Agricultural Machinery Cluster Formation Model

under Import Substitution in Russia

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Abstract

The overall efficiency of Russia's agricultural machinery industry (AMI) was seriously undermined during the period of stagnation following the collapse of the Soviet Union. Western sanctions against Russia and counter-sanctions that began in 2014 revealed the problem of extremely high import dependence in the agrarian sector in general and AMI in particular, which led the Russian government to shift urgently to an import substitution policy based on innovative strategies.

This study first overviewed the current situation and identified both positive changes and immense problems remaining in the industry and stated that traditional strategies of industrial development could not provide the necessary solutions, given the need for quick improvements. Transition to the innovative path of the AMI development requires the acceleration of scientific and technical progress and the introduction of new technologies. The implementation of industrial clusters is an effective instrument for the development of an innovative economy.

The main objective of this study was to propose that the formation of a cluster in the Rostov region, where the most efficient AM manufacturers have been traditionally concentrated, would positively affect the domestic AMI in general and enhance the individual competitiveness of companies making up the cluster.

Through the manufacturers' actual performance analysis, this study demonstrated that the region was an appropriate location for the rational import substitution program realization. Using an AHP model, it determined the most pertinent participants for the potential cluster and proposed a model for cluster formation. The actual level of “innovative readiness” of AM companies in the Rostov region and their potential profitability in the cluster compared with individual profitability was estimated using economic and

mathematical modeling tools.

Based on the calculations, it was concluded that functioning under the cluster was more economically efficient than functioning as independent enterprises for Rostselmash, Klever, and Salskselmash companies. The study proved that the formation of the cluster, centered on the manufacturer Rostselmash, would positively affect the productivity, innovation activity and development of all enterprises comprising the cluster.

The development of its domestic AMI would allow Russia to conduct an independent policy of import substitution for food products, machinery, and equipment, and contribute to the food security of the country.

Chapter 1 Introduction

Limited natural resources and environmental degradation make it crucial to ensure access to safe, high-quality food in sufficient quantities in all countries of the world, including Russia.

Russia is one of the largest grain producing and processing regions in the world, and it possesses 20% of the world's supply of fertile land. According to the Food and Agriculture Organization of the United Nations, Russia could potentially feed two billion people. However, this potential has been limited by the post-Soviet Union period, which had adverse effects for many sectors of the Russian economy, particularly agriculture (Kalabekov, 2010). A declining share of agriculture in gross added value, a lack of investment and a decrease in the competitiveness of domestic food products resulted in the state being forced to import significant volumes of food from abroad. This situation seriously hindered development of the agro-industrial complex and posed a threat to the food security of Russia (Ministry of Industry and Trade of Russia, 2017).

The EU and US imposed sanctions on the Russian economy and Russia responded with counter-sanctions in 2014, resulting in a radical change in the geopolitical and economic conditions. This stimulated the Russian government to prioritize increasing the potential for import substitution in the real economy. In the anti-crisis plan adopted in January 2015, a "rational" import substitution policy was suggested, which involved promoting the development of companies that were already successfully operating as industry leaders on a countrywide scale (The Government of Russian Federation, 2015). A key direction for Russia's new economic policy of import substitution is to improve the competitiveness of domestic industry by stimulating innovative activity. The transition to this innovative path of development involves the acceleration of scientific and technical progress and the introduction of new technologies in the agriculture sector. However, Russian agriculture has struggled with deficiencies of basic material and technological obsolescence, which have hampered the application of innovative technologies (Sandu, 2010).

Various studies point out that implementation of industrial clusters is an effective instrument for the development of an innovative economy (Kiminami and Nakamura, 2016). An industrial cluster is a group of technologically interacting enterprises and nonproduction institutions that are closely located geographically and united to ensure their sustainable and effective development, on the basis of partnership and alignment of interests (Delgado et al., 2016; Feser et al., 2008; Ketels, 2013; Krugman, 1991; Porter, 2000).

Now there is a sufficient academic work on clusters, involving a theory, empirical analysis, and policy implications. Policies to develop industrial clusters have been adopted since the 1990s (Porter, 1998; Enright, 2000; Krugman, 1991; Ellison and Glaeser, 1997, Kiminami and Nakamura, 2016). Furuzawa and Kiminami (2011) stated that "if, say, three companies form a cluster through a business alliance, and each company simultaneously realizes process and product innovations, then their production costs will fall and their product quality will increase, as a result of spillover effects. If the entities making up the cluster are able to establish such win-win relationships, the competitiveness of the entire cluster would be improved, which would lead to a concurrent increase in consumer surplus" (Furuzawa and Kiminami, 2011).

In Russia, the principles for cluster policies are established in three documents, the Long-Term Development Concept 2030 (Ministry of Economic Development of Russia, 2013), the Innovative Development Strategy of Russia until 2020 and the Government Decision of July 31, 2015, No. 779 “On Industrial Clusters and Specialized Organizations of Industrial Clusters” (hereafter, the Decision). According to the Decision, cluster enterprises included in the register of industrial clusters established by the Ministry of Industry and Trade of Russia can apply for subsidies of up to 50% of costs, provided that joint cluster projects be implemented.

Despite such government support, to date, only one industrial cluster has been registered by the Ministry of Industry and Trade, the agricultural machinery (AM) cluster established on December 19, 2016, in the Altai region. Theoretical and empirical evidence of cluster formation under import substitution have been insufficient to promote greater cluster formation. Given the need for urgent action, we suggest that the formation of industrial clusters in other regions of Russia will accelerate import substitution.

Historically, AM production in Russia has been concentrated in the Rostov region. The situation in this region can be interpreted as representing a latent AM cluster. The enterprises produce heterogeneous products (although many small enterprises tend to work closely with a large customer, Rostselmash), but they face common problems and work in related markets, which are based on demand from the same consumers. The main AM producers in the Rostov region are Rostselmash, Millerovoselmash, Salskselmash, Kormmash, Klever, and Aksaikardandetal. The Azov-Black Sea Agro-engineering Academy and the North-Caucasian State Zonal Machine Testing Station in Zernograd could take the lead in organizing the scientific research core of the cluster. Universities of the region, such as Southern Federal University, Don State Technical University, and Don State Agrarian University, could provide the basis for fundamental research.

In this paper, I first provide an overview of the current situation and the various problems faced by the domestic agricultural machinery industry (AMI). Based on its actual performance, I assume that the Rostov region is an appropriate location for the rational import substitution program and suggest that the formation of a cluster in the region will positively affect the AMI in general and enhance the individual competitiveness of companies making up the cluster. Finally, I select and evaluate individual companies that are the potential participants of the proposed cluster.

Despite the availability of a variety of theoretical and practical research on the issue of cluster interaction in the literature hardly developed evaluation questions of synergistic efficiency. Thus, Kulagin and Kulagin noted: "there is no clear, uniform methodology for evaluating the effectiveness of integrated units" (Denisov, 2012).

The theoretical basis of assessing the feasibility of creating an AM cluster is based on synergistic effect. Hermann Haken founds synergetic at the end of the 1960s (Haken, 1983 a; Haken, 1983 b). The complete picture of the synergistic effect as a multi-faceted concept is revealed in the R. Mathews model, where the effect of the interaction of economic agents should exceed the total effects from their autonomous activity (outside the cluster) (Matthews, 2005).

Recognizing the research importance of these scientists for the theory and practice of the strategic development of Russian industry, the problems of the real potential of import substitution of industrial clusters in the region, arising in radically changed geopolitical and economic conditions, were little studied.

The theoretical, methodological and empirical importance of these problems, the practical importance of their solution in the new economic policy conditions of the country determined the choice of the research topic.

Chapter 2 Materials and Methods

2.1 Overview

Analysis of the current AMI situation is based on a substantial study of relevant documents, including government regulations, government programs related to the AMI and official statistics. Data from the Federal State Statistics Service, the agency ASM-Holding, which specializes in consulting and analytics in the AMI, and the Association of Agricultural Equipment Producers (Rosspecmash) were used. In addition, data published by the manufacturing companies themselves were accessed.

I examined the AMI companies in the Rostov region to substantiate the concept that the competitive potential of the AMI could be increased based on cluster formation under the rational import substitution policy. I propose an analytic hierarchy process (AHP) as a tool to select prospective participants of the cluster. After screening the accounting reports of all 12 AM manufacturers in the Rostov region, I rejected six on the basis of insufficient information or because their operations had ceased. I collected background information on the six remaining manufacturers operating in the region and then applied AHP to provide a targeted data synthesis and to hierarchically structure the results. Based on the results, I determined that three manufacturers were most suitable for involvement in the formation of a cluster and suggested the AM Cluster Model. Then, I assessed the feasibility of the AM cluster creation in the Rostov region, focusing on measuring its efficiency (or inefficiency) for potential participants using economic and mathematical modeling tools based on synergistic effect.

2.2 The Study Site

Rostov region is a federal subject of Russia, located in the Southern Federal District (Figure 1). The region has an area of 100,800 square kilometers and a population of 4,277,976 (Federal State Statistics Service, 2010), making it the sixth most populous federal subject in Russia. Its administrative center is the city of Rostov-on-Don, which also became the administrative center of the Southern Federal District in 2002. Rostov region borders Ukraine, Volgograd and Voronezh Oblasts in the north, Krasnodar and Stavropol Krais in the south, and the Republic of Kalmykia in the east.

The main producers of agricultural machinery in Rostov region are Rostselmash, Millerovoselmash, Salskselmash, Kormmash, Klever and Aksaikardandetal.

The innovation of cluster oriented to effective import substitution in industry is a necessary condition for their functioning. The Azov-Black Sea Agroengineering Academy and the North-Caucasian State Zonal Machine Testing Station in Zernograd can take the lead in organizing the research module of the cluster of agricultural machinery in the Rostov region, taking into account the accumulated scientific and innovative potential. The basis of the educational module, aimed at increasing innovation-oriented human resources of the cluster, can be the universities of the region, such as Southern Federal University, Don State Technical University and Don State Agrarian University.

Figure 1. Study Site

2.3 The Analytic Hierarchy Process (AHP)

The AHP is a method of measurement involving pairwise comparisons. It is one of the most widely used multiple-criteria decision-making tools (Saaty, 2007). AHP enables qualitative decisions to be made more objectively and it supports systematic decision-making by expressing the interaction and hierarchy of factors, thus reducing the danger of a rough estimation (Chen and Huang, 2004). Owing to these advantages, I adopted AHP to evaluate the AM manufacturers for the cluster formation under the import substitution policy. The information obtained was processed through a web-based AHP online system (AHP OS).

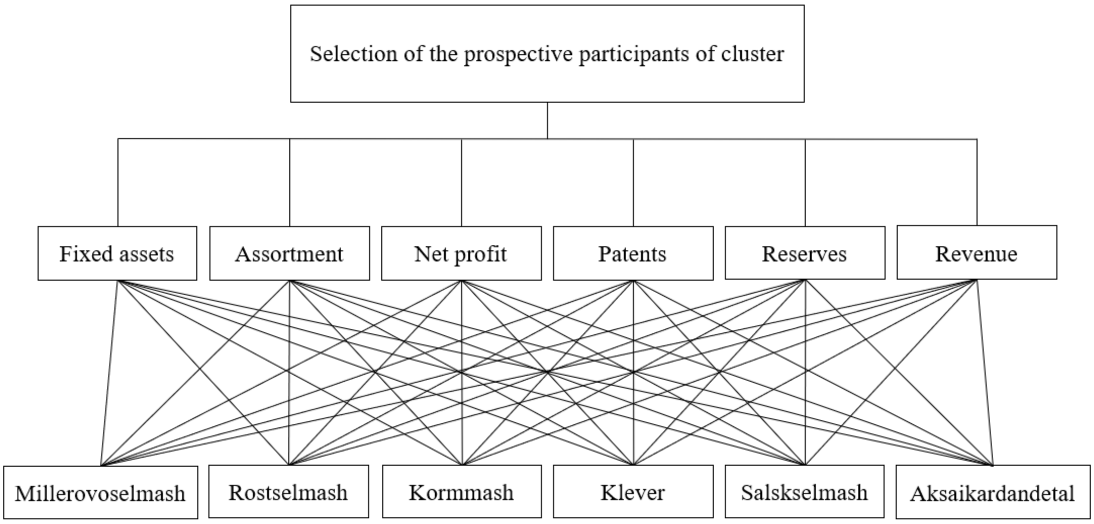

Figure 2. The AHP Model

AHP involves three steps: decomposition, comparative judgment and synthesis of priorities. The first step required the construction of a hierarchical network to present the problem, with the top level representing the overall objective, the middle representing the criteria and the lowest level representing the alternatives. Here, the objective was to evaluate which AM manufacturers would be best suited for the cluster formation under the import substitution policy. Therefore, the main objective, ‘‘selection of the prospective participants of cluster’’, was placed at the top level of the analytic hierarchy, as shown in Figure 2. The second step was to identify key evaluation criteria for assessing the objective. I adopted six key criteria, identified through a literature review and interviewing the experts, as follows: net profit, patents, assortment, fixed assets, revenue and reserves (Revsine et al., 1999; Mescon et al., 1998; Rodrigues and Rodrigues, 2018; Vimrova, 2015; Saraceni et al., 2015). Finally, six AM manufacturers were placed on the lowest level of the AHP model, representing the alternatives. These included Rostselmash, Millerovoselmash, Salskselmash, Kormmash, Klever and Aksaikardandetal.

The next step was to compare the factors at the same level in pairs and measure their comparative contribution to the main objective. A comparison matrix was set up to compare pairs of criteria or alternatives. A scale of values ranging from 1 (indifference) to 9 (extreme preference) was used for the preferences. This pairwise comparison allows the decision-maker to evaluate each factor's contribution to the objective independently, thereby simplifying the decision-making process. Here, the six alternatives were compared in pairs to measure their importance under each criterion. In the final step, a synthesis of priorities was conducted to calculate a composite weight for each alternative, based on the preferences derived from the comparison matrix. Following calculation of the composite weight, I obtained the relative priority of the AM manufacturers for inclusion in the cluster. The workflow is described in Figure 3.

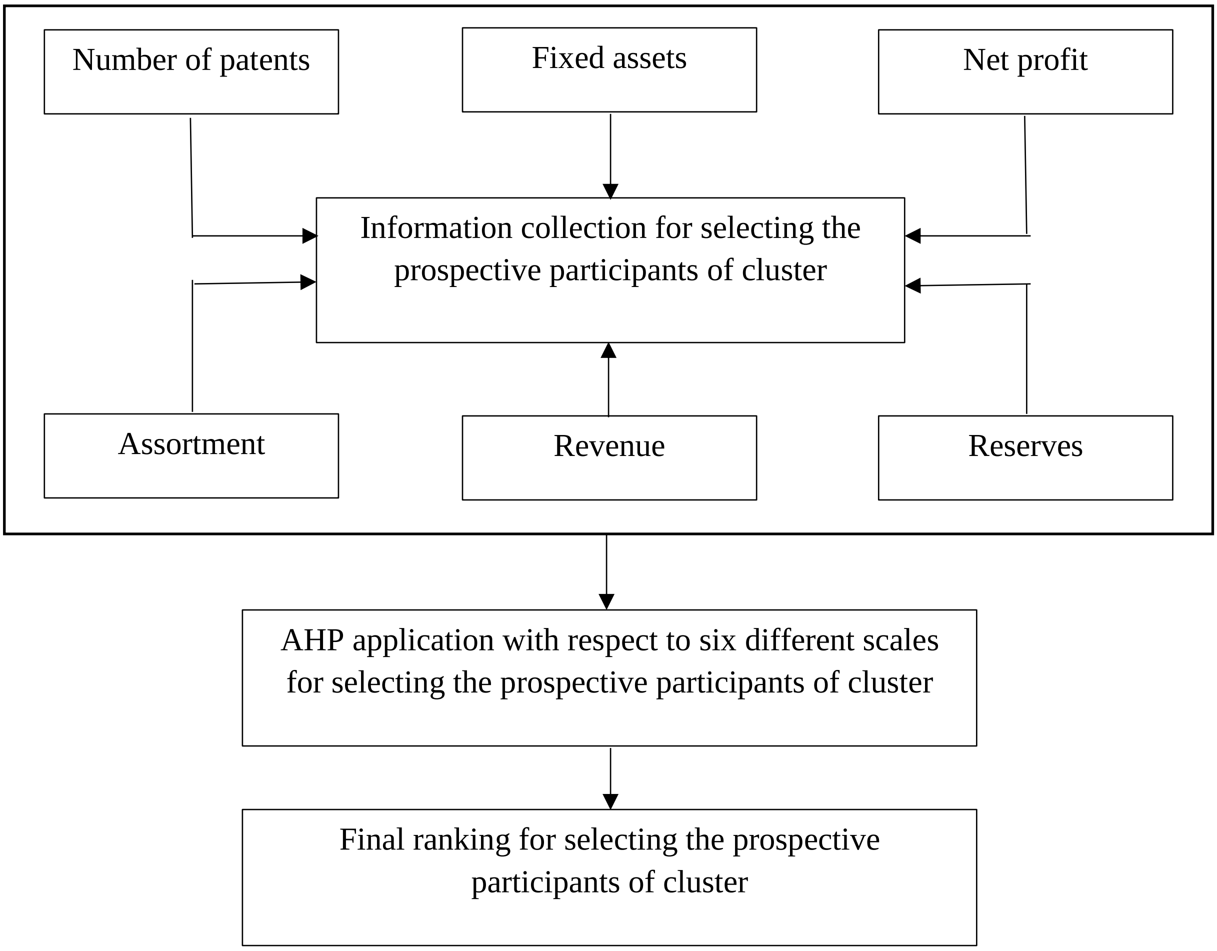

Figure 3. Methodological Steps in the Application of the AHP

2.4. The Synergistic Effect

Effect from the interaction of economic agents (cluster-forming activities) S should exceed the total effects of their autonomous activity $\sum_{i=1}^{m} Si$ (outside the cluster):

$$S > \sum_{i=1}^{m} Si = S_1 + S_2 + \ldots + S_m \quad (1)$$

A synergistic effect (S_k) is expressed by the difference:

$$S_k = S - \sum_{i=1}^{m} Si \quad (2)$$

There are three options:

1) $S_k > 0$ (positive synergetic effect; the larger the S_k value, the more productive functioning of the cluster is and the better the interaction of participants).

2) $S_k = 0$ (synergistic effect is zero, interaction loses its meaning).

3) $S_k < 0$ (negative synergistic effect, the interaction is not possible).

Chapter 3 Results and Discussion

3.1 Current state of AMI in Russia

Historically, Russian agricultural machinery industry developed in the agricultural regions where its products were used the most. For example, plants producing grain harvesting machines are located in the North Caucasus (Rostov-on-Don, Taganrog) and in the south of Eastern Siberia (Novosibirsk, Krasnoyarsk); flax and forage harvester plants are in the Central district; potato harvester plants are in Ryazan and Tula cities in the Central district; and rice harvester plants are in the Far East district. Tractor production is located in Western Russia (near Europe), because the metallurgical production centers are also located there (e.g., in Vladimir, St. Petersburg, Volgograd, Cheboksary, Petrozavodsk, Bryansk) (Zheltikov, 2001).

The agricultural machinery industry of Russia is divided into three main sectors of production: tractors (35%), other self-propelled agricultural machinery (15%), and trailed, mounted and stationary agricultural machinery (50%) (Ministry of Industry and Trade of Russian Federation, 2011).

During the period 1990–2015, the efficiency of the domestic AMI decreased significantly. By 2017, companies producing domestic AM contributed only 0.13% to gross domestic product (GDP) (Ministry of Industry and Trade, 2017). This low share of GDP share is the result of a number of factors affecting the AMI. For instance, the low solvency of agricultural producers means that the equipment manufacturing plants are faced with low domestic demand for machinery and equipment. As a result, AM factories operate at 40–70% of their production capacity (Ministry of Industry and Trade, 2017). Figure 4 indicates that there is little agricultural equipment manufactured in Russia. However, a recent subsidy program allowing for renewal of obsolete machinery has led to an increase in its production (Federal State Statistics Service, 2018).

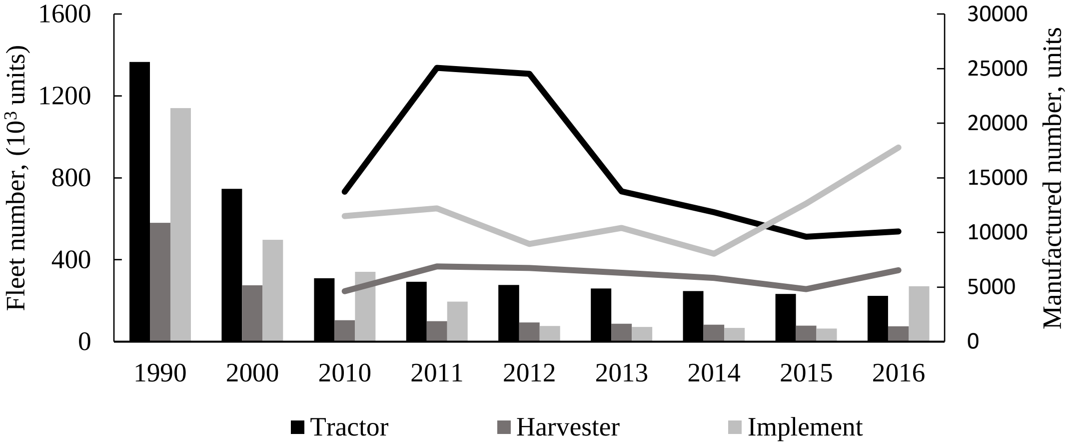

Figure 4. Main Agricultural Machinery Possessed and Manufactured

(Source: The Federal State Statistics Service, 2018)

The most common type of machinery used in Russian agriculture are tractors and combine harvesters. Their levels of production indicate the entire sub-sector efficiency (Ministry of Industry and Trade of Russian Federation, 2009). During the period 1990–2016, the condition of the existing AM significantly deteriorated, and the availability of the main types of AM decreased each year (Figure 4). In 2016, approximately 65% of the tractors and 48% of the grain harvesters in Russia were over 10 years old, meaning that their work life had already expired (Ministry of Industry and Trade, 2017) (Table 1).

Table 1. Age Structure of Main Agricultural Machinery in Russian Agricultural Companies, %

Kind of machinery	2006			2008			2016		
	up to 3 years	from 4 to 8 years	9 years and over	up to 3 years	from 4 to 8 years	9 years and over	up to 3 years	from 4 to 9 years	10 years and over
Tractor	5.6	11.2	83.2	9	12.9	78.1	14.6	23.1	62.3
Cultivator	12.9	17.8	69.3	7.6	30.1	62.3	12.5	32.4	55.1
Seeder	13.2	18.4	68.4	14.8	84.6	0.6	12.8	31.5	55.7
Grain harvester	11.2	16.0	72.8	18.2	24.8	57.0	17.1	35.4	47.5
Forage harvester	12.6	24.7	62.7	19.5	24.6	56.0	21.7	28.2	50.1
Beet harvester	16.0	24.2	59.8	20.5	37.4	42.1	15.9	42.8	41.3
Milking machine	7.6	11.1	81.2	13.3	13.6	73.2	12.4	23.5	64.1

(Source: The Federal State Statistics Service, 2018)

According to the Ministry of Agriculture of the Russian Federation, the average age of a tractor in Russian agricultural machinery fleet was 25 years. For grain harvester, the same indicator was eight years, for forage harvester was 7 years.

In 2014, tractor availability was equivalent to a total of 247.3 thousand units. However, considering the total area of cultivated land, the need for tractors was 900 thousand units. A deficit of AM for 1,000 ha of planted crops limits the technical capabilities of farmers and reduces labor productivity in agriculture (Table 2). The annual load of one harvester is increased to almost 500 ha, extending the harvesting period to almost 2 months instead of the standard 7–10 days (Ushachev, 2015).

Table 2. Tractor and Harvester Availability in Russian Agricultural Companies*

Indicators	2005	2010	2011	2012	2013	2014	2015	2016	Ratio of 2014/2005 (%)
Tractors per 1,000 ha of arable land, units.	6	4	4	4	4	3	3	3	50
The load of arable land per tractor, ha	181	236	247	258	274	289	307	305	159.66
Grain harvesters per 1000 ha of arable land, units.	4	3	3	3	3	2	2	2	50
Crops acreage per one grain harvester, ha	253	327	354	369	399	408	422	425	167

* at year-end
(Source: The Federal State Statistics Service, 2018)

Low availability of equipment and inability to meet the requirements of modern intensive technologies with the existing machinery has resulted in harvest losses of 40–50% and uncompetitive agricultural products and it impedes the implementation of innovative technologies, which require a mechanization level of 60–65% (Ushachev, 2015).

The result of Russia's entry into the World Trade Organization (WTO) in 2012 was the reduction of the import customs duty on agricultural machinery. Hence, the share of imported products increased. December 2012, the Government of the Russian Federation launched a mechanism to subsidize production and marketing of domestic producers of agricultural machinery. However, the mentioned measure was used by foreign producers (primarily Belarusian ones), who began to supply partially disassembled equipment to Russia. As a result, according to Rosspetsmash, in 2013 the cumulative share of imports on the Russian market of agricultural machinery accounted for 76%. Nevertheless, in

2014 there was a turning point in this trend, and up to the present time there has been an increase in the share of the full-cycle production of domestic companies in the market. Western sanctions and a food embargo of Russia in 2014 revealed the import dependence of the agrarian sector and highlighted the need to reduce the percentage of agricultural products and equipment imported. Although it is steadily declining, the share of imported agricultural equipment (see Figure 5) continues to account for more than 46% of the Russian machinery fleet (Federal State Statistics Service, 2017). Therefore, to achieve import substitution and overcome its domestic production shortage, Russia must take measures to modernize its AMI in the near future.

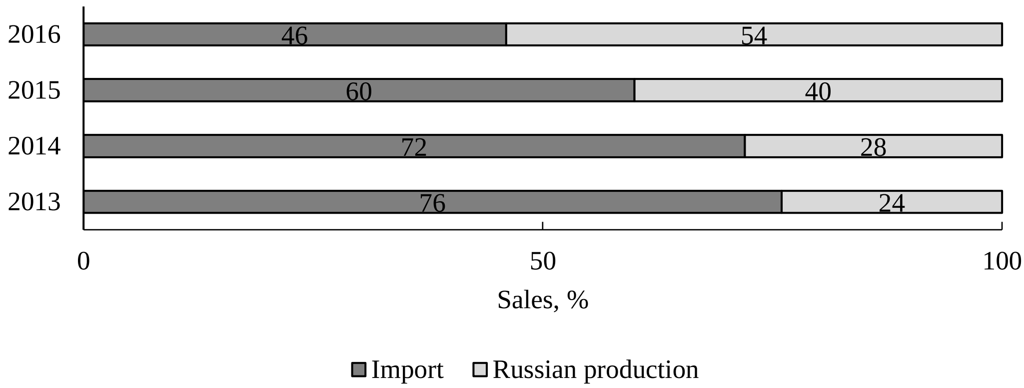

Figure 5. Agricultural Machinery Market

(Source: The Federal State Statistics Service, 2017)

Today, approximately 1.5 thousand Russian companies are involved in the production of AM and its components, and it is the main activity for 57 of these companies (Butov, 2017). In 2016, the R&D expenditures of Russia’s AM manufacturers were equivalent to 0.67% of their revenue, whereas the world’s largest AM producers devote more than 4% of revenue to R&D. This significantly limits the capacity of industrial enterprises producing AM to realize their potential for growth. In addition, while the total number of

AMI employees amount to 31.3 thousand, the number of mechanical engineers employed by AM producers is 737 employees, which indicates the low innovative activity of such enterprises (Ministry of Industry and Trade of Russia, 2017).

At the same time, there are some clearly pronounced positive trends in terms of innovations. R&D expenditures have expanded 6.6 fold since 2014 and the number of employed mechanical engineers has increased by 98 people (+15.3%) (Butov, 2017).

Three main manufacturers of agricultural equipment—Combine Plant Rostselmash Ltd., Concern Tractor Plants and JSC Petersburg Tractor Plant—account for 92% of the equipment produced in the country. Combine harvesters sector, in turn, is represented by 12 plants, with only 4 manufacturers producing domestic models (e.g. Cheboksary machinery plant - 100 units, "Nazarovoagrosnab" - 6 units, JSC "Remselmash" - 46 units) (Ushachev, 2015).

Among the manufacturers in the Commonwealth of Independent States (CIS) countries, the leading position is occupied by Belarusian companies. For example, Minsk Tractor Works produces approximately 30 farm tractor models and has three assembly plants in Russia with localization levels up to 15%, and Gomselmash, which produces grain and forage harvesters, has localization levels up to 25%. Ukraine has several manufacturers, the leader being Kharkiv Tractor Plant, with localization levels below 10%.

Among the global foreign manufacturers of agricultural machinery are John Deere, CNH Industrial, Claas and AGCO. All of these companies have assembly facilities in Russia, however, their levels of localization do not exceed 5%–10% (excluding Claas, at 17.30%) (Ministry of Industry and Trade of Russian Federation, 2011).

In terms of production concentration, the Russian agricultural machinery industry has a similar structure to western countries. The American manufacturers of agricultural machinery John Deere and AGCO account for 68% of domestic United States (US) production, a similar situation to the Russian companies Rostselmash and Concern Tractor Plants, which account for 53.4% of domestic production (Radishevskii, 2011).

Compared with foreign equipment suppliers, domestic equipment manufacturers have both disadvantages and advantages. Russian AM producers offer a poorer range of machinery and have low investment levels in technical and technological innovations. However, their main competitive advantages are low prices, service availability and the state's protectionist policy, which adds to the cost of imported equipment. Conversely, the competitive advantages of the foreign technologies are reliability and productivity (Poluhin and Plygun, 2015). Belarusian AM, although imported, holds a significant and dominant sales position because of its low prices. There is a tight economic interdependence between Russian and Belarus; the latter benefits from the Russian government's protectionist policies because of its common Soviet history and membership in the Customs Union.

Comparison indicators for domestic and foreign AM are shown in Table 3, based on the "Strategy of Development of the AMI of Russia until 2020".

Table 3. Russian Agricultural Machinery versus Foreign Agricultural Machinery

	Indicator	Domestic production	Import production
Tractor	Engine power, kW	22–313	60–500
Tractor	Number of models, units	about 30	681 (European market)
Tractor	Environmental engineering standards	Euro 2–3	Euro 3–4
Tractor, harvester	Price, %	60–70%	100%
Harvester	Engine power, kW	<373	<612
Harvester	Number of models, units	23	147

(Source: Ministry of Industry and Trade of Russia. 2011. Science research work: The strategy of development for agricultural machinery industry of Russia until 2020).

It indicates that Russian machinery lags behind foreign machinery in many indicators. Systemic problems hindering the effective development of the AMI can be divided into two main categories: general economic factors and industrial factors (Konstantinov, 2013). General economic factors include high bank interest rates (25–27%) and a reduction in government subsidies for agricultural producers, coupled with rapid price increases for raw materials and energy. In the period 2000–2016, the prices for fuel and energy resources for manufacturers increased rapidly: electricity and heat energy increased by 19% every year, gas by 23%; and metal by up to 20%. Industrial factors are the low export share and the dependence on foreign component parts, arising from the insufficient quality and range of domestic materials. The lack of stable, effective demand in the domestic market is another hindering factor. The demand for AM depends on the financial situation of the agricultural producers. Therefore, the development of the AMI is curtailed by the low price of grain and by the low profitability of agriculture (Sandakova et al., 2017).

To stimulate investments in AMI, Russian Government Resolution No. 1432, dated December 27, 2012, has been implemented. Under the program, the state compensates the buyers of domestic equipment for 25% of its value, or 30% if the equipment is provided for Siberia and the Far East regions. The amount of state support is determined by the import substitution program adopted by the government from 2014 (Kolesnikova et al., 2017). Agricultural exports increased by 15.9% between 2015 and 2016, which demonstrates the effectiveness of the import substitution program. The 2014 devaluation of the ruble against the dollar and euro also had a considerable impact on trade. Spikes in the prices of imported AM and component parts led buyers to seek alternatives, including purchasing cheaper domestic equipment sold in the local currency.

For further dynamic development of AMI, it is essential to undertake the following actions: fully develop the capacity of the Russian AMI to produce tractors, grain and forage harvesters, tillers, seeding machines and other kinds of AM and equipment; improve the Russian AM market potential by establishing a dealer network, ensuring availability of spare parts and services, and offering low prices; increase investment in R&D for developing new technologies to expand the product range; and use state support programs efficiently. The industrial cluster strategy can contribute to the revival of Russia's AMI with a new innovation-based focus.

Table 4. SWOT-analysis of AMI in Russia

STRENGTHS	OPPORTUNITIES
1. Availability of developed production sector since USSR, accumulated experience and developed economic ties; 2. Priority attention from the government; 3. Significant domestic sales market; 4. Lower labor costs in comparison with European countries.	1. The presence of potential demand in the domestic market, due to the current lack of equipment and a high degree of depreciation of machinery available in the existing fleet; 2. Further development of the leasing sales scheme; 3. Fuller use of import substitution opportunities; 4. Development of export sales channel.
WEAKNESSES	THREATS
1. Technological backwardness in comparison with the world's leading manufacturers; 2. High dependence of state support; 3. Considerable distance from the leading world markets, which predetermines high costs for supply logistics; 4. Undeveloped export sales channel, practically limited to CIS countries	1. Low effective demand in the domestic market; 2. Limited capacity of the state to increase or maintain the current level of support; 3. Failure of the strategy for export development due to a number of possible problems in the political and economic spheres.

3.2 AM Cluster Formation Model

The results of the calculations regarding the ranking of manufacturers which could potentially enter the cluster are provided in Table 5, based on the AHP methodology.

Table 5. Global Priorities Calculation

Companies	Criteria						Global priorities
	Net profit	Patents	Assortment	Revenue	Fixed assets	Reserves	
	The numerical value of the priority vector						
	0.25	0.43	0.17	0.05	0.08	0.03	
Rostselmash	0.53	0.56	0.55	0.57	0.57	0.57	0.55
Millerovoselmash	0.04	0.05	0.06	0.03	0.04	0.04	0.05
Salskselmash	0.10	0.23	0.10	0.09	0.18	0.07	0.16
Kormmash	0.07	0.08	0.02	0.04	0.05	0.04	0.06
Klever	0.24	0.03	0.20	0.24	0.11	0.25	0.14
Aksaikardandetal	0.02	0.05	0.06	0.04	0.05	0.03	0.04

The results indicated that maximum priority should be given to the patents criteria (ranking of 0.43), whereas the minimum priority was the reserves criteria (0.03). In Table 5 the numerical values are hundredth number rounding. However, calculations for each criterion based on the numerical value were made on the exact number.

Further options were paired and compared with criteria. According to the weights of the net profit criteria, Rostselmash company had the maximum contribution (0.53) and Aksaikardandetal (0.02) had the minimum contribution. According to the weights for the patents criteria, Rostselmash with 0.56 and Klever with 0.03 had the maximum and minimum contributions, respectively. For assortment criteria, the maximum and minimum preferences belonged to Rostselmash (0.57) and Kormmash (0.02), respectively. Again, Rostselmash was the leader for the revenue criteria, with a weight of 0.55, whereas Millerovoselmash had the minimum preference (0.03). Based on the fixed assets criteria, the highest weight and maximum preference were allocated to Rostselmash (0.57), whereas Millerovoselmash (0.04) had the minimum preference. Finally, based on the weights for the reserves criteria, Rostselmash (0.57) and Aksaikardandetal (0.03) had the maximum and the minimum preferences, respectively. Next, I calculated the global priorities. Variables with a maximum global priority value were considered the best. Rostselmash is the best among the six companies in all six indicators, and therefore it is the center of the cluster. I need to use the AHP to select companies based on the quantitative indicators. According to the results, these are Rostselmash, Salskselmash and Klever manufacturers (Figure 6).

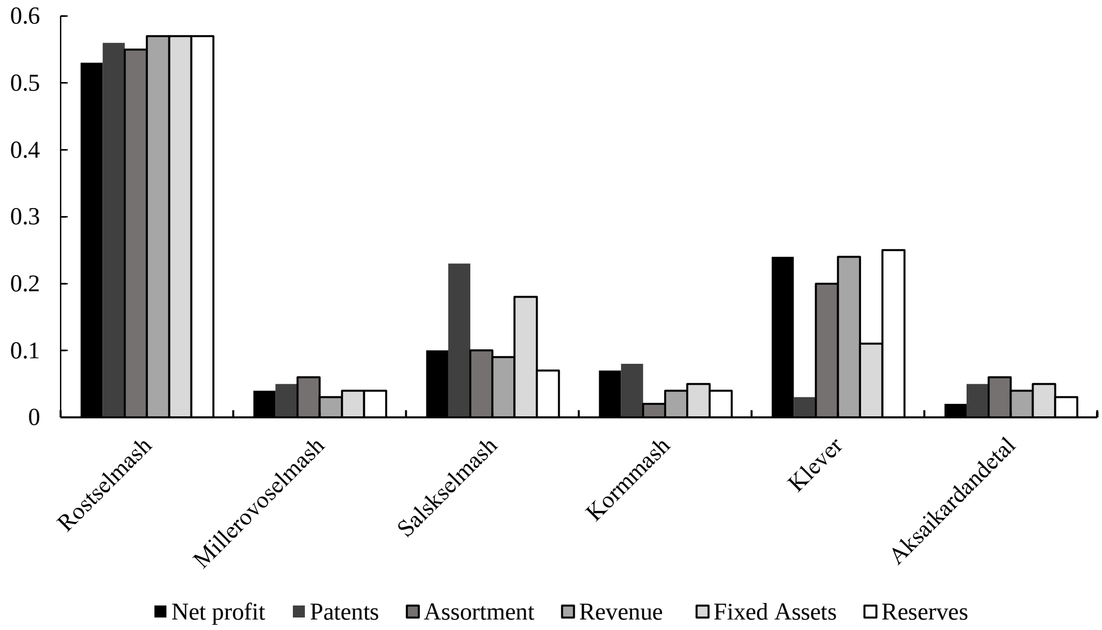

Figure 6. Weights of Alternatives

Summing up the results of the calculations from the viewpoint of AM cluster creation in the Rostov region, I identified the most preferable manufacturers (that is, based on justified expediency) as Rostselmash, Salskselmash, and Klever. The AHP application allowed us to allocate those manufacturers according to their global priorities for innovative development, and to simultaneously highlight the strengths and weaknesses of each participant and the potential cluster in general. The proposed composition of the AM cluster in the Rostov region, focused on increasing the potential for import substitution, is shown in Figure 7. I recommend that these companies form a cluster with Rostselmash at its center if additional proof of the effectiveness of such integration can be provided.

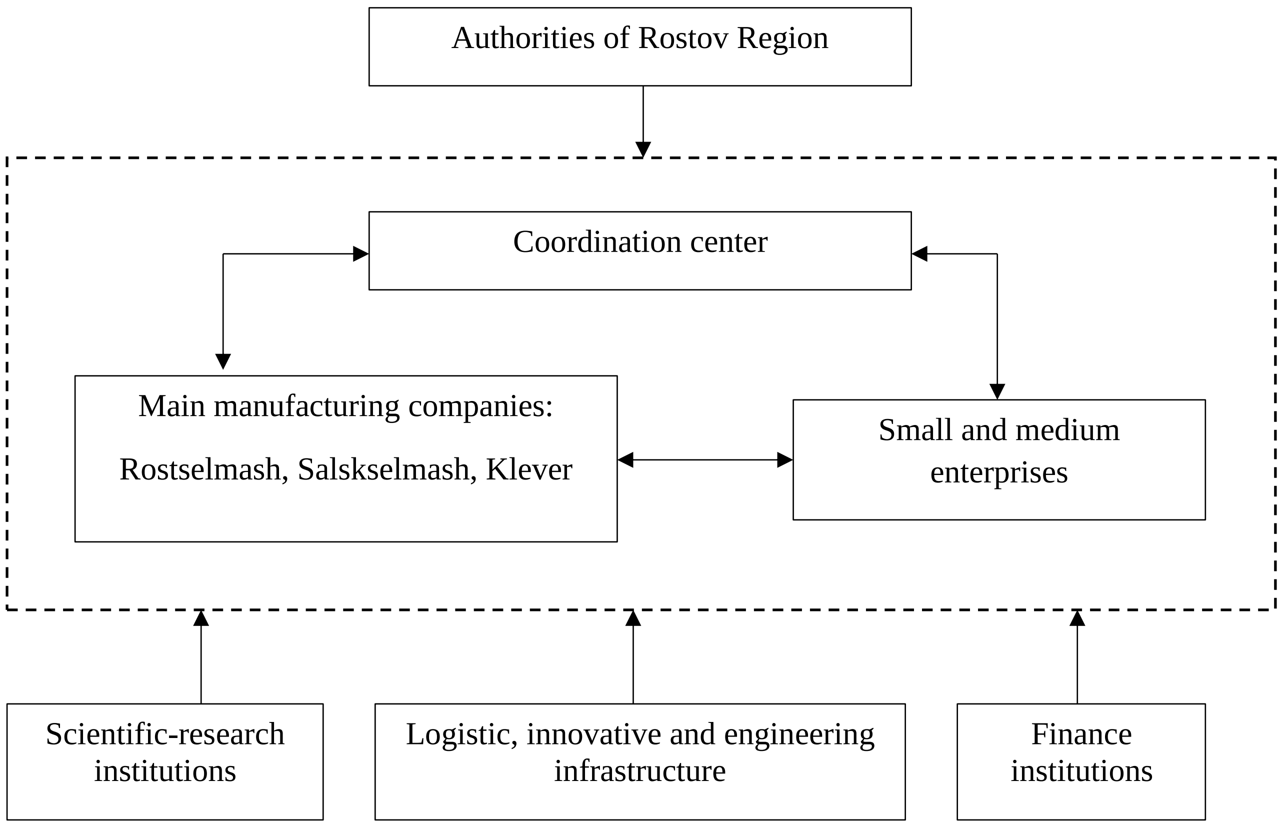

Figure 7. Agricultural Machinery Cluster Model of the Rostov Region

3.3 Economic Efficiency of AM Cluster Formation

The financial efficiency of a company is one of the most important economic criteria. Generally, it can be represented by the ratio of production costs and the obtained result (Revsine et al., 1999; Mescon, 1998). I will assess the feasibility of creating an AM cluster in the Rostov region, focusing on the proof of its efficiency (or inefficiency) for potential participants. The following enterprises will be considered: Rostselmash (Figure 8), Salskselmash (Figure 9) and Klever (Figure 10). The previous analysis indicated that these three companies had the highest potential as participants of the proposed cluster.

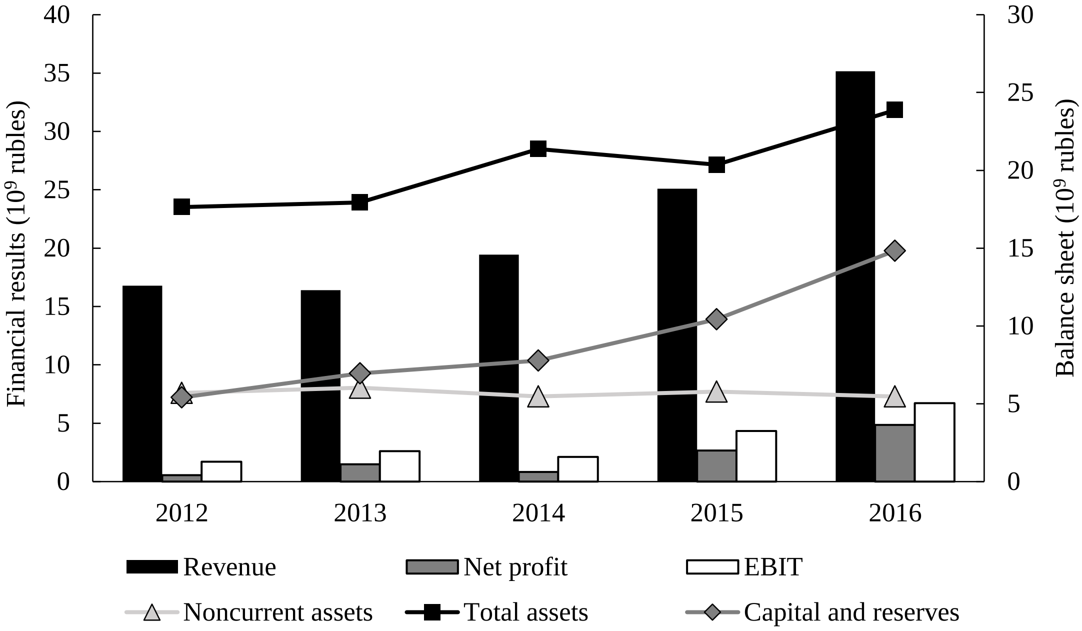

Figure 8. Financial Results and Balance Sheet of Rostselmash

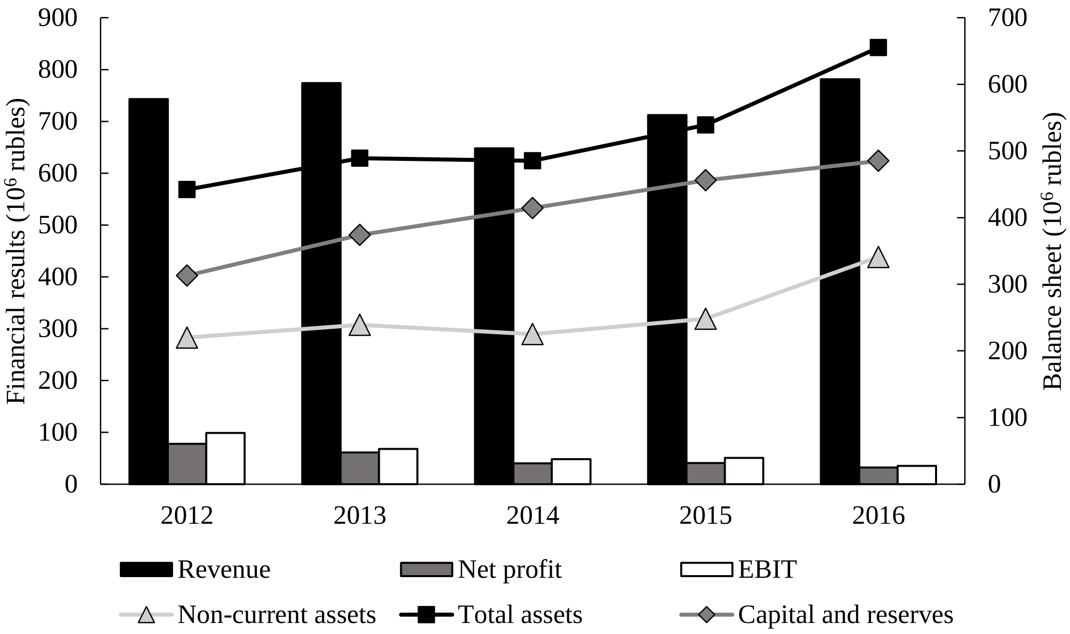

Figure 9. Financial Results and Balance Sheet of Salskselmash

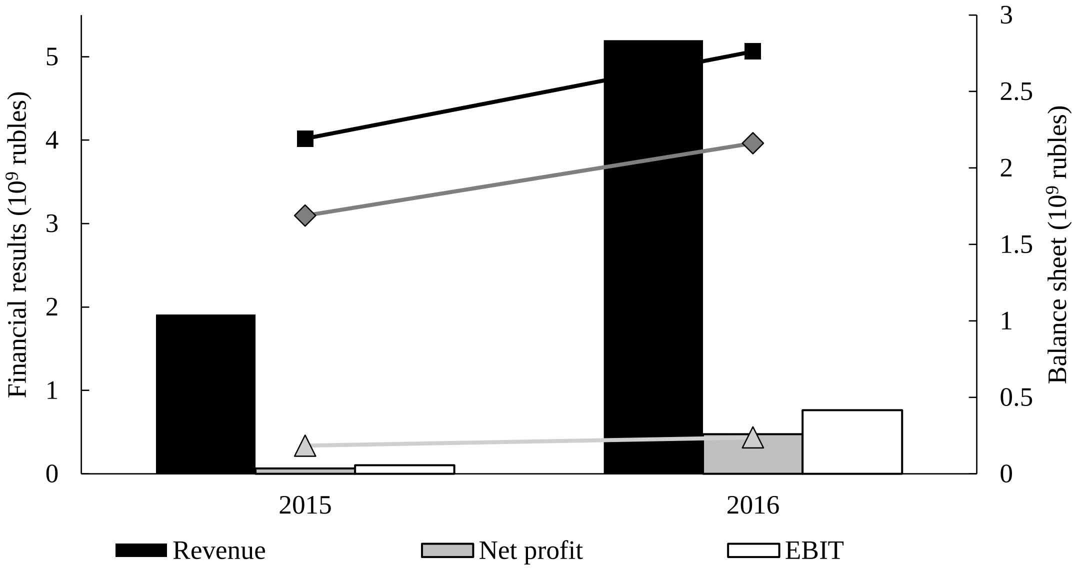

Figure 10. Financial Results and Balance Sheet of Klever

The efficiency of companies entering the cluster can be represented as follows:

$$E = \frac{R}{C} \qquad (3)$$

where E denotes efficiency, R denotes result and C denotes production costs.

The profit margin of the company, a resource indicator, was used for assessing the efficiency of the company's economic activities. I used the net profit (NP) of the company and, for costs, all assets of the company (A), for the period under study.

Thus, the efficiency of the enterprise can be measured as follows:

$$E = \frac{NP}{A} \qquad (4)$$

For companies operating within the cluster, it is necessary to measure the integrated efficiency because this is the key indicator. It enables assessment of whether the volumes of the final product produced correspond to the planned volumes when all resources are used (Cappellin and Wink, 2009; Ilyenkova, 2007). The integrated efficiency of the cluster functioning shows the combined economic effect obtained by the cluster from the use of all cluster assets. I determine the efficiency of the cluster as follows:

$$E_c = \frac{NPc}{A_c} \qquad (5)$$

$$NP_c = \sum_{i=1}^{n} NP_i \qquad (6)$$

$$A_c = \sum_{i=1}^{n} A_i \qquad (7)$$

where E_c is the efficiency of the cluster, NP_c is the net profit of the cluster, A_c is the total assets of the cluster, NP_i is the net profit of company i, A_i is the total assets of company i and n is the number of companies (in our case, three). Thus, the integrated efficiency of the cluster is equal to the quotient of dividing the total net profit by total assets. For the initial analysis of the cluster function, the integrated efficiency index is sufficient.

The question arises as to whether the functioning of enterprises in a cluster is more efficient than the functioning of each company separately and, if so, to what degree? The efficiency indicator (E) does not answer this question. To answer it, it is necessary to obtain an indicator that correlates with the integrated efficiency of the cluster functioning with an indicator reflecting the overall efficiency of the enterprises when they operate independently. For the latter indicator, I can use the mean value of the efficiency indicators calculated using equation (4) for each company.

First, I use the formula of the arithmetic mean (E_{AM} = 0.10). Thus, the formula for calculating the target indicator (TI) is as follows:

$$TI = \frac{Ec}{E_{AM}} \tag{8}$$

where TI is the target indicator, E_c is the integrated efficiency of the cluster and E_{AM} is the mean economic value of the efficiency indicators.

Let us refer to the target indicator as the interaction indicator (II). The II correlates the efficiency of the cluster and the mean efficiency of the cluster companies. For the sake of simplicity, the E_{AM} will be denoted by Em. In general, the II can be represented as follows:

$$II = \frac{Ec}{Em} \tag{9}$$

Thus, to determine the quality of the interaction under the cluster, the integrated efficiency of the cluster and the mean efficiency of the cluster companies must be correlated.

Table 6. Interaction Indicator Calculation

Indicator	Rostselmash	Salskselmash	Klever
Net profit	2779578	37975	269620
Total assets	21870628	559757	2476848
Efficiency i E_i	0.127	0.067	0.108
E_c		0.123	
II		1.23	

* II denotes interaction indicator.

** We used Russian currency due to drastic fluctuations and devaluation of the ruble against the dollar.

(Source: Companies' accounting reports, averages for 2014, 2015 and 2016)

In this case, S is Interaction Indicator (II), $\sum_{i=1}^{m} Si$ is integrated efficiency of companies (E_i):

$S > \sum_{i=1}^{m} Si = S_1 + S_2 + \ldots + S_m$

$1.23 > 0.302 = 0.127 + 0.067 + 0.108$

A synergistic effect (S_k) is expressed by the difference:

$S_k = S - \sum_{i=1}^{m} Si$

$S_k = 1.23 - 0.302 = 0.928 > 0$

According to the value of synergistic effect, the interaction indicator exceeds the integrated efficiency of the companies, and it is above zero. Therefore, I can conclude that there is a positive synergistic effect. It means that functioning under the cluster is more productive, economically efficient and effective than functioning as independent enterprises for Rostselmash, Klever, and Salskselmash.

Chapter 4 Conclusion

A period of stagnation following the collapse of the Soviet Union seriously undermined the overall efficiency of Russia's agriculture in general and the AMI in particular. Low quality and reliability and a narrow product range of domestic equipment, combined with inadequate state support, resulted in extremely high import dependence. Western sanctions and counter-sanctions that began in 2014 revealed these existing problems in the agrarian sector and led the government to make an urgent shift to an import substitution policy based on innovative strategies.

Government support programs, coupled with depreciation of the ruble, which has resulted in extremely high prices for foreign machinery and component parts, have proved to be beneficial for the AMI sector. Since 2014, import dependence on machinery has been steadily declining, whereas industry investments and the share of R&D expenditures of AM manufacturers have been increasing.

Despite this progress, immense problems remain in the industry. Given the need for quick improvements, and the arduous geopolitical and economic context, traditional strategies of industrial development cannot provide the necessary solutions. Here, I have suggested the formation of an industrial cluster in the Rostov region, where the most efficient AM manufacturers have been traditionally concentrated.

Using an AHP model, I determined the most appropriate participants for the potential cluster. Then, based on Russia's new economic policy of import substitution, I proposed a model for cluster formation. I estimated the actual level of "innovative readiness" of AM companies in the Rostov region and their potential profitability in the cluster compared with individual profitability using economic and mathematical modeling tools based on synergistic effect.

Based on my calculations, I drew the following conclusion. It is economically profitable to unite the companies analyzed in an industrial AM cluster, focused on import substitution. I proved that the formation of the cluster, centered on the manufacturer Rostselmash, will positively affect the productivity, innovation activity and development of all enterprises comprising the cluster.

The proposed model of AM cluster in Rostov region can be implemented in other regions of Russia, focused on increasing the potential for import substitution. Formation of AM clusters in Russia will accelerate import substitution. The development of its domestic AMI would allow Russia to conduct an independent policy of import substitution for food products, machinery, and equipment, and contribute to the food security of the country.

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Appendix 1

The Analytic Hierarchy Process

Table 1 presents the scales of relative importance or the superiority of alternatives according to the selected criteria.

Table 1. Intensity of importance on an absolute scale

Value	Definition
1	Equal importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values between the two adjacent judgments

The work on the AHP involves the estimation of priority weights of a set of criteria or alternatives from a square matrix of pairwise comparison $A = [a_{ij}]$, which is positive and if the paired comparison judgment is perfectly consistent it is reciprocal, i.e., $a_{ij} = 1/a_{ji}$ for all ij = 1, 2, 3 . . . n. The final normalized weight of its i-th factor, w_i, is given by Eq. (1).

$$w_i = \frac{a_{ij}}{(\sum_{k=1}^{n} ak_j)} \quad \forall i = 1, 2, \ldots, n. \tag{1}$$

In the real life, judgment an error on the judgment is unavoidable. The suggested Eigenvalue method computes was the principal right Eigenvalue of the matrix A or w satisfies the following system of n linear equations:

A w= k max w, where k max is the maximum Eigenvalue of A. This was calculated by using Eq. (2).

$$w_i = \frac{\sum_{j=1}^{n} a_{ij} w_j}{\lambda \ \max} \quad \forall i = 1, 2, \ldots, n. \tag{2}$$

The natural measure of inconsistency or deviation from consistency, called consistency index (CI) is defined by Eq. (3).

$$CI = \frac{\lambda \ \max - n}{n - 1} \tag{3}$$

The consistency index of a randomly generated reciprocal matrix from scale 1 to 9, with reciprocals forced, for each size of matrix called random index (RI) is presented in Table 2.

Table 2. Incompatibility index of random matrixes

Matrix order	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Consistency ratio (CR) = CI/RI, where RI is function of matrix size and CR < 0.01 is as an acceptable limit, otherwise need to be revised and adjusted accordingly. Another task in the hierarchy is the synthesis of the judgments throughout the hierarchy in order to compute the overall priorities of the alternatives with respect to the goal. The weights are created by summing the priority of each element according to a given criterion by the weights of that criteria.

Appendix 2

Table 3. Initial data for potential participants ranking in the cluster

Company	Net Profit	Patents	Assortment	Revenue	Fixed Assets	Reserves
Rostselmash	2779578	32	5000	26563650	1574137	7412384
Millerovoselmash	13456	1	890	157063	42953	98828
Salskselmash	37975	6	1221	713788	266652	165790
Kormmash	22810	2	369	282350	68684	126117
Klever	269620	0	1733	3583731	195932	1343099
Aksaikardanetal	3797	1	910	274568	50848	78693

(Source: Accounting reports, the average for 2014, 2015, 2016)

Appendix 3

AHP evaluations experts:

1. Prof. Oleg Marchenko, Head of the Department of Fodder Production, All-Russian Research Institute of Agricultural Mechanization, Secretary General of the National Committee of the Russian Federation and the Euro-Asian Association (Russia, Belarus, Ukraine) on engineering in agriculture. Honorary Vice President of the International Commission on Engineering in Agriculture (CIGR). Expert of the United Nations, OECD, and FAO in the Technical Committee for the establishment of the Asian-Pacific Association for Testing Agricultural Machinery (ANTAM). General Director of the Department of Mechanical Engineering, Academician of the International Academy of Science and Business Integration (MAINB).
2. Prof. Daba Radnaev, Head of the Department of Mechanization of Agricultural Processes, Buryat State Academy of Agriculture, Doctor of Technical Sciences.

The content of evaluation:

The objective was to evaluate which agricultural machinery manufacturers would be best suited for the cluster formation under the import substitution policy. The next step was to compare the factors at the same level in pairs and measure their comparative contribution to the main objective. The question: which criterion concerning AHP priorities is more important? Please evaluate the intensity of importance on a scale of 1 to 9. I provide the initial data for potential participants ranking in the cluster according to accounting reports, the average for 2014, 2015, 2016) and Question Form for Evaluation.

Appendix 4

Question Form for Evaluation

The objective is to evaluate which agricultural machinery manufacturers would be best suited for the cluster formation under the import substitution policy. Please compare the factors at the same level in pairs and measure their comparative contribution to the main objective.

Which criterion concerning AHP priorities is more important? Please evaluate the intensity of importance on a scale of 1 to 9.

1 - Equal importance;

3 - Moderate importance of one over another;

5 - Essential or strong importance;

7 - Very strong importance;

9 - Extreme importance;

2, 4, 6, 8 - Intermediate values between the two adjacent judgments.

Table 1. AHP priorities for evaluation criteria

Importance (or preference) of one criterion over another					Value
1		Net profit		Patents	
2		Net profit		Assortment	
3		Net profit		Revenue	
4		Net profit		Fixed assets	
5		Net profit		Reserves	
6		Patents		Assortment	
7		Patents		Revenue	
8		Patents		Fixed assets	
9		Patents		Reserves	
10		Assortment		Revenue	
11		Assortment		Fixed assets	
12		Assortment		Reserves	
13		Revenue		Fixed assets	
14		Revenue		Reserves	
15		Fixed assets		Reserves	

Table 2. AHP priorities for "Net Profit"

Importance (or preference) of one criterion over another					Value
1		Rostselmash		Millerovoselmash	
2		Rostselmash		Salskselmash	
3		Rostselmash		Kormmash	
4		Rostselmash		Klever	
5		Rostselmash		Aksaikardandetal	
6		Millerovoselmash		Salskselmash	
7		Millerovoselmash		Kormmash	
8		Millerovoselmash		Klever	
9		Millerovoselmash		Aksaikardandetal	
10		Salskselmash		Kormmash	
11		Salskselmash		Klever	
12		Salskselmash		Aksaikardandetal	
13		Kormmash		Klever	
14		Kormmash		Aksaikardandetal	
15		Klever		Aksaikardandetal	

Table 3. AHP priorities for “Patents”

Importance (or preference) of one criterion over another					Value
1		Rostselmash		Millerovoselmash	
2		Rostselmash		Salskselmash	
3		Rostselmash		Kormmash	
4		Rostselmash		Klever	
5		Rostselmash		Aksaikardandetal	
6		Millerovoselmash		Salskselmash	
7		Millerovoselmash		Kormmash	
8		Millerovoselmash		Klever	
9		Millerovoselmash		Aksaikardandetal	
10		Salskselmash		Kormmash	
11		Salskselmash		Klever	
12		Salskselmash		Aksaikardandetal	
13		Kormmash		Klever	
14		Kormmash		Aksaikardandetal	
15		Klever		Aksaikardandetal	

Table 4. AHP priorities for “Assortment”

Importance (or preference) of one criterion over another					Value
1		Rostselmash		Millerovoselmash	
2		Rostselmash		Salskselmash	
3		Rostselmash		Kormmash	
4		Rostselmash		Klever	
5		Rostselmash		Aksaikardandetal	
6		Millerovoselmash		Salskselmash	
7		Millerovoselmash		Kormmash	
8		Millerovoselmash		Klever	
9		Millerovoselmash		Aksaikardandetal	
10		Salskselmash		Kormmash	
11		Salskselmash		Klever	
12		Salskselmash		Aksaikardandetal	
13		Kormmash		Klever	
14		Kormmash		Aksaikardandetal	
15		Klever		Aksaikardandetal	

Table 5. AHP priorities for "Revenue"

Importance (or preference) of one criterion over another					Value
1		Rostselmash		Millerovoselmash	
2		Rostselmash		Salskselmash	
3		Rostselmash		Kormmash	
4		Rostselmash		Klever	
5		Rostselmash		Aksaikardandetal	
6		Millerovoselmash		Salskselmash	
7		Millerovoselmash		Kormmash	
8		Millerovoselmash		Klever	
9		Millerovoselmash		Aksaikardandetal	
10		Salskselmash		Kormmash	
11		Salskselmash		Klever	
12		Salskselmash		Aksaikardandetal	
13		Kormmash		Klever	
14		Kormmash		Aksaikardandetal	
15		Klever		Aksaikardandetal	

Table 6. AHP priorities for "Fixed assets"

Importance (or preference) of one criterion over another					Value
1		Rostselmash		Millerovoselmash	
2		Rostselmash		Salskselmash	
3		Rostselmash		Kormmash	
4		Rostselmash		Klever	
5		Rostselmash		Aksaikardandetal	
6		Millerovoselmash		Salskselmash	
7		Millerovoselmash		Kormmash	
8		Millerovoselmash		Klever	
9		Millerovoselmash		Aksaikardandetal	
10		Salskselmash		Kormmash	
11		Salskselmash		Klever	
12		Salskselmash		Aksaikardandetal	
13		Kormmash		Klever	
14		Kormmash		Aksaikardandetal	
15		Klever		Aksaikardandetal	

Table 7. AHP priorities for “Reserves”

Importance (or preference) of one criterion over another					Value
1		Rostselmash		Millerovoselmash	
2		Rostselmash		Salskselmash	
3		Rostselmash		Kormmash	
4		Rostselmash		Klever	
5		Rostselmash		Aksaikardandetal	
6		Millerovoselmash		Salskselmash	
7		Millerovoselmash		Kormmash	
8		Millerovoselmash		Klever	
9		Millerovoselmash		Aksaikardandetal	
10		Salskselmash		Kormmash	
11		Salskselmash		Klever	
12		Salskselmash		Aksaikardandetal	
13		Kormmash		Klever	
14		Kormmash		Aksaikardandetal	
15		Klever		Aksaikardandetal	

Appendix 5

Results of the pairwise comparison

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons

	Category	Priority	Rank
1	Net profit	24.9%	2
2	Patents	42.6%	1
3	Assortment	16.8%	3
4	Revenue	5.3%	5
5	Fixed assets	7.7%	4
6	Reserves	2.7%	6

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3	4	5	6
1	1	0.50	2.00	6.00	4.00	7.00
2	2.00	1	3.00	9.00	8.00	9.00
3	0.50	0.33	1	4.00	4.00	5.00
4	0.17	0.11	0.25	1	0.33	5.00
5	0.25	0.12	0.25	3.00	1	4.00
6	0.14	0.11	0.20	0.20	0.25	1

Number of comparisons = 15
Consistency Ratio CR = 7.7%

Principal eigen value = 6.480
Eigenvector solution: 6 iterations, delta = 1.1E-8

Figure 1. Comparative assessment for Criterion

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons

	Category	Priority	Rank
1	ROSTSELMASH	52.9%	1
2	MILLEROVOSELMASH	3.6%	5
3	SALSKSELMASH	10.4%	3
4	KORMMASH	6.9%	4
5	KLEVER	23.9%	2
6	AKSAIKARDANDETAL	2.4%	6

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3	4	5	6
1	1	8.00	7.00	8.00	5.00	9.00
2	0.12	1	0.25	0.33	0.17	2.00
3	0.14	4.00	1	2.00	0.25	7.00
4	0.12	3.00	0.50	1	0.17	5.00
5	0.20	6.00	4.00	6.00	1	8.00
6	0.11	0.50	0.14	0.20	0.12	1

Figure 2. AHP priorities for Net Profit

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons

	Category	Priority	Rank
1	Rostselmash	56.1%	1
2	Millerovoselmash	5.0%	4
3	Salskselmash	22.8%	2
4	Kormmash	7.9%	3
5	Klever	3.3%	6
6	Aksaikardandetal	5.0%	4

Number of comparisons = 15
Consistency Ratio CR = 4.6%

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3	4	5	6
1	1	9.00	5.00	8.00	9.00	9.00
2	0.11	1	0.20	0.50	2.00	1.00
3	0.20	5.00	1	5.00	6.00	5.00
4	0.12	2.00	0.20	1	3.00	2.00
5	0.11	0.50	0.17	0.33	1	0.50
6	0.11	1.00	0.20	0.50	2.00	1

Principal eigen value = 6.287
Eigenvector solution: 5 iterations, delta = 5.8E-8

Figure 3. AHP priorities for Patents

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons

	Category	Priority	Rank
1	Rostselmash	55.3%	1
2	Millerovoselmash	5.7%	5
3	Salskselmash	10.4%	3
4	Kormmash	2.3%	6
5	Klever	20.1%	2
6	Aksaikardandetal	6.3%	4

Number of comparisons = 15
Consistency Ratio CR = 9.4%

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3	4	5	6
1	1	8.00	7.00	9.00	6.00	8.00
2	0.12	1	0.50	4.00	0.20	1.00
3	0.14	2.00	1	7.00	0.50	2.00
4	0.11	0.25	0.14	1	0.14	0.17
5	0.17	5.00	2.00	7.00	1	6.00
6	0.12	1.00	0.50	6.00	0.17	1

Principal eigen value = 6.589
Eigenvector solution: 6 iterations, delta = 8.1E-8

Figure 4. AHP priorities for Assortment

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons

	Category	Priority	Rank
1	Rostselmash	56.7%	1
2	Millerovoselmash	2.7%	6
3	Salskselmash	9.0%	3
4	Kormmash	3.7%	5
5	Klever	24.2%	2
6	Aksaikardandetal	3.8%	4

Number of comparisons = 15
Consistency Ratio CR = 9.7%

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3	4	5	6
1	1	9.00	9.00	9.00	6.00	9.00
2	0.11	1	0.20	0.50	0.12	0.50
3	0.11	5.00	1	4.00	0.20	3.00
4	0.11	2.00	0.25	1	0.12	1.00
5	0.17	8.00	5.00	8.00	1	8.00
6	0.11	2.00	0.33	1.00	0.12	1

Principal eigen value = 6.606
Eigenvector solution: 6 iterations, delta = 5.9E-8

Figure 5. AHP priorities for Revenue

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons

	Category	Priority	Rank
1	ROSTSELMASH	57.4%	1
2	MILLEROVOSELMASH	3.7%	6
3	SALSKSELMASH	18.0%	2
4	KORMMASH	5.1%	4
5	KLEVER	10.8%	3
6	AKSAIKARDANDETAL	5.1%	5

Number of comparisons = 15
Consistency Ratio CR = 3.9%

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3	4	5	6
1	1	9.00	5.00	9.00	8.00	9.00
2	0.11	1	0.14	0.50	0.25	1.00
3	0.20	7.00	1	4.00	2.00	3.00
4	0.11	2.00	0.25	1	0.33	1.00
5	0.12	4.00	0.50	3.00	1	2.00
6	0.11	1.00	0.33	1.00	0.50	1

Principal eigen value = 6.243
Eigenvector solution: 4 iterations, delta = 7.1E-8

Figure 6. AHP priorities for Fixed Assets

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons

	Category	Priority	Rank
1	ROSTSELMASH	56.6%	1
2	MILLEROVOSELMASH	4.0%	5
3	SALSKSELMASH	7.4%	3
4	KORMMASH	4.1%	4
5	KLEVER	25.1%	2
6	AKSAIKARDANDETAL	2.8%	6

Number of comparisons = 15
Consistency Ratio CR = 9.0%

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3	4	5	6
1	1	9.00	9.00	9.00	6.00	9.00
2	0.11	1	0.33	1.00	0.14	2.00
3	0.11	3.00	1	2.00	0.14	4.00
4	0.11	1.00	0.50	1	0.14	2.00
5	0.17	7.00	7.00	7.00	1	8.00
6	0.11	0.50	0.25	0.50	0.12	1

Principal eigen value = 6.561
Eigenvector solution: 6 iterations, delta = 7.0E-8

Figure 7. AHP priorities for Reserves