Macromodelling of food and raw material links between large-scale specialized zones for the development of animal husbandry

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Abstract. One of the ways to improve the efficiency of production is the deepening of specialization and the development of interregional relations. The problems of rational specialization and optimal commodity flows have been troubling the scientific economists over the past two centuries. It is especially important to address the issues of territorial and sectoral division of labor for industries whose production efficiency differs significantly in different regions and is suitable for transportation. The article describes the methodological approaches to the improvement of interregional raw materials and food links in animal husbandry based on the formation of large-scale specialized commodity zones on the example of the Russian Federation. The first task of the study was to identify several large-value zones of specialization in the production of livestock products. As a result of solving the second task, two goals were achieved at the same time: (a) optimization of cattle breeding and (b) the interregional exchange of feed and meat and dairy products. To achieve the goals, we used a combination of statistical and economic-mathematical methods, a combination of several models of optimal linear programming. As a result of the research, five areas of specialization were identified, depending on the level of livestock production and the availability of the natural and economic potential for the development of the subsector, the placement of livestock in those zones has been optimized. In addition, a scheme has been developed for the interregional food exchange and the development of commodity relations. The presented methodological approaches can be used to solve similar problems both at the international level (CIS, EAEU, etc.), and for smaller territorial units, such as federal districts or individual regions.

1. Introduction
Improving food and raw material links between regions contributes to the effective use of existing natural and economic advantages, allows saturating the market with high-quality products and ensuring a reduction in their value. Russia, being the largest territorial state, is characterized by a large variety and considerable ramification of inter-regional trade flows. This is largely due to the large scale of the natural and socio-economic conditions of various territories, historically established features of the development of agricultural production. For a relatively even and more complete
provision of the population of Russia with food, interregional ties are more important than for most other states.

Foundations of the formation and development of interregional ties were laid in the 18th century by A. Smith and D. Ricardo in the theory of absolute and relative advantages [1]. A significant contribution to the development of the theory of interregional exchange was made by I. G. Tyunen [2], V. Kristaller, V. Launhardt, and A. Weber [3]. Classical theories of accommodation were continued in the concept of territorial integration (F. Naumann) [4]. Since the 1930s, theories of spatial development began to develop rapidly (A. Lesch) [5]. The development of economic and geographical theories (N. N. Baransky, N. N. Kolosovsky, M. K. Bandman, and others) showed that the main factors of regional competitiveness in interregional exchange are technological specialization, the development of cooperation and the effect of agglomerations [6].

The concepts of trade based on the works of D. Ricardo, E. Heckscher, B. Olin, and P. Samuelson, see in trade not only a mutually beneficial exchange, but also a tool for reducing development gaps between territorial units. The second half of the twentieth century was marked by a sharp increase in world trade and increased competition between countries and regions. Theories of competitive advantages of individual territories began to appear (M. Porter [7], P. Krugman [8, 9, 10, 11]).

Proponents of interregional cooperation development [12, 13] link food ties with “… interregional exchange in terms of the sale and purchase of agricultural products, raw materials, and food between individual regions of the country”, which largely determines the ability of some regions to provide local people with food and even export certain types of it to internal and external agri-food markets, and others, primarily due to the shortage of local production, to partially meet domestic needs for agricultural raw materials and food due to interregional trade flows.

In connection with the above, the development of inter-regional food exchange, based on the rational use of production and bioclimatic potential through the creation of specialized high-tech zones of production of certain types of agricultural products, helps to reduce regional disparities in the provision of public domestic food production, and requires the development of methodological approaches to the improvement of inter-regional commodity and food links.

2. Methods

The rational placement and deepening of specialization in cattle breeding should be based on the growth of incomes of agricultural producers and the rural population, based on the sustainable development of the sub-sector and the effective use of the resource potential, creating economic and technological conditions for increasing milk and beef production. The task of optimizing the location of production and consumption of agricultural products is one of the most complex in structure among economic and mathematical models, since it requires simultaneously taking into account a large number of different mutually opposite goals: integrating the specialization of individual regions and natural zones in the production of agricultural products; meeting the needs of the population in meat and dairy products at the level of recommended standards and ensuring food independence of the country; determining the needs of individual regions in the volume of imports of livestock products; establishing long-term relationships between producing and consuming regions to expand the supply of livestock products; creating conditions for the physical and economic accessibility of milk and beef, as vital types of food for the entire population of the country.

Developing territorial organization and increasing food supply of the regions of meat and dairy products require the formation of large-scale specialized areas of milk and beef production, the development and improvement of interregional relations. A specialized zone for the production of marketable agricultural products is characterized by a specific economic and geographical unity, the peculiarity of the natural and economic conditions that determine the specialization of production. It is a part of the territory of a country (region) where, based on the rational use of natural and economic
conditions favorable for the production of a particular agricultural product, a relatively high level of productivity could be achieved with increased (and sometimes unique product quality and relatively lower production costs are observed) [13]. This fact allows us to export a significant amount of the dominant commodity output outside the territory.

Isolation of specialized zones and the determination of their role in the total volume of production is a complex process, combining the classification of regions according to natural, economic, technical, and technological factors, as well as economic and mathematical modeling of the distribution of livestock breeding by zones identified in the classification. In the process of classification of regions from a variety of factors, the dominant role is assigned to natural conditions, the availability of forage lands, economic conditions, which together affect, primarily, the development of their own food supply, since over the vast territory of the country soil and climatic parameters differ significantly [14, 15].

The authors of the economic and mathematical model take into account important features: first, the process of developing and solving the problem is based on a combination of mathematical statistics, linear programming, and traditional methods of economic analysis; second, when determining the most likely options for locating livestock production, the levels of the main economic indicators of the development of the sub-sector and the possible distribution of production resources according to their use are predicted; third, the economic justification of options for locating the production of livestock products is based on the use of multi-criteria optimization approaches; fourth, taking into account the conditions associated with the transportation of marketable animal products included in the economic-mathematical model (when building the optimal variant for locating the production of milk and beef), it creates economic prerequisites for deepening its specialization and concentration.

3. Results

According to the authors, the classification of Russian regions should be based on the following factors: the availability of fodder lands and favorable natural conditions for the development of cattle breeding. According to their totality, the authors proposed to divide the regions into five large-scale zones.

The first zone should unite subjects with relatively low availability of pastures and close to epy Central Russian natural conditions, the bioclimatic potential of which is sufficient to obtain the necessary yields of fodder crops and the development of dairy cattle breeding. The regions of the second zone are characterized by the greater provision of natural forage lands, a relatively high level of natural soil fertility for the development of meat and dairy cattle breeding. In the third zone, it is advisable to include those regions that combine the highest availability of pastures and sufficient bioclimatic potential for the development of beef cattle breeding. The fourth zone unites the Northern regions of the European part of the country, as well as the Far East, and Siberia, which combine unfavorable natural conditions for the development of cattle breeding and low availability of natural forage lands. The fifth zone should be allocated to Moscow and St. Petersburg, the largest cities in the country, which are characterized by low availability of feed areas, closeness to the average Russian environmental conditions, and the need to import a significant part of the consumed milk and beef.

The role of the specialized zone in the total volume of livestock production should be determined using an economic-mathematical model for the placement of livestock. The modeling of the zonal system of development of the sub-sectors should take into account the characteristic features underlying the classification of regional systems, as well as a combination of livestock sub-sectors that determine the region’s place in the territorial-sectoral division of labor.

To model the optimal placement of livestock, a linear programming model should be used. The optimality criterion can be: maximum profit, minimum cost, maximum gross production (taking into account the satisfaction of needs in cattle meat and milk).
It is advisable to include four sets of variables and five blocks of constraints in the model (Figure 1).

| Variables | Production volumes of livestock | Animal population | Amount of feed used | Economic indicators |
|-----------|--------------------------------|-------------------|--------------------|---------------------|
| I Block. The need for milk and beef | II Block. Production and transportation livestock products | III Block. Need for feed | IV Block. Availability, production and import of feed | V Block. Estimated economic indicators characterizing the process of production, transportation and sale of milk and meat of cattle |

*Figure 1.* Simulation of optimal placement of cattle population and the formation of specialized product areas.

The first block contains restrictions on the maximum and minimum requirements of each zone for each type of livestock production. Restrictions should also include probable milk and beef transport flows from one zone to another. In the second block, conditions are specified that establish the correspondence between livestock products and the livestock of the corresponding group of livestock. The third block consists of restrictions on the optimal feed rations of each livestock group, including conditions on the minimum nutritional value of the feed ration, the share of each group of feed in the diet and the content of certain types of feed in the diet. The fourth block contains conditions that limit the use of certain types of feed, while it is important to consider possible ways of importing missing feed from one zone to another. The fifth block involves the calculation of financial and economic indicators characterizing the process of production, transportation, and sale of milk and beef.

The solution of an economic-mathematical problem according to the proposed model is possible both from actual data and from predicted values. The option of preparing initial data for solving an optimization problem is determined by the study objectives. In order to assess the degree of influence of livestock distribution on the production efficiency, actual data should be used, as well as to determine the promising parameters of production using projected values. The preparation of baseline information begins with a justification of the prospective need for milk and beef and the prediction of livestock productivity for each region of the country and for each age and sex group. Establishing quantitative restrictions on the maintenance of animals in a particular region, one should take into account the possible impact of the achievements of scientific and technological progress, allowing to increase the productivity of livestock, improve the quality of livestock products, more effectively use the resource potential.

When solving the optimization problem, the maximum profit obtained by agricultural producers was selected as the optimality criterion, ensuring that the rational needs of the population in milk and beef were met. Technical and economic indicators of the problem were calculated on the basis of actual data: livestock productivity; selling prices of milk and meat of cattle; the cost of keeping animals, feeding costs, transportation costs; availability of fodder lands. Along with the actual indicators, we used the standard indicators on the nutritional value of feed, the minimum and maximum nutritional standards of feed rations and the content of groups and certain types of feed in the diets, feed output per hectare of forage land.

The improvement of interregional exchange is the most important reserve for reducing the cost of livestock production. Considering the importance of developing interregional ties, the following points were put in the optimization model: (a) production of transportable beef is concentrated where there are the most favorable conditions that would ensure minimization of production costs; (b) perishable
and low-transportable dairy products are made whenever possible in each zone taking into account the needs of the regions [12, 13].

The regions that form the zone of dairy cattle breeding have the opportunity to provide milk not only with “their own” zone, but also with the regions having the potential for the development of beef cattle breeding, as well as importing regions (Fig. 2). From regions with a potential for the development of meat and dairy cattle breeding, it is advisable to ensure the export of milk to the dairy cattle breeding development zone and the largest cities in the country. It is advisable to supply the beef, taking into account transport and production costs from the area of meat and dairy cattle breeding in I, IV, and V zones. The regions with the potential for the development of dairy cattle breeding will be provided with beef (due to its import from the zone of meat and dairy cattle breeding) and the meat and dairy cattle breeding (due to deliveries from the zone with the potential for the development of meat cattle breeding).

Figure 2. Interregional import and export of cattle breeding products of the Russian Federation by zones, t.

Those regions that export livestock products need to use internal reserves of growth of commodity resources to improve the quality of products, optimize the direction of commodity and raw materials flows.

The results of solving the problem confirm that the rational distribution of cattle increases the specialization in cattle breeding, optimizes inter-regional exchanges, allows using the identified reserves of livestock growth, and ensures more efficient use of existing forage land. Thus, it can significantly improve the sub-sector efficiency by increasing the level of self-sufficiency of the country’s milk and beef. Reducing costs will improve the efficiency and competitiveness of livestock products of own production.

The economic effect obtained as a result of optimization of placement, deepening of specialization and improvement of interregional exchange in cattle breeding, based on the interests of consumers of products, is determined by the reduction of total costs for products produced by the sub-industry. The interests of the state in improving the territorial-sectoral division of labor in cattle breeding as a spokesman for the interests of society as a whole, along with the increasing income of commodity producers and the purchasing power of the population consuming milk and beef, are determined by the increase in revenues of state budgets of all territorial levels. Even with the actual level of productivity of cattle for fattening, the break-even management of beef cattle is possible in an area with the potential for its development.

The development of cattle breeding and the deepening of specialization in product areas will allow manufacturers to obtain an aggregate gross profit of 119.9 billion rubles. At the same time, the level of profitability from the sale of milk will reach 26.7% against 6.6% in 2015. Due to the sale of large meat, the cattle loss ratio will drop from 34.6 to 12.4%. A significant increase in economic efficiency
will be achieved by optimizing: rations for feeding animals in dairy and beef herds in each zone, taking into account animal productivity and the availability of forage land; transport of livestock products from specialized areas; allocating livestock by zones, taking into account the productivity of forage lands, the cost of production and transportation of products and selling prices, as well as the increase in the number of livestock animals, taking into account the availability of forage base and natural forage lands in the formed zones.

4. Discussion
Determining the optimal placement, deepening specialization, and increasing the concentration in the cattle breeding of the Russian Federation require the construction of multicomponent models of different levels for the development of the sub-industry as an integrated system. In the study, the authors proposed a model of placement by specialization zones. The next step is to simulate the placement by region for each of the zones. The development of such a system of economic and mathematical models will provide an opportunity to choose the best ways to achieve the goals of livestock production, options for their development.

As a result of solving optimization problems at different levels, trends are determined in the location and structure of agricultural production, the capacity of their markets (both for the country as a whole and for individual regions), the volumes and directions of the commodity flows of milk and beef and their products, taking into account the existing interregional and interstate relations, evaluation of their effectiveness. As a result of the macromodelling of the subsector, the following aspects are determined: (a) directions for the development of cattle breeding based on the needs of the country and its regions in milk and beef; (b) factors that have the most significant impact on the development of the sub-sector with their quantitative assessment; (c) performance indicators of livestock development for different hypotheses of development of the sub-sector.

5. Conclusion
An important and necessary condition for the optimization of interregional commodity flows, including the reduction of interregional differences in the food supply of the population with milk and beef, is the deepening of the territorial-sectoral division of labor in the country’s cattle breeding. To optimize interregional exchange, which is characterized by extensive commodity and raw materials flows and distribution channels for livestock products, it is advisable:

- Comprehensively assessing the current state and location of livestock breeding, identify trends in the development of the subsector, establish territorial, intra-industry, inter-industry, industry, and inter-regional imbalances and reserves for the growth of milk and beef production;
- Assessing the effectiveness of the established interregional food relations and regional agro-industrial specialization, changes in the territorial and sectoral division of labor, and their impact on the development of domestic milk and beef markets;
- Establishing the influence of the region’s agricultural potential, the possibilities of its rational use, as well as the geographical location and level of development of the transport and logistics system on the development of interregional exchange;
- Identifying the needs of the country and its individual regions in meat and dairy products of livestock, taking into account the possible volumes of imports and exports of products and raw materials, as well as the need to create federal and regional operational and strategic reserves of food funds;
- Exploring options for rationalizing the current interregional exchange in livestock breeding, the volumes and optimal directions of interregional food relations, taking into account the reserves of growth of commodity resources for livestock products, changes in the national and
world dairy and beef markets, the possible volumes of export-import supplies of meat and dairy products, and the increased specialization and concentration of agro-industrial production improving its territorial and sectoral structure;

− Developing a sound system of measures to improve the existing interregional relations, combining the deepening of specialization and concentration, developing the cooperative movement, and integrating the production, processing, and marketing of agricultural products, as well as the use of economic and mathematical modeling.

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