefficient (exponent) 0.282 and the data in Fig. 4.

The diagram values in Fig. 5 also support the reasonable conclusion that there is no statistically significant relationship between the UR-CPG factors.

It confirms the hypothesis of the study that the output growth of private subsidiary farms (greenhouses), PFO % is closely related to the unemployment rate indicator of the total workforce, UR, %. The relationship has an inverse correlation of -0.913. In this regard, the relationship was found by constructing a dual regression equation $y = -0.617x + 71.57$ and defining the elasticity coefficient of the indicators %. The minus sign confirms the inverse correlation between

Table 1. Normalized indicators of agriculture, income and employment in the Republic of Uzbekistan.

Indicators	Years										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Crop production growth, CPG, index	1.06	1.05	1.07	1.06	1.06	1.05	1.06	0.98	0.96	1.05	1.03
Normalized value of CPGn, in shares	0.99	0.98	1.00	0.99	0.99	0.99	0.99	0.92	0.89	0.98	0.97
Output growth of private subsidiary farms (greenhouses), PFO, index	1.07	1.08	1.08	1.08	1.08	1.07	1.08	1.04	1.02	0.99	1.02
Normalized value of PFOn, in shares	0.99	0.99	1.00	1.00	0.99	0.99	1.00	0.97	0.95	0.92	0.94
Unemployment rate, of the total workforce, UR, %	5.4	5.0	4.9	4.9	5.1	5.2	5.2	5.8	9.3	9.0	10.5
Normalized value of URn, in shares	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.9	0.9	1.0
Real growth of total income, RIG, index	1.2	1.2	1.1	1.1	1.07	1.04	1.09	1.07	1.07	1.05	1
Normalized value of RIGn, in shares	1.00	1.00	0.94	0.95	0.89	0.87	0.90	0.89	0.89	0.87	0.84
Household structure by the number of members, HS, people	5.3	5.1	5.1	5.0	5.0	5.0	5.1	5.1	5.0	5.0	5.0
const HSn ≈ 1 (on a normalized scale)											
Growth rates of agricultural products, APG, index	1.06	1.06	1.07	1.07	1.06	1.06	1.06	1.01	1	1.03	1.03
Normalized value of APGn, in shares	0.99	0.99	1.00	0.99	0.99	0.99	0.99	0.94	0.93	0.96	0.96

Source: Calculated by the authors based on their own research

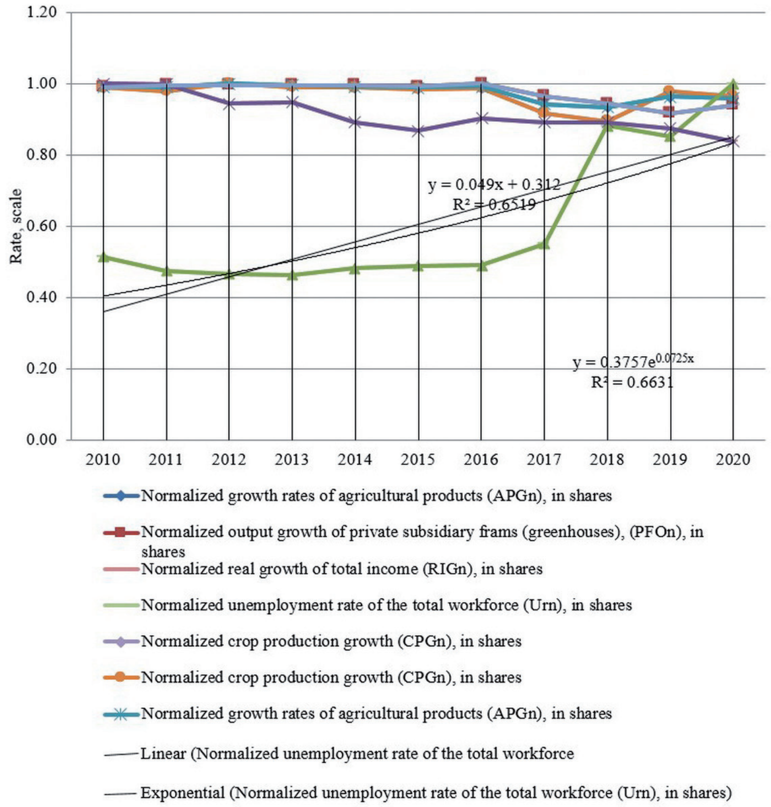

Fig. 3. Graphical representation of the normalized factor scores of the accepted model. Source: Calculated by the authors based on their own research.

an increase in greenhouse production and a decrease in the unemployment rate as an indicator of poverty in the country. The growth of greenhouse farms by 1 percent will lead to a decrease in the unemployment rate by- 1.134%, that is, to the level of 9.366 percent relative to the level of 2020. It is obvious that an increase in output growth indicators will lead to a greater decrease in unemployment rates. Household structures and their specialization level have been found not to influence the poverty indicators in the country.

While the hypothesis of the study, aimed to analyze how an increase in the number of households involved in greenhouse farming will reduce the level of poverty in the country has turned to be true, nevertheless, it should be noted the study of Mugera and Langemeier [29], in which 543 agricultural associations were evaluated and it was found that the size of the farm directly affects its effectiveness (as presented in the Table 3).

As Fig. 2 shows, the farm size directly affects its efficiency, the smaller the agricultural association (greenhouse farm efficiency 0.4872), the lower its efficiency (large agricultural association 0.7983). It should be noted that the results and conclusions of the study Mugera and Langemeier [29] are also

Table 2. Mean values of PFO and UR by years of calculation

Indicators / year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Output growth of private subsidiary farms (greenhouses), PFO %	107.2	107.7	107.7	107.7	107.6	107.4	108.2	104.5	102.3	99.2	101.7
Normalized value of PFOn, in shares	0.99	0.99	1.00	1.00	0.99	0.99	1.00	0.97	0.95	0.92	0.94
Unemployment rate, of the total workforce, UR, %	5.4	5.0	4.9	4.9	5.1	5.2	5.2	5.8	9.3	9.0	10.5
Normalized value of URn, in shares	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.9	0.9	1.0
$\overline{PFO}$, %	105.6										
$\overline{UR}$, %	6.4										

Source: Calculated by the authors based on their own research

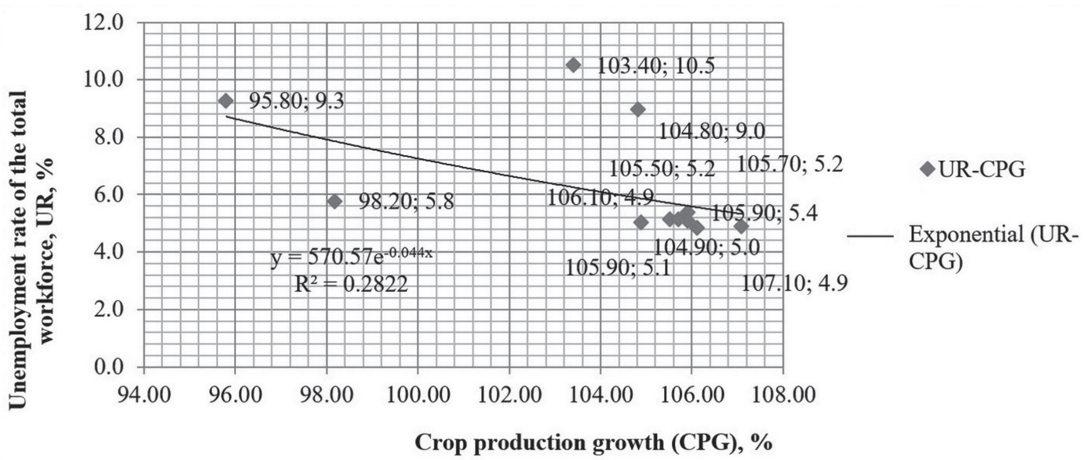

Fig. 4. UR-CPG correlation field. Source: Calculated by the authors based on their own research.

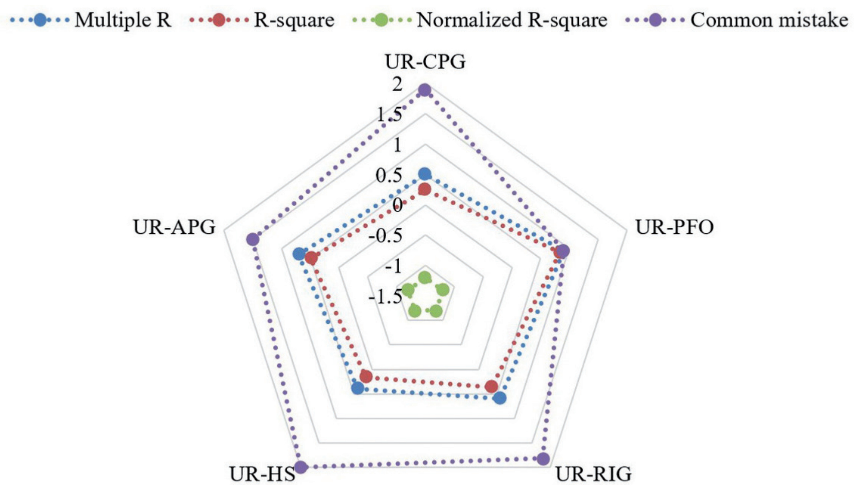

Fig. 5. Regression statistics parameters. Source: Calculated by the authors based on their own research.

Table 3. Dimension, specialization of the agricultural association and its performance.

Farm Size and Specialization	Efficiency Score	Efficiency Bias Corrected	Bias	Standart Error	Lower Bound	Upper Bound
The size of the agricultural association and its operation efficiency						
Very small	0.4872	0.4214	0.0657	2.0021	0.4194	0.4773
Small	0.5631	0.5414	0.0217	2.8421	0.5233	0.5595
Medium	0.6678	0.6245	0.0432	0.7622	0.5977	0.6610
Large	0.7983	0.6958	0.1025	0.0032	0.6677	0.7814
Average	0.5925	0.5499	0.0426	1.9033	0.5321	0.5858
The specialisation of the agricultural association and its operation efficiency						
Livestock	0.5866	0.5449	0.0417	2.0027	0.5263	0.5802
Mixed	0.5864	0.5480	0.0383	1.9937	0.5294	0.5808
Crops	0.6060	0.5559	0.0501	1.6988	0.5398	0.5984
Average	0.5926	0.5499	0.0426	1.9033	0.5321	0.5858

Source: Developed by the authors on the basis of research of Mugera and Langemeier [29] confirmed by the results of this research: there is no connection between the growth of total income (RIG) and poverty reduction (Fig. 4). At the same time, the same study Mugera and Langemeier [29] revealed that the specialization of an agricultural association does not affect the growth of economic and technical efficiency of the farm.

It should also be noted that the implementation of state programs in the field of agriculture is technically inefficient compared to private initiatives [30, 31]. In other words, the development of greenhouses and the adoption of state programs in this field will not have a drastic impact on reducing poverty, which is confirmed by the value of the % elasticity coefficient according to the results of this investigation.

Conclusions

Thus, it can be summarized that the purpose of the study has been achieved – the relationship between personal subsidiary farming (in the form of greenhouses) and the change in the level of poverty in the country has been established. Household structures and their specialization level have been found not to influence the poverty indicators in the country. With regard to the goal to achieve, the following objectives were solved: a review of the literature sources on the subject area of the study was carried out; the content of the subject area of the study was descriptively disclosed using statistically reliable data; the results of the study are presented in an accessible and economically justified form.

The research findings established that the type of the dual regression equation directly reflects the dependence of the poverty level indicator and the output of greenhouse farms in the country with a reliability of more than 0.9 and an elasticity of % indicators. In turn, there is a close relationship between private subsidiary farming in the form of greenhouses and changes in the unemployment rate as a regulatory factor of the poverty level in the country.

The performed calculations showed that growth factors like crop production growth, CPG, %; the real growth of total income, RIG, %; the structure of households by the number of members, people; the growth rate of agricultural products, APG, % are poorly correlated with the resulting indicator, the unemployment rate of the total workforce. The size of the farm directly affects its efficiency, the smaller the agricultural association, the lower its efficiency.

The main limitations of the conducted research were: available resources, the number of rural households studied in the socio-economic environment under consideration, the coverage area and the time frame of the study. The vector of further scientific developments using the results of the given study determines the subsequent design of the considered parameters, namely: indicators of crop production growth, the output growth of private subsidiary farms (greenhouses), the unemployment rate of the total workforce, the real growth of total income, the structure of households by the number of members and the growth rate of agricultural products.

The practical value of this paper and, in particular, the presented scientific developments lies, firstly, in clarifying and supplementing methodological approaches to the application of methods for modeling agricultural activities of households. Secondly, the conducted investigation provided evidence for the hypothesis formulated by the authors of the study, according to which the level of poverty, measuring the level of unemployment, can be reduced by higher output of greenhouse farming and more households involved in this type of economic activity.

Conflict of Interest

The authors declare no conflict of interest.

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