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Development of Tax Support for Agriculture in the Context of Enhancing the Effectiveness of Various Tax Regimes

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Abstract. The paper proposes our own methodological approach based on the data of financial statements of agricultural organizations and allowing us to assess the impact of taxation regimes on the results of their activities. The subject of the study is the system of statistical indicators of agricultural organizations characterizing the level of economic production. The aim of the work is to substantiate the architecture of the tax incentive system for the industry, as well as to design further directions for the development of tax support for agriculture. Research methods include typical grouping, machine learning models (decision tree, random forest and gradient boosting). As a result, the methodological approach was tested and significant differences in the performance indicators of agricultural organizations depending on the choice of taxation systems were substantiated, and net profit forecasting models were built for each of them. The constructed models allow us to identify the nature of the influence of tax factors on the

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performance of agricultural entities. Recommendations for improving the system of tax incentives for the industry are presented. The developed methodological approach helps to assess the differences in taxation systems using the grouping method and machine learning methods, as well as to build high-quality forecasting models. The scientific novelty of the study consists in developing a set of proposals for improving tax incentives for the industry, taking into account (1) the optimal architecture of the tax support system at the macro level and (2) systemic problems of applying industry tax incentives at the micro level. Proof of the optimality of the architecture of the tax incentive system for agriculture was revealed using our methodology for assessing the impact of the tax regime on the performance indicators of agricultural producers, based on the use of machine learning methods.

Key words: tax regime, tax forecasting, agriculture, tax factor, machine learning methods, decision tree, random forest, gradient boosting.

Introduction

Experts from the Food and Agriculture Organization of the United Nations (FAO) and the Organization for Economic Cooperation and Development (OECD) believe that the global agri-food sector will face fundamental challenges in the near future[1]. Among them, there are problems with food provision, climate change, as well as economic problems related to food supplies. The FAO agricultural forecast assumes that the growth rate of the global agro-industrial complex will be at the level of 1.1%. The prospects for the Russian agricultural sector development look more optimistic. Thus, the Strategy for the Development of the Agro-Industrial Complex until 2030 plans an average annual growth rate of production in the agro-industrial complex from 2023 at a level of at least 3%[2].

Agriculture is the central element of the Russian agro-industrial complex. The activities of agricultural organizations are influenced by many factors, among which tax factors play a significant role (Tikhonova, 2015). It is no coincidence that modern financial science considers tax cuts as one of the ways to increase the profits of economic entities. In particular, a study by Chinese scientists has shown that the agricultural taxation reform of the 2000s in the country has produced positive results, including through increased capital investment, increased agricultural productivity, and the promotion of structural transformation (Li et al., 2024). Russian research also proves the effectiveness of state tax incentive measures for agricultural producers (Kosov et al., 2023). Taxation regime is the most common indicator reflecting the influence of all tax factors and taking into account all the characteristics mentioned above. The development of the agro-industrial complex depends on the choice of taxation system and its impact on the financial results of agricultural producers (Lyalina et al., 2021).

Currently, agricultural producers (organizations) can apply the following tax regimes: general taxation regime or special taxation regimes in the form of single agricultural tax (SAT), simplified taxation system (STS; *Tab. 1*). When choosing special taxation regimes, producers must meet the established criteria. Thus, in order to switch to SAT, the share of income from the sale of agricultural products, including products of their

[1] OECD-FAO Agricultural Outlook 2023–2032. OECD Publishing, Paris. DOI: https://doi.org/10.1787/08801ab7-en

[2] On approval of the strategy for the development of agro-industrial and fishery complexes of the Russian Federation for the period up to 2030: RF Government Resolution 2567-r, dated September 8, 2022.

Table 1. Application of taxation systems for agricultural organizations

System	Rate	Conditions
General taxation system (GTS)	Corporate income tax 0%	Under the terms of Article 346.2 of the Tax Code of the Russian Federation
	Corporate income tax 20%	For organizations that do not fall under the definition of agricultural producers in accordance with Article 346.2 of the Tax Code of the Russian Federation, as well as for profits from non-agricultural activities
	Corporate property tax no more than 2.2%	Excluding land plots and other natural resources (water bodies and other natural resources)
	Value added tax (VAT) 10%	When selling a number of agricultural products and food products according to the list established by the Government of the Russian Federation (Resolution 908, dated December 31, 2004)
	Value added tax (VAT) 20%	For other types of products (works, services)
Single agricultural tax (SAT)	0–6% of income after expenses	Agricultural commodity producers meeting the criteria established by Article 346.2 of Chapter 26.1 of the Tax Code of the Russian Federation. Replaces: profit tax, corporate property tax, VAT (exempted voluntarily if revenue does not exceed 60 million rubles per year).
	VAT at income up to 60 million rubles not levied (or calculation) VAT at income above 60 million rubles 10 or 20%	When selling a number of agricultural products and food products according to the list established by the Government of the Russian Federation (Resolution 908, dated December 31, 2004)
	Corporate property tax not more than 2.2%	With the exception of land plots and other objects of natural resources (water bodies and other natural resources), as well as real estate directly used in agricultural production
Simplified taxation system (STS)	On income 1–6% On income after expenses, 5–15%	Replaces: profit tax, corporate property tax (except for tax, value added tax (except for tax on importation of goods into the territory of the Russian Federation and other territories under its jurisdiction)
	VAT at income up to 60 million rubles not levied (or calculation) VAT at income above 60 million rubles 10 or 20%	When selling a number of agricultural products and food products according to the list established by the Government of the Russian Federation (Resolution 908, dated December 31, 2004)
Under any regime	Transportation tax rate per: 1 hp (kW); 1 ton of capacity; 1 kg of traction force; 1 unit of vehicle	Tractors, self-propelled combines of all brands, special vehicles (milk trucks, cattle trucks, special vehicles for poultry transportation, vehicles for transportation and application of mineral fertilizers, veterinary assistance, technical service) registered to agricultural producers and used in agricultural work for the production of agricultural products are not subject to taxation
	Land tax not more than 0.3% for agricultural land	It is allowed to establish differentiated tax rates depending on the categories of land and (or) the permitted use of the land plot
Compiled according to: Tax Code of the Russian Federation (Part Two): Federal Law 117-FZ, dated August 5, 2000 (amended December 29, 2014). SPS "Consultant Plus": Legislation: Prof. version. Available at: http://base.consultant.ru (accessed August 25, 2023).		

primary processing, produced from agricultural raw materials of own production, from the provision of services to agricultural producers, must be at least 70% of the total income from sales. To switch to the simplified taxation system, based on the results of the first nine months of the year in which the organization submits a notification of the transition to the simplified taxation system, revenues for the analyzed period should not exceed 337.5 million rubles starting from 2025.

At the micro level, each agricultural producer chooses the most optimal taxation system for themselves, which would minimize the tax burden as much as possible and positively affect the results of financial activities. Nevertheless, the "blurring" differences in the general taxation system and the single agricultural tax, and the ongoing controversy about the effectiveness of various tax regimes (discussed below) make it necessary to answer to the question of the architecture of building a system of tax incentives for the industry at the macro level. The fact is that foreign practice, as a rule, is represented by two options for building such a system: (1) a differentiated approach in which the taxation system includes special sectoral taxes and fees; (2) a unified system in which sectoral taxation features (a) are either integrated into standard corporate income taxes and indirect taxes (b) or they are not represented at all, and state support is provided in the form of subsidies. The first option is found, for example, in the countries of the European Union, the second – in China. Thus, the aim of the study is to substantiate the architecture of the agricultural tax incentive system at the macro level in the Russian Federation, as well as to further refine specific support measures that take this architecture into account, based on the practice of their application at the micro level. The goal defined the following research objectives:

1) to develop a methodological approach based on the use of data mining tools and machine learning methods, which makes it possible to assess the impact of taxation regimes on the performance of agricultural organizations;

2) based on the approbation of our own methodology, to substantiate the choice of applying a differentiated or unified approach to tax support for the industry at the macro level in the Russian Federation;

3) to identify the system-wide problems of taxation in the industry, which have the most significant impact on the choice of a special taxation regime at the micro level;

4) to propose ways to improve the system of tax incentives for agriculture.

The hypothesis of the study is that the adjustment of the agricultural tax incentive system should be carried out in the context of its optimal architecture, which takes into account the effectiveness of tax incentives at the macro level, as well as take into account the system-wide problems of applying such benefits at the micro level (by specific enterprises).

The scientific novelty of the research consists in the development of a set of proposals for improving tax incentives for the industry, taking into account (1) the optimal architecture of the tax support system at the macro level and (2) the system-wide problems of applying sectoral tax incentives at the micro level. The proof of the optimality of the architecture of the agricultural tax incentive system was revealed using our own methodology for assessing the impact of taxation regime on the performance of agricultural producers, based on the use of machine learning methods.

Literature review

The paper complements three blocks of research areas.

The first block is theoretical and includes papers that discuss the architecture of the agricultural tax incentive system. They are divided into three groups. The first group of researchers adheres to a differentiated approach to tax incentives, suggesting the availability of several support options, including, as a rule, a number of special tax regimes and individual benefits when applying the general taxation system. Proponents of this approach point out that differentiated support makes it possible to successfully address key problems of the agrarian economy that differ in content (Zaruk, 2015), and carry out effective taxation with regard to producers in regions with different natural and economic

potential (Gashenko et al., 2019). According to N.I. Malis, the general approach to taxation of agricultural organizations is greatly complicated by its specifics, which determine "the expediency of introducing not only individual benefits within the framework of the general taxation system, but also the introduction of a special tax regime – the taxation system for agricultural producers" (Malis, 2016).

The second group of scientists advocates a unified approach to tax support based either on the use of only one special tax regime (subgroup "A"), or on the complete absence of sectoral regimes when applying benefits within the framework of the general system (subgroup "B"). Analyzing the work of the scientists from subgroup "A" is carried out at various levels (region, country, group of countries). Thus, when considering the impact of tax incentives on the regional agro-industrial complex of Sevastopol, the provision of tax benefits under the SAT is noted as a necessary or forces measure of state support (Grebeshkova et al., 2021). Z.O. Imanbayeva came to a similar conclusion about the important role of fiscal stimulation of the industry in Kazakhstan (Imanbayeva, 2023). At the same time, when assessing the impact of SAT on the financial performance of agricultural producers, some researchers draw the opposite conclusions, noting the inexpediency of minimizing taxes in the industry, since the desire of business leaders to reduce the amount of accrued taxes leads to a decrease in financial performance (Kataev, Sasina, 2011). Given that the work analyzed above was implemented in 2011, its results should be tested in fundamentally different current economic conditions. It is no coincidence that in a later work, researchers also come to the conclusion that, despite the presence of positive effects, SAT needs to be radically improved and should be designed in such a way as to ensure tax revenues to the budget and at the same time stimulate the development of the industry (Barashyan, 2021). Representatives of subgroup "B" emphasize that special regimes in foreign practice are used mainly to simplify tax relations so as to take into account the specifics of farming activities, rather than to improve the financial security of agricultural business entities (Prokopchuk, 2016). It is noted that an agricultural tax can potentially hinder structural transformations (Grabowski, Shen, 2013), as well as distort the incentives for the development of other industries. In particular, the authorities will have to develop industrial production and stimulate the expansion of the tax base of production after the abolition of the agricultural tax (Tang, 2025). As China's experience shows, the abolition of the agricultural tax has not had a significant impact on household incomes from agriculture or their costs of agriculture (Grabowski, Shen, 2013).

Thus, in the context of our research, special attention should be paid to the architecture of building a system of tax support for agriculture at the macro level. Today, a differentiated approach is used in Russia (the substantiation is presented in Table 1); however, an assessment of the nature of the impact of various tax regimes on the performance of producers will justify the further development of a differentiated approach or the transition to a single architecture.

The second block is a practical one, devoted to assessing the effects of tax benefits at the micro level and choosing the highest priority regime. Scientific research within its framework is carried out, as a rule, on the data of certain companies, a limited sample of agricultural producers, or applied to an abstract taxpayer. According to this block, there is no consensus in science and practice regarding a more profitable system for agricultural production. So, L.M. Petrova (Petrova, 2019), M.V. Polinskaya (Polinskaya et al., 2023) believe that it is most advantageous to apply a single agricultural tax, but in a number of studies, preference is given to the general taxation system (Zyryanova, Zagursky, 2019; Shnigir, Melman, 2021). In turn, T.M. Efremova

and co-authors have revealed that among the special tax regimes, the simplified taxation system has the greatest effectiveness (Efremova, 2015). It is important to note that in practice, each agricultural producer chooses a taxation regime based on the conditions and restrictions of its use and the parameters of its own economic activity. At the same time, it is the restrictions on the use of tax benefits at the micro level that most often act as a decisive factor in choosing the taxation regime, and therefore need to be evaluated and refined at the micro level.

Finally, within the framework of the third block, in order to develop a methodology for assessing the impact of taxes on the performance of agricultural organizations, it is advisable to investigate the quantitative methods used in such an assessment. In scientific papers, the impact of taxes on the industry is assessed either quantitatively or qualitatively. A qualitative assessment is an analysis of the practice of applying certain legislative norms (Solyarik, Eliseeva, 2018). However, quantification is of the greatest interest. The study of the effect and effectiveness of tax incentives in agriculture in a significant number of Russian studies is based on a simple assessment of the indicators of commodity producers applying various tax regimes (Efremova et al., 2015; Borodina et al., 2022). This approach is called typical grouping in statistical science. However, it has a number of disadvantages. First, the fact that the grouped objects belong to the general population leads to the appearance of some common features that mask the differences between the types. Second, the lack of a clear designation of individual types and the multiplicity of features of the object description complicates the qualitative grouping. Third, the typical grouping does not allow identifying the main and most significant features.

Another method often used in the work of agricultural economists is correlation and regression analysis (CRA), when a profit indicator is used in the construction of regression models (Korotkikh, 2022; Komarova et al., 2024; Zhang et al., 2023). In general, profit forecasting makes it possible to assess business risk factors that appear in difficult market conditions, and acts as an important tool for the government, business and society as a whole (Guindani et al., 2024). However, the use of CRA leads to the need to comply with a large number of prerequisites of the least squares method, which are difficult to take into account in the conditions of a diverse sample of agricultural producers (violation of the premise of normal distribution), the dependence of many indicators of companies in the industry on their size (violation of the premise of autocorrelation, etc.).

Also, the statistical method of investigating the impact of taxes on agriculture, based on the analysis of panel data, is the "difference in differences" (DID or DD). Its essence consists in comparing the average change over time of the outcome variable for the test group with the average change for the control group (Xu et al., 2024). The main disadvantage of this method is the need to ensure the condition of a parallel trend, which consists in assuming the same development of control and test samples, which is practically unattainable in a real economy. Otherwise, there is a bias in estimates. Dynamic models for assessing the tax sensitivity of individual industries are also widely used in science (Balatsky, 2023). However, in the context of the ongoing economic and political transformations caused by the coronavirus infection and sanctions against the Russian Federation, the effectiveness of building dynamic models is significantly reduced. "Time series have significant structural shifts, factors become unreliable, and as a result, it becomes impossible to assess tax sensitivity" (Gerasimova, 2024).

Research methods and data

The abovementioned shortcomings in the methods of studying the influence of tax factors on the performance of agricultural organizations have led to the need to find new methods. Modern

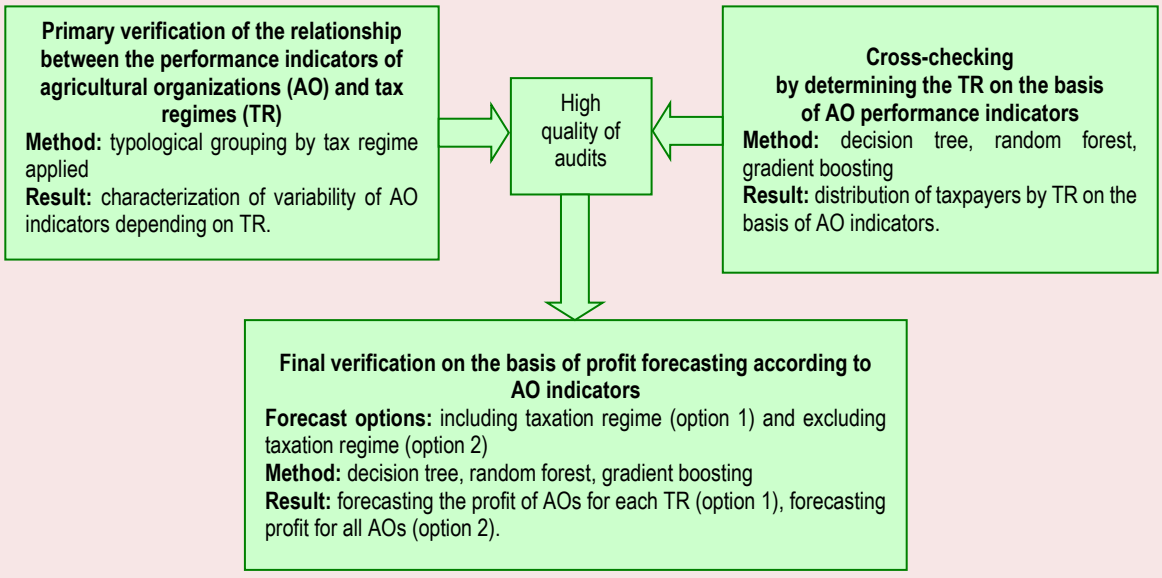
forecasting tools, such as machine learning and neural network analysis methods, make it possible to eliminate the problems of using simpler quantitative assessment methods, improve the quality of forecasts, and reduce the time spent on data processing and model building. To substantiate the approach to the architecture of tax incentives for the industry at the macro level, it is necessary to assess the performance of a large number of diverse agricultural entities. In this regard, it is advisable to use a cross-sectional approach comparing the results obtained in various ways (Tikhonova, 2023). Schematically, our methodological approach is shown in *Figure*.

As part of the initial assessment, accounting data (159 indicators) for 27,948 enterprises for 2022 from SPARK system were used to assess the impact of the tax regime on the performance of agricultural organizations. As a result of cleaning and primary processing of the database, the size of the studied population for typological grouping decreased to 27,490 organizations by 99 indicators. The taxation regime is used as a grouping feature.

Cross-validation also requires processing of the initial data: in particular, diagnostics of indicators for the presence of emissions was carried out. As a result, 3,428 organizations and 57 indicators were removed from the aggregate (42 indicators remained for machine learning analysis).

Several methods have been used to classify organizations by tax regime: decision tree, random forest, and gradient boosting. The choice of methods is justified by the fact that they do not depend on the scale of the feature and do not require prior standardization of data. The decision tree method is a branching structure where a classification feature is divided into groups depending on the value of a factor. The method works quite effectively with nonlinear and non-trivial relationships (Nasteski, 2017). The random forest algorithm is based on a set of decision trees based on independent samples to obtain more accurate results. The final forecast is made by averaging the forecasts of all the trees in the forest, so this method is resistant to outliers and noise in the data, and is also less susceptible to overfitting

Methodological approach to substantiating the architecture of the tax incentive system at the macro level



Source: own compilation.

than a single decision tree. "Gradient boosting" combines several weak decision tree models to produce stronger models. The algorithm selects a decision tree model for the initial data, and then completes additional models to correct the errors made in the previous step. At each step, the new model is adjusted to the negative gradient of the loss function relative to the predictions of the model built in the previous step. The final model is constructed as a weighted sum of all constructed models (Nasteski, 2017).

When obtaining high-quality models during initial and cross-validation, the third stage is implemented – the final verification. At this stage of the methodological approach, depending on the classification results, forecasting models can be built for all agricultural organizations as a whole, without taking into account the taxation regime, or separately for each regime. At the same time, decision tree, random forest, and gradient boosting models are also used for forecasting, but as regression tasks. The forecast value may vary depending on the indicators that have been preserved as a result of data preprocessing. In general, the methodology is universal and suitable for almost any sample of organizations, since the models do not depend on the number of factors, as well as on the dimension of the features.

The following indicators were used at all stages of the methodology for substantiating the approach to building the architecture of the tax incentive system at the macro level *(Tab. 2)*.

Table 2. Substantiation of the indicators used in the methodology

Group	Name	Feature	Tax aspect of influence
Work experience	Average age, years	From the moment of registration	Characterizes the attractiveness of the tax regime for newly established companies
Size indicators	Authorized capital	Line 1310 of the balance sheet (BS)	Allows assessштп the attractiveness and demand for tax regimes by entities of different sizes, taking into account their investment potential (long-term financial investments), activity in the innovation process (intangible assets) and expenditures on human capital (labor remuneration)
	Intangible assets	Line 1130 BS	
	Fixed assets	Line 1150 BS	
	Long-term financial investments	Line 1170 BS	
	Total assets	Line 1600 BS	
	Labor remuneration	Line 4122 of the Cash Flow Statement	
Financial risk indicators	Due diligence index (DDI)	Multidimensional average. Characterizes the level of "reliability" for counterparties. A value above 40 may indicate signs of a "technical company"	Characterizes the level of tax risk in interaction with agricultural organizations. The lower the DDI, the higher is the companies' potential for effective sales of products
	Financial risk index (FRI)	Multidimensional average. Indicates the presence of signs of unsatisfactory financial condition. Optimal value: not higher than 30	Positive impact of taxes on the financial performance of companies will be manifested in a decrease in the FRI
	Share of working capital in the company's assets	(Current assets – Current liabilities) / Total assets	Characterizes the source of working capital utilization. Positive impact of taxes should increase the share through the provision of tax incentives
Financial situation indicators	Autonomy ratio	Equity / Assets total. Must exceed 0.5	Positive impact of taxes on the financial performance of companies will be manifested in the achievement of normative values by these ratios
	Equity maneuverability ratio	Own working capital / Equity capital. The norm is from 0.2 to 0.5	
	Own current assets provision ratio	(Equity – Non-current assets) / Current assets. The norm is from 0.1 and more. Optimal value is more than 0.5	
Profit withdrawal indicators	Share of profits withdrawn in the form of tax	Ratio of net profit to profit before taxation	Characterizes the effective tax rate on the financial performance of agricultural organizations

Source: own compilation.

This methodological approach is implemented using Python programming language with Anaconda distribution in Jupyter Lab environment. The following packages are used to download and analyze data: numpy, pandas, seaborn, matplotlib, and sklearn. It is worth noting that due to long-term cyclical fluctuations in the agricultural sector (Gaisin, 2019), the implementation of the methodology should be repeated with a frequency that corresponds to the average cycle length. This fact increases the practical value of the approach.

At the micro level, a qualitative analysis of the rules and regulations of taxation in the industry was carried out in order to identify systemic deficiencies in the tax incentives of the industry that affect the choice of the tax regime by specific producers.

Research results

Substantiation of the architecture of the agricultural tax incentive system at the macro level

1. The results of the initial verification – typological grouping. The set of organizations in question is represented by special tax regimes (GTS, SAT, STS and ASTS), as well as a group of 187 organizations that pay both STS and SAT at the same time (that is, during the analyzed period, they either switched from STS to SAT, or vice versa; *Tab. 3*). All groups, except for STS, are sufficient for interpretation of the results.

The results of the grouping indicate that it is not possible to identify the most attractive regime for new agricultural organizations (the differences between this indicator by group are insignificant). At the same time, the "oldest" organizations use SAT. There is a clear relationship between the size of organizations and the applicable taxation regime. The largest agricultural organizations are based on the general taxation system, while special tax regimes are used by smaller companies. Special attention should be paid to the fact that the indicators of long-term financial investments are 2.8 times higher in the case of GTS than in the case of SAT, and 88 times higher than in the case of STS. The differences in available intangible assets are even more significant. This characterizes the higher potential for innovation and investment activity of large agricultural producers and the need to expand investment benefits when using SAT.

Table 3. Comparative characteristics of indicators of agricultural organizations applying different taxation regimes

Indicators on average per 1 organization	Taxation regime					Sum (average)
	General regime	SAT	STS	STS+ SAT	ASTS	
Number of organizations	9690	7748	9863	187	2	27490
Average age, years	12.9	16.9	13.2	14.4	12.3	14.2
DDI	17.0	10.0	27.7	25.0	13.5	18.9
FRI	50.6	40.4	51.5	53.4	22.0	48.0
Authorized capital, thousand rubles	45099	19429	1351	1667	105	21869
Intangible assets, thousand rubles	113912	2723	24	29	0	40929
Fixed assets, thousand rubles	313499	171051	7028	17196	0	161355
Long-term financial investments, thousand rubles.	53468	18819	607	851	0	24374
Total assets, thousand rubles	900595	374515	24542	43387	2359	432109
Ratio of net profit to profit before taxation	0.96	0.97	0.84	0.92	0.87	0.96
Labor remuneration, thousand rubles	42067	22692	471	1515	0	21403
Share of working capital in the company's assets, %	-1.2	-0.7	-9.5	-0.4	1.0	-4.0
Autonomy ratio, %	-6.4	-0.6	-26.8	-0.4	0.5	-12.1
Equity maneuverability ratio, %	-8.8	-3.1	-3.5	-1.2	1.0	-5.2
Own current assets provision ratio, %	-23.1	-6.7	-40.8	-7.4	0.5	-24.7
Compiled according to: SPARK data.						

Agricultural organizations have a low level of commercial risk, that is, they carry out real activities, are not "technical companies", and therefore can act as reliable counterparties in commercial transactions, which reduces business tax risks. At the same time, SAT payers are characterized by the lowest index of due diligence, a similar situation may result from the production nature of the activities of agricultural organizations. The industry as a whole is characterized by a high level of financial risk, which is reduced with the use of SAT, which positively affects the financial condition of companies (from 50.6 to 40.4 points). Despite the fact that the financial condition indicators are significantly lower than the regulatory values and characterize the low financial stability of the agricultural sector, when using the industry-specific SAT and benefits for GTA, the coefficients studied are higher than when using STS. It is important to note that the highest risk of insolvency was identified in those organizations that switched from STS to SAT, and vice versa (5.3% higher than the average), which may be, among other things, the reason for the change in the tax regime. Tax regimes have a positive effect on own sources of financing for current assets (the share of working capital, despite its negative value, is higher in the case of GTS and SAT than in the case of the non-industry regime of STS). Of particular importance in the context of the effect of tax regimes is the ratio of net profit to profit before taxation, which characterizes the share of tax deductions on financial results. The highest tax deduction is typical for STS (16%) and ASTS (13%), while only 4% of the profit is gained under GTS, and 3% under SAT. Due to the fact that the dependencies were most clearly manifested when using three regimes (GTS, SAT and STS), for further analysis it is advisable to consider only the organizations that use these regimes.

2. The results of the cross-validation – classification of agricultural organizations. In order to assess the differences in the activities of organizations depending on taxation regimes, we use machine learning algorithms that allow us to classify agricultural organizations based on indicators and determine the tax regime they apply. Moreover, machine learning methods are devoid of the disadvantages that were identified in the literature review and are inherent in other methods and approaches. The tax regime will be considered as an effective (predictive) feature. The obtained models are characterized by accuracy indicators and the F1 metric. Accuracy characterizes the number of correctly classified organizations in the total number. The F1 metric is a balanced metric that takes into account both the accuracy of the model as a whole and the classification quality of individual classes. The models were built on a training sample, and quality control was carried out on a test (model with training). To build the models, an algorithm for selecting optimal parameters was initially implemented using GridSearchCV function. The results of the algorithms are presented in *Table 4*.

According to the results, the distribution of agricultural organizations by estimated tax regime gives the highest accuracy when using gradient boosting: this model correctly classifies 73.6% of all

Table 4. Assessing the quality of classification models

Classification model	Accuracy, %	F1 metrics, %
Decision tree model	69.2	69.1
Random forest model	65.8	64.8
Gradient boosting model	73.6	73.4
Source: own compilation.		

agricultural organizations by tax regime. At the same time, the share of organizations named correctly by the classifier (precision) is 77% for GTS, 72% for SAT, and 73% for STS. The F1 metric of this model also turned out to be the highest of the reviewed ones (73.4%). The accuracy of other models is quite high; this is why to assess the contribution of individual factors, the feature_importances metric was evaluated *(Tab. 5)*. Using the feature_importances function, estimates of the degree of influence of individual factors on classification results for three models (DT, RF, GB) were obtained. The metric data were also summarized by group.

We can conclude that the size indicators have the greatest impact on the classification results (0.48–0.49). The impact of financial risk indicators (0.21–0.22) and financial condition (0.14–0.17) is also significant, i.e. the choice of taxation regime depends on the financial stability of organizations. The work experience indicator has the least impact on the classification, which is justified by the previously obtained conclusion that there is no priority in choosing a regime for a newly opening business.

Thus, we can note that the cross-examination showed the existence of a relationship between the taxation regime and the performance of agricultural organizations. The presence of such a dependence made it advisable to build a forecasting model for each taxation regime separately at the third final stage.

3. The results of the final assessment – forecasting the profit of agricultural organizations. The expediency of applying the third stage of verification is due to the fact that with a really significant impact of the tax regime on the activities

Table 5. Feature_importances metric for selected groups of indicators

Name	Decision tree		Random forest		Gradient boosting	
	I	S	I	S	I	S
Work experience						
Average age, years	0.05	0.05	0.06	0.06	0.05	0.05
Size indicators						
Authorized capital	0.15	0.48	0.11	0.48	0.10	0.49
Intangible assets	0.11		0.11		0.09	
Fixed assets	0.03		0.04		0.05	
Long-term financial investments	0.08		0.09		0.12	
Assets, total	0.09		0.10		0.10	
Labor remuneration	0.02		0.03		0.03	
Financial risk indicators						
Due diligence index (DDI)	0.09	0.22	0.09	0.22	0.08	0.21
Financial risk index (FRI)	0.07		0.07		0.08	
Share of working capital in the company's assets	0.06		0.06		0.05	
Financial situation indicators						
Autonomy ratio	0.03	0.17	0.01	0.14	0.03	0.17
Equity maneuverability ratio	0.08		0.07		0.08	
Own current assets provision ratio	0.06		0.06		0.06	
Profit withdrawal indicators						
Share of profits withdrawn in the form of tax	0.08	0.08	0.10	0.10	0.08	0.08

Note: I – individual metrics, S – summation of metrics by group.
Source: own compilation.

of producers within each typical group (according to the tax regime applied), stable dependencies will appear between indicators that can be verified during the construction of the forecast model. The net profit indicator was chosen as a forecast value for agricultural organizations. The average age of the organization is identified as the factors of the model; DDI; FRI; balance sheet indicators of organizations; labor costs; coefficients of autonomy, maneuverability of own funds, provision of own working capital. The rationale for their use is presented in Table 2 above. The models were evaluated by the coefficient of determination and the average error. For comparative characteristics, a forecasting model was built for all agricultural organizations that does not take into account taxation regimes *(Tab. 6)*.

The gradient boosting model showed the highest quality for agricultural organizations that use SAT. Thus, the coefficient of determination was 93.9%, i.e. only 6.1% of the variation in net profit is explained by factors that were not taken into account in the model. To assess the stability of the constructed model, a quality assessment was carried out on independent samples (cross-validation): the coefficient of determination in the samples varies from 91.3 to 94.1%. The gradient boosting model also showed the best forecasting results for organizations that use GTS. The coefficient of determination indicates that 89.2% of the variation in net profit can be explained by the influence of the factors included in the model. The cross-validation showed that the coefficient of determination varies from 89.1 to 91.2%. Thus, the quality of the constructed models based on GTS and SAT can be considered high, and the model is suitable for forecasting.

The quality of forecasting models for organizations using STS is significantly lower than for other groups. The coefficient of determination is 72.7%. At the same time, a fairly high average error was detected relative to the average (81.5–131%). According to the results of the cross-validation, the coefficient of determination varies from 65.6

Table 6. Assessing the quality of regression models by taxation regime

Regression model	Coefficient of determination, % (R^2)	Mean average error (MAE)	Ratio of mean error to population average, %
GTS			
Decision tree model	84.7	2606719.2	31.2
Random forest model	84.2	2853516.9	34.1
Gradient boosting model	89.2	1879786.4	22.5
SAT			
Decision tree model	68.8	4040237.4	47.3
Random forest model	86.2	2750397.8	32.2
Gradient boosting model	93.9	1436465.5	16.8
STS			
Decision tree model	37.4	2702984.7	131.0
Random forest model	62.9	2064956.3	100.1
Gradient boosting model	72.7	1682536.9	81.5
Total for all tax regimes			
Decision tree model	54.7	4394838.9	71.2
Random forest model	82.9	2566435.8	41.6
Gradient boosting model	88.8	1741364.8	28.2
Compiled according to: SPARK data.			

to 74.3%, which is a significant variation. The quality of the model for STS and in general, without taking into account special modes, is significantly lower than for GTS and SAT. This may be due to the fact that, as a rule, agricultural organizations that are engaged in other types of activities make the choice in favor of STS; therefore, this group is more characterized by the heterogeneity of its constituent entities. Thus, the lower quality of the profit forecasting model without taking into account the tax regime factor indicates the importance of the latter in the formation of performance indicators of agricultural organizations.

Let us formulate a general conclusion based on the results of the study at the macro level. We show the effectiveness of GTS and SAT applied by agricultural producers, which is characterized by a high positive degree of influence of tax regimes on the performance of agricultural enterprises. The simplified taxation system, despite the fact that it is widely used in the industry, has shown a low impact on the financial results of the industry. This circumstance justifies the inexpediency of further refining the simplified taxation system at the micro level in order to apply it to agricultural producers. Thus, in modern Russian realities, it seems appropriate to have a differentiated architecture of the agricultural tax incentive system, including industry-specific benefits for agricultural subsidies and a special tax regime for agricultural subsidies.

Designing proposals for improving the system of tax incentives for agriculture to increase its effectiveness at the micro level

Further adjustment of tax measures should be a consequence of the result of the analysis conducted at the macro level.

The study showed that organizations using SAT have a lower innovation and investment potential than companies based on GTS. This is largely due to the fact that the list of expenses that can be taken into account when applying a special tax regime is closed. This has a negative impact on the investment attractiveness of the industry. Thus, the first direction should include expansion of the closed list of expenses for SAT, which in the current economic conditions are necessary for agricultural producers. Three groups of expenses can be as follows:

1) for current activities: for participation in fairs and exhibitions of animals, for the delivery of finished products to the buyer, services under the tolling agreement, the cost of own-made products that are used as feed or seeds;

2) investment: expenses for the repair and maintenance of fixed assets for non-production purposes (not taken into account on the basis of the letter of the Ministry of Finance 03-11-06/2/32263, dated August 9, 2013), improvement costs (not taken into account on the basis of the letter of the Ministry of Finance 03-11-04/1/3, dated January 25, 2006, but there is a controversial judicial practice), household waste disposal costs;

3) innovative: payment for the use of the right to selection achievements (not taken into account on the basis of the letter of the Ministry of Finance 03-11-04/1/21, dated September 7, 2007).

It has been shown that SAT has a more significant impact on improving the financial condition indicators (coefficients of autonomy, maneuverability of own funds, provision of own working capital) of agricultural organizations than SAT, in particular due to the fact that SAT takes into account the seasonality and duration of agricultural production (the tax is calculated and paid once every six months). At the same time, there is no such mechanism when using GTS. In this regard, it is proposed to establish a special procedure for accounting for financial results under GTS by types of agricultural production with a long cycle. Today, tax legislation provides for the possibility of special accounting for corporate income tax expenses and the procedure for paying VAT on the production of goods defined by the list of the Government

of the Russian Federation[3]. In particular, when taxable profits are generated under contracts with a long production cycle (over 6 months), profits are distributed either evenly or proportionally to expenses during the term of such contracts. In other words, the payment of tax obligations is carried out gradually. In the case of VAT calculation for such transactions, VAT on advances is not paid, and the tax base is determined on the last day of each tax period in which the sale was actually carried out (letter of the Ministry of Finance of the Russian Federation 03-07-14/23424, dated March 31, 2021). However, not a single type of agricultural product is included in the list under consideration, while it takes several years to raise cattle for meat or certain types of fur-bearing animals. In this regard, it is advisable to supplement the specified list with certain types of agricultural products with long (more than 1 year) production periods.

A study at the macro level has proved the low efficiency of STS when it is applied by agricultural producers; therefore, it is necessary to finalize the rules for the transition to the payment of SAT from other tax regimes. Currently, companies that use SAT cannot account for the costs of manufacturing finished products that were produced under the previous tax regime but not sold. They are not included in the closed list under Paragraph 2 of Article 346.5 of the Tax Code of the Russian Federation. Taking into account that these expenses are actually incurred and aimed at generating income, it seems advisable to allow their accounting at the time of sale of such products.

Table 3 shows that SAT is mainly used by midsize and small agricultural enterprises. While most of them do not pay VAT, and in the current conditions, this exemption is becoming the most important factor in choosing a special tax regime. Today, organizations with a certain amount of revenue and applying SAT are exempt from paying VAT. This amount of revenue is 60 million rubles. Per year, it has not changed since 2022; however, given the high rate of inflation, in 5–7 years most of SAT payers will be recognized as VAT payers, which, under other conditions comparable to those under GTS, may offset the positive effect of applying a special tax regime. In this regard, it is advisable to establish an indexation of the maximum amount of revenue, exceeding which a SAT payer automatically becomes a VAT payer. It is also important to note that since 2025, the simplified taxation system has been significantly transformed, the subjects of which became VAT payers upon reaching the revenue threshold (exceeding 60 million rubles per year). At the same time, organizations that use STS have the right to choose the option of calculating VAT: at standard tax rates (10 or 20%) with tax deductions or at preferential tax rates (5 or 7%) without tax deductions. In order to equalize the conditions of special tax regimes, it is advisable to establish the possibility of applying preferential VAT rates for SAT payers, which will partially offset the lack of indexation of the revenue threshold.

Discussion

The results obtained that show the effectiveness of fiscal support generally correlate with a significant number of studies in the field of agricultural taxation; and the discrepancies with the works analyzed above (Kataev, Sasina, 2011) are largely due to a significant time gap in the research periods. Over the past 5–7 years, both the single agricultural tax and other taxation regimes have undergone fundamental changes.

A methodological approach that formed the evidence base on the need for further improvement of agricultural taxation can be subject of discussion.

[3] List of goods (works, services), the duration of the production cycle of which is more than 6 months. Ministry of Finance. Available at: https://www.garant.ru/products/ipo/prime/doc/70017236/

Forecasting methods based on artificial intelligence are widely used both for analyzing agricultural indicators (Khudyakova et al., 2021; Demichev, 2022; Zinchenko et al., 2022) and for predicting financial performance of organizations (Lomakin et al., 2020a; Lomakin et al., 2020b). The limitation of our study is that organizations were included in the analyzed sample based on the OKVED code; however, belonging to the corresponding code does not mean that the company has only an agricultural activity profile, which may affect the results.

The constructed net profit forecasting models can be adapted to the construction of tax burden forecasting models if this information is available in the purified sample. Forecasting the tax burden of organizations helps to identify factors affecting performance indicators, as well as to monitor them by comparing them with industry averages in order to identify discrepancies and conduct tax audits (Mandroshchenko, 2023). The possible ways of tax planning in organizations also depend on the level of tax burden (Nazarova, Kozharinov, 2019). Knowing the estimated tax burden makes it possible to more accurately assess the financial condition of an enterprise, calculate cost-effectiveness, predict profitability, and make substantiated investment decisions (Kelley, 2024).

Conclusion

Within the framework of the paper, a methodology has been developed to assess the impact of the agricultural producers' tax regime, which includes three research stages (preliminary, cross-cutting and final), based on the use of machine learning models and making it possible to substantiate the architecture of the industry's tax incentive system. The approbation of this methodology has shown that the financial results of agricultural organizations largely depend on the applicable taxation regime. At the same time, the main influence was exerted by GTS and SAT, which formed the basis of the proposed architecture.

The presence of significant effects of tax factors at the macro level has justified the expediency of further improving fiscal support measures for the agricultural sector at the micro level, among which the following are proposed:

– expanding the closed list of expenses when applying SAT (with detailed proposals);

– establishing a special procedure for accounting for financial results and calculating VAT for long-term production of agricultural products;

– changing the accounting procedure for the production of agricultural products during the transition to SAT;

– changing the mechanism for calculating VAT when applying the preferential tax regime of SAT.

In general, the implementation of these proposals to improve tax incentives for agricultural organizations is of great importance for the development of the industry, as well as for addressing global issues related to food security and sustainable development. Practical significance of the study lies in the possibility of applying the proposed methodological approach to assessing the impact of taxes on the activities of agricultural organizations following the completion of each agricultural cycle, as well as in using practice-oriented proposals to improve the taxation rules of the industry.

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