Technological re-equipment of agricultural enterprises in Russia

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Abstract. The factors affecting the procurement of equipment in agricultural organizations in Russia are analyzed. They are tested for multicollinearity. The multiple correlation method allowed us to establish relationships between variables. As a result, regression equations with a sufficiently high coefficient of determination are formulated. The obtained dependencies can be used to predict the amount of procurement of equipment at the level of entities and at the federal level in the Russian Federation.

1. Introduction

Prediction of amount of the procurement of agricultural machinery at the regional and federal levels is of particular importance for the country's agrarian policy.

Agricultural activities in the Russian Federation are carried out by large and medium agricultural organizations, small business, peasant (farmer) economy, individual entrepreneurs, and subsidiary farming.

All-Russian agricultural censuses of 2006 and 2016 provide information of and make it possible to trace the dynamics of the availability of machinery in all categories of farms: 54% tractors of the total were in personal subsidiary plots and other individual farms of citizens in 2016 there were (37% in 2006) (table 1).

The Federal State Statistics Service of the Russian Federation (Rosstat) systematically monitors the availability of equipment in agricultural organizations. There were 206,700 tractors, 55,000 grain harvesters, 11,8 forage harvesters in the agricultural enterprises in 2019., the number of tractors decreased by 2%, the number of grain harvesters decreased by 3%, and the number of forage harvesters decreased by 4% in 2019 as compared to 2018.

According to the Strategy for the Development of Agricultural Engineering for the Period until 2020, for effective agricultural production, the tractor fleet should be about 610,000 units and the fleet of grain and forage harvesters should be 147,000 units [2].

According to the Ministry of Agriculture of Russia, in order to move on to increasing the fleet of agricultural machinery and to achieve the estimated provision in the near future, agricultural organizations need to annually purchase 45,000 tractors, 12,000 grain harvesters and 2,000 forage harvesters. The actual purchase size is less (table 2).
Table 1. Availability of agricultural machinery in various categories of farms in Russia.

| Farm categories | Tractors 2006 | Tractors 2016 | Tractor mowers 2006 | Tractor mowers 2016 | Tractor plows 2006 | Tractor plows 2016 | Combine harvesters 2006 | Combine harvesters 2016 |
|-----------------|---------------|---------------|---------------------|---------------------|-------------------|-------------------|------------------------|------------------------|
|                 | Unit % of total | Unit % of total | Unit % of total | Unit % of total | Unit % of total | Unit % of total | Unit % of total | Unit % of total |
| Agricultural organizations, total | 530,808 | 49,222 | 205,846 | 28,367 | 60,834 | 28,367 | 38,731 | 45,166 |
| Including: | | | | | | | | |
| Large and medium agricultural organizations | 437,752 | 40,521 | 133,679 | 15,428 | 49,434 | 18,927 | 17,807 | 21,341 |
| Small business | | 7,341 | 12,283,327 | 15,444 | 9,144 | 22,274 | 16,971 | 34,392 |
| Subsidiary farming of non-agricultural organizations | | | 13,440 | 12,041 | 2,256 | 2,256 | 6,488 | 35,971 |
| Peasant (farmer) economy and individual entrepreneurs | | 158,827 | 190,486 | 27,375 | 27,375 | 6,868 | 21,821 | 21,821 |
| Personal subsidiary plots and other citizen personal farming | | 41,863 | 555,200 | 133,665 | 133,665 | 22,860 | 35,820 | 35,820 |
| Total | 1,101,512 | 1,040,732 | 1,040,732 | 1,040,732 | 1,040,732 | 1,040,732 | 1,040,732 | 1,040,732 |

Source: Calculated by the authors based on the data of the All-Russian agricultural censuses of 2006 and 2016 [1].
Table 2. Equipment to be purchased by agricultural producers in Russia.

| Equipment type       | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | 2013-2019 |
|----------------------|-------|-------|-------|-------|-------|-------|-------|-----------|
| Tractors             | 15.265| 14.120| 10.832| 11.287| 11.035| 10.472| 10.714| 83.725    |
| Grain harvesters     | 5.502 | 5.336 | 5.375 | 6.193 | 6.221 | 5.221 | 4.627 | 38.475    |
| Forage harvesters    | 824   | 835   | 670   | 718   | 694   | 650   | 624   | 5015      |

Source: compiled by the authors based on National Progress Reports on the progress and results of the implementation of the State Program for the Development of Agriculture and Regulation of Agricultural Products, Raw Materials and Food Markets for 2013-2019.

Among the most important factors affecting the volume of equipment purchased, the following is distinguished: area and yield of cultivated crops; amount of own funds (revenue, profit, depreciation); the possibility of obtaining borrowed funds, state support, etc. [3-5].

Various assessments are made of the amount of cash needed to upgrade our country's machinery fleet: at least 150 billion rubles annually [6], 500 billion rubles in all (including for the purchase of 56,000 tractors in the amount of 330 billion rubles, 16,000 forage harvesters in the amount of 135 billion rubles, and 2,400 grain harvesters in the amount of 10 billion rubles) [7].

The purpose of the research is to study the possibility of using multiple correlation to predict the procurement of agricultural machinery at the regional and federal levels.

2. Materials and research methods
This study used the statistical method, namely, multiple correlation method, and the expert method. Factors affecting the procurement of machines are selected by experts taking into account experience, analysis of the factors used in previous studies and the possibility of finding numerical values of factors.

In the absence or small amount of state support, the renewal of the equipment fleet becomes possible and directly depends on the amount of net profit received (which, in turn, depends on the volume of sales of products and other factors), borrowing, the pricing policy of agricultural machinery enterprises, and the market conditions for agricultural products [8]. Profitability index is a criterion by which the success of an organization is evaluated [9]. Features of agriculture are lower profitability in comparison with other sectors and, accordingly, attractiveness for external investors [10]. According to the data of the Federal State Budgetary Scientific Institution “Federal Research Center of Agrarian Economy and Social Development of Rural Areas – All-Russian Research Institute of Agricultural Economics” (FSBSIFRC AESDRA VNIIESH), purchasing power becomes a real production parameter with a profitability of at least 20 %. Agricultural enterprises are not able to fully update the machinery fleet, as the profitability is by 5-12 % lower than the level specified [11].

V M Korotchenya estimated technical efficiency of the use of agricultural resources using a model (in which the amount of agricultural products and resources, i.e. agricultural land, economically active population in the field of agriculture, agricultural machinery and equipment, livestock, poultry, fertilizers, etc., were assumed as an output). The Data Envelopment Analysis (DEA), a nonparametric method based on linear programming, was used. The essence of the DEA method is to evaluate the effectiveness of homogeneous decision-making units due to building of the common border of production capabilities based on real data (amount of resources and types of output). A version of the DEA model, the so-called CCR-I model, a DEA radial model with constant returns to scale and resource orientation, was used [12].

K Hill, among the factors that should be considered before procuring agricultural machinery, calls the compliance of a machine with process steps to be used by the agricultural producer, the potential amount of funds that the farmer can allocate for the procurement, local rules for registering and using
the machine, price-quality ratio of the machine, and options for procuring a new or a supported
machine (as an alternative to a new one) [13].

C A Bisschoff refers merchantability, serviceability, pre-order planning, after-sales service,
ergonomics, ease of use, cost of credit and potential savings to the factors affecting the buying
behavior of South African farmers with regard to new agricultural tractors.

A L Kehinde, when studying tractor rental in Nigeria, included area of cultivated land, crop yields,
membership in the ruling party to number of factors determining the use of a tractor [14].

Li Wei investigated the impact of the following factors on the agricultural equipment level (AEL),
agricultural mechanization level (AEM) in China: level of economic development; land resource
endowment, demographic factors; policy environmental factors; benefit factors. Each of the factors
included several indicators (Table 3).

**Table 3.** Factors and indicators affecting the level of agricultural machinery and the level of
mechanization of agriculture.

| Factor                                | Indicators (measurable variables)                  | Variable codes |
|---------------------------------------|---------------------------------------------------|----------------|
| Level of economic development (ECON) | GDP per capita                                    | AGDP           |
|                                       | Farmers’ net income per capita                    | INCO           |
|                                       | Primary industry GDP / regional GDP               | FODP           |
| Land resources (LAND)                 | Sown area per employee                            | CULT           |
|                                       | Hilly and mountainous area / agricultural land area | HILL          |
|                                       | Sown area of wheat / total sown area of crops     | WHEA           |
| Demographic factor (DEMO)             | Number of agricultural workers / rural population | FEMP           |
|                                       | Labor movement                                    | TLAB           |
|                                       | Rural level of education / year                   | EDUC           |
| Political and environmental factors (POEN) | Average amount of subsidies per unit area of agricultural land | SUBS |
|                                       | Number of workers associated with the use of agricultural machinery per 10,000 workers | TEMP |
|                                       | Agricultural machinery price index                | PRIC           |
| Benefit factors (BENE)                | Cost of agricultural products per employee        | OUTV           |
|                                       | Grain production per employee                     | YIEL           |
| Agricultural machinery level (AEL)    | Total capacity of agricultural machinery          | POWE           |
|                                       | Initial cost of agricultural machinery            | VALU           |
|                                       | Total tractor power                                | TRAC           |
| Agricultural mechanization level (AML) | Plow mechanization level                           | MCUL           |
|                                       | Sowing mechanization level                         | MSOW           |
|                                       | Harvest mechanization level                        | MHAR           |

Source: Li Wei, 2018.

The results of research (analysis) have showed that the level of economic development has the
greatest impact on the level of mechanization. Demographic factors and benefit factors affect the level
of mechanization not only directly but also indirectly through the level of economic development.
Land resources, political and environmental factors have only an indirect effect on the level of
economic development [15].
In Bangladesh, relatively few farms invest in their own agricultural machinery. A large number of smallholder farmers gain access to agricultural machinery services through special employment agreements. A M Khondoker researched agricultural mechanization in Bangladesh and factors influencing the acquisition of machinery. The results of the study showed that ownership of machinery is positively associated with household assets, availability of loans, electrification and road density [16].

In this study, the source of the procurement of equipment is the results achieved in the previous year; targets (dependent variables) are taken for the \( j \)-th year; factors (independent variables) are taken for the previous \((j-1)\) year. Thus, the initial data for the study are as follows.

- Units and planning period: constituent entity of the Russian Federation, year.
- Targets (dependent variables):
  - \( y_1 \) is a number of tractors purchased in the \( i \)-th constituent entity of the Russian Federation for the \( j \)-th year (for the years 2013-2017, they are taken from the relevant issues of the National report on the progress and results of the implementation of the State program for the development of agriculture and regulation of agricultural products, raw materials and food markets for 2013-2020), as well as information from the Ministry of Agriculture of the Russian Federation;
  - \( y_2 \) is a number of combine harvesters purchased in the \( i \)-th constituent entity of the Russian Federation for the \( j \)-th year;
  - \( y_3 \) is a number of forage harvesters purchased in the \( i \)-th constituent entity of the Russian Federation for the \( j \)-th year.
- Factors affecting the procurement of machines (independent variables) (taken from the collections “Agribusiness of Russia” for 2013-2017) [17-18]:
  - \( x_1 \) is agricultural production at farms of all categories at actual prices in the \((j-1)\)-th year, million rubles;
  - \( x_2 \) is investments in fixed assets aimed at the development of agriculture in the \((j-1)\)-th year, million rubles;
  - \( x_3 \) is availability of tractors (without tractors on which earthmoving, reclamation and other machines are mounted) in the \((j-1)\)-th year, units;
  - \( x_4 \) is availability of combine harvesters at the end of the year in the \((j-1)\)-th year, units;
  - \( x_5 \) is supply of plant protection agents in the \((i-1)\)-th year, metric tons;
  - \( x_6 \) is liming of acidic soils in the \((j-1)\) th year, thousand ha;
  - \( x_7 \) is soil phosphorization in the \((j-1)\) th year, thousand ha;
  - \( x_8 \) is the application of mineral fertilizers for crops in agricultural organizations \((j-1)\)-th year, thousand hundredweight in terms of active substance;
  - \( x_9 \) is the application of organic fertilizers for crops in agricultural organizations in the \((j-1)\)-th year, thousand metric tons;
  - \( x_{10} \) is an area of arable land used by enterprises, organizations and citizens in the \((j-1)\)-th year, thousand ha;
  - \( x_{11} \) is an area of forage land used by enterprises and citizens engaged in agriculture in the \((j-1)\)-th year, thousand ha;
  - \( x_{12} \) is a sown area of grain and leguminous crops in farms of all categories in the \((j-1)\)-th year, thousand ha;
  - \( x_{13} \) is gross harvest of grain and leguminous crops in farms of all categories in the \((j-1)\) th year, thousand tons;
  - \( x_{14} \) is a number of cattle in farms of all categories at the end of the year in the \((j-1)\)-th year, thousand heads;
  - \( x_{15} \) is a number of pigs in farms of all categories at the end of the year in the \((j-1)\)-th year, thousand heads;
  - \( x_{16} \) is a milk yield per cow in agricultural organizations in the \((j-1)\)-th year, kg;
$x_{18}$ is a pre-tax profit for all activities of agricultural organizations, including subsidies from the budgets in the $(j-1)$-th year, million rubles;

$x_{19}$ is budget subsidies attributable to the results of financial and economic activities of agricultural organizations in the $(j-1)$-th year, million rubles;

$x_{20}$ is a profitability level for all activities of agricultural organizations, including subsidies from budgets in the $(j-1)$-th year.

The factors were tested for multicollinearity. High multicollinearity leads to instability of estimates, which is expressed in an increase in statistical uncertainty, i.e. the variance of estimates (specific results of the assessment can vary greatly for different samples, despite the fact that the samples are homogeneous).

As a criterion of high dependence, it was accepted that the pair correlation coefficient is $r > 0.7$. The analysis showed that there was a high interdependence between some factors. These factors were excluded from the multiple regression equations. Also, some factors were excluded using the preliminary logical analysis, for example, factors $x_4$ (availability of combine harvesters at the end of the year in the $(j-1)$-th year, units), $x_5$ (availability of forage harvesters at the end of the year in $(j-1)$-th year, units), etc. The remaining factors were once again tested for multicollinearity.

### 3. Results

As a result, the following multiple regression equations were finally obtained:

$y_1 = f(x_1, x_3, x_6, x_7, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17}, x_{19})$, 

$y_2 = f(x_1, x_2, x_4, x_7, x_8, x_9, x_{10}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17}, x_{19}, x_{20})$, 

$y_3 = f(x_1, x_2, x_5, x_8, x_{12}, x_{17}, x_{20})$.

The multiple regression coefficients were calculated using the "Regression" tool of the Excel "Data Analysis" add-in (Table 4).

**Table 4. Coefficients of multiple correlation and determination between the procurement of tractors, grain and forage harvesters and factors.**

| Dependent variable | Independent variables | Multiple correlation coefficient [R] | Coefficient of determination [R^2] | Qualitative characteristic of communication tightness |
|--------------------|-----------------------|-------------------------------------|-----------------------------------|-----------------------------------------------------|
| $y_1$              | $x_1, x_3, x_6, x_7, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17}, x_{19}$ | 0.8273 | 0.6844 | High |
| $y_2$              | $x_1, x_2, x_4, x_7, x_8, x_9, x_{10}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17}, x_{19}, x_{20}$ | 0.8147 | 0.6638 | High |
| $y_3$              | $x_1, x_2, x_5, x_8, x_{12}, x_{17}, x_{20}$ | 0.4655 | 0.2167 | Low |

The obtained equations of multiple regression between the number of tractors, combine harvesters and selected factors have a high communication tightness, those for forage harvesters have a low communication tightness.

### 4. Conclusion

The obtained dependencies can be used to predict the volume of procurement of equipment at the level of constituent entities of the Russian Federation and at the federal level.

Identification of factors influencing decision-making on the willingness of agricultural organizations to procure this or that equipment is important for foreign and Russian agricultural engineering enterprises in developing their development strategies.
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