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Methodical features for substantiating the directions and evaluations of the effectiveness of innovative development in meat cattle breeding of the region

Características metodológicas para corroborar la efectividad del desarrollo innovador en la cría de ganado de carne de la región

BERSHITSKIY, Yuriy Iosifovich 1; SAFONOVA, Margarita Fridrikhovna 2 & SAYFETDINOV, Aleksandr Rafailovich 3

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ABSTRACT:
A method of substantiating areas and assessing the economic efficiency of the innovative development of the region's meat cattle breeding, based on the construction and analysis of boundary production functions and taking into account the size and heterogeneity of the resource base of producers, is proposed. The results of the economic analysis of indicators of cattle meat production in agricultural organizations of one of the leading agricultural regions of Russia - the Krasnodar Territory. Performance indicators were calculated, and potential volumes of cattle meat produced in the region were identified using the proposed methodology. The analysis of the factors that determine the level of technical, allocative and economic efficiency of meat cattle breeding in the Krasnodar Territory is carried out, and the directions of innovative development of this sub-industry were determined from it.
Keywords: meat cattle breeding; economic

RESUMEN:
Se propone un método para fundamentar áreas y evaluar la eficiencia económica del desarrollo innovador de la cría de ganado de carne de la región, basado en la construcción y análisis de las funciones de producción de límites y teniendo en cuenta el tamaño y la heterogeneidad de la base de recursos de los productores. Se presentan los resultados del análisis económico de los indicadores de la producción de carne de ganado en organizaciones agrícolas de una de las principales regiones agrícolas del Territorio de Krasnodade Rusia. Se calcularon los indicadores de desempeño y se identificaron los volúmenes potenciales de carne de ganado producido en la región utilizando la metodología propuesta. se determinaron a partir de él Se lleva a cabo el análisis de los factores que determinan el nivel de eficiencia técnica, de asignación y económica de la cría de ganado de carne en el Territorio de Krasnodar, y las direcciones de desarrollo innovador de esta sub-

efficiency; boundary production function; resource base; level and directions of development of the sub-industry

industria.
Palabras clave: Cría de ganado vacuno; eficiencia económica; función de producción de límites; base de recursos; nivel y direcciones de desarrollo de la sub-industria.

1. Introduction

From 1990 to 2017, the number of cattle in the agricultural organizations of Russia was continuously reduced, due to the weakening of state support for the industry and a decrease in its resource potential. By 2017, the share of imported commodities in the Russian meat market reached 40%, with the country being almost entirely self-sufficient in poultry and pork meat. One of the main reasons for the current situation is the low profitability of cattle meat production due to the relatively low productivity of animals and the high cost of production.

At the same time, the primary production and economic indicators in the Russian meat cattle breeding sub-industry vary significantly among different producers. For example, in recent years, the live weight of sales of one head of cattle to processing enterprises ranged from 200 to 500 kg for various agricultural organizations. This is justified by the low productivity of the breed composition of animals used in most agricultural organizations, the use of outdated technologies of herd reproduction and fattening. Therefore, the compilation of international experience and the experience of advanced domestic producers will improve the efficiency of meat cattle breeding, increase production volumes, thereby reducing the country's import dependence on this food type.

There are works on assessing the economic efficiency of beef cattle in Western countries, using various methodological approaches (Ceyhan and Hazneci; 2010; Otieno et al., 2012; Rakipova et al., 2003). However, similar studies of the efficiency of beef cattle in Russia are practically absent.

In this regard, the purpose of this work is to refine and adapt the existing methodological tools to the modern features of the production of cattle meat in the regions of Russia.

2. Methodology

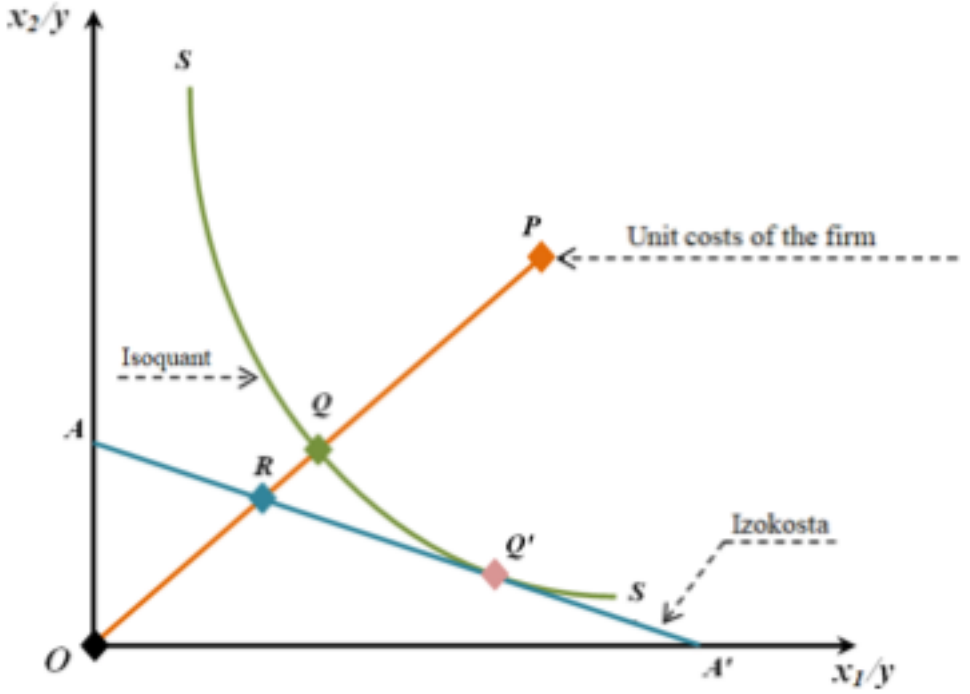
The method for constructing and analyzing boundary production functions based on the methodical approach proposed by Farrell (1957) is the basis for evaluating the effectiveness of the functioning of the sub-industry of beef cattle. The basis of his idea was the assertion that an economic entity can be considered cost-effective only if it produces commodities to the maximum possible extent with the technology used and the available resource base.

The economic efficiency of production can be divided into two components: technical and allocative. Technical efficiency is defined as the ability of a commodity producer in using the technology to produce the maximum possible volume of commodities from a given amount of production resources or to achieve a particular volume of production with minimal production costs. Allocative efficiency is defined as the ability to use it in the production of commodities, the optimal structure of production resources, taking into account the prevailing pricing environment.

Figure 1, which illustrates the unit costs of x1 and x2 production resources in the production of a single type of commodity y, gives a visual representation of the essence of technical, allocative and economic efficiency.

In the figure, the SS' curve (isoquantum) shows the minimum possible unit costs of x1 and x2 production resources, and producers who have reduced their unit costs of resources to this minimum level will be considered technically efficient. Straight line AA' (isocost) shows possible combinations of x1 and x2 production resources, the value of which is constant.

Figure 1
Graphic interpretation of the technical, allocative and economic efficiency of the commodity producer when it is oriented towards reducing production costs



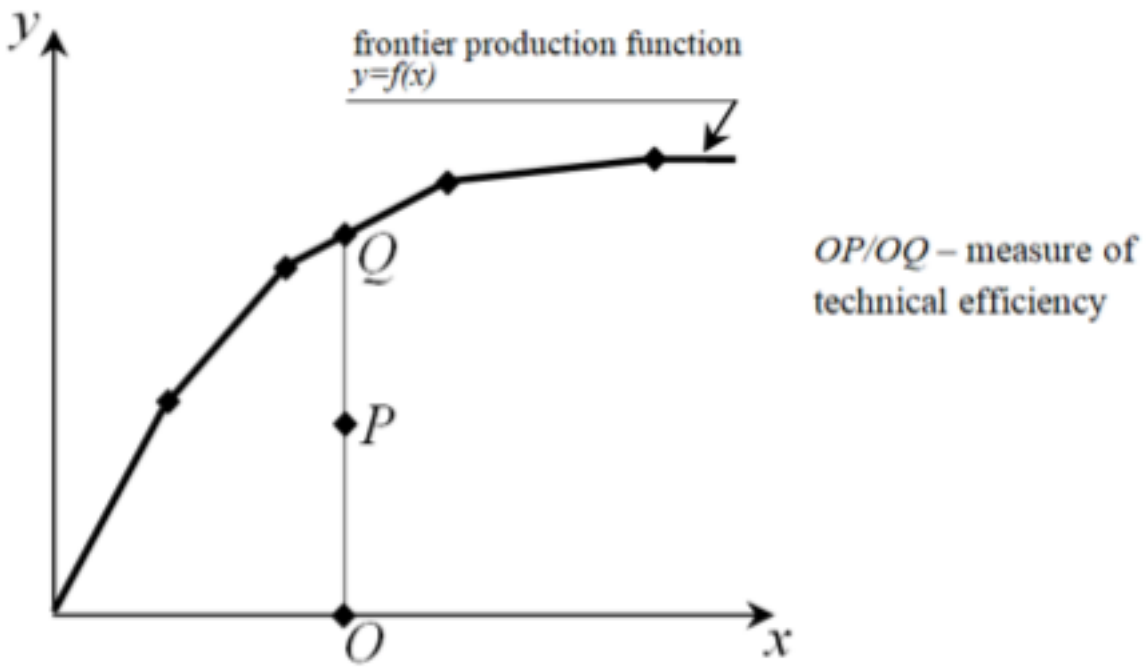
Y – production volumes; x_1, x_2 – production resource costs; *OQ/OP* – technical efficiency; *OR/OQ* – allocative efficiency; *OR/OP* – economic efficiency.

The value of the technical efficiency of an enterprise with specific resource costs corresponding to point P in Figure 1 is equal to the ratio of OQ/OP segments' lengths, which indicates the possibility of reducing the cost of resources without reducing production volumes or degrading the quality of commodities. The allocative efficiency is represented by the ratio of OR/OQ segments' lengths, which shows a possible reduction in production costs when moving production volumes from the technically effective point Q to the technically and allocativelly effective point Q'. Economic efficiency is defined as the production of technical and allocative estimates of efficiency, with RP/OP ratio indicating a possible overall reduction in production costs (Coelli, 1995).

Figure 1 reflects the essence of technical, allocative and economic efficiency with an orientation towards reducing the costs of material and financial resources for a given production volume. However, assessments of technical, allocative, and economic efficiency with such a methodical approach will not always accurately reflect the possibilities of increasing production volumes.

Figure 2 shows a graphical interpretation of the technical efficiency of a commodity producer, with its orientation towards the growth of production volumes for a given volume of production resources.

Figure 2
Graphical interpretation of the technical efficiency of the enterprise with a focus on the growth of production volumes



It is proposed to use a boundary concave non-decreasing production function constructed using non-parametric techniques when focusing on increasing production volumes for calculations of the producer's technical efficiency.

Let us assume that the operating activity k of producers for a certain period is described by set M, such that M={(xi,yi)| i=1,…,k}, where xi=(xi1,…,xin) is the cost vector of n production resources in the i[th] enterprise of the sample (xi∈ℜn+), yi is the volume of production i[th] enterprise of the sample (yi∈ℜn+).
Afriat (1972) depicted the boundary nonparametric production function f(x) in the following form:

$$f(x)=\max_i\left[y^i : x^i \le x\right] \quad (1)$$

Function f(x) is concave if for all sets of production resources xi and non-negative values λi such that Σλi=1, the condition Σλif(xi)≤f(Σxiλi) is met, and non-decreasing if Σxiλi≤x⇒f(Σxiλi)≤f(x). Then, the function f(x) is concave and non-decreasing if the following condition is met:

$$\sum x^i\lambda^i \le x \Rightarrow \sum \lambda^i f\left(x^i\right) \le f(x) \quad (2)$$

Using expressions (1) and (2), Afriat obtained a boundary concave non-decreasing production function f(x), suitable for the set M, in the following non-parametric form:

$$f(x)=\max_\lambda\left[\sum_{i=1}^k y^i\lambda^i : \sum_{i=1}^k x^i\lambda^i \le x, \lambda \ge 0, \sum_{i=1}^k \lambda^i = 1\right] \quad (3)$$

where λ=(λ1,…,λk) is the vector of non-negative "weights," the restriction on the sum of which, in addition to the condition of the function's concavity, is also ensured by the condition of variable returns on the scale of production.
Using function (3), one can determine the potential volume of production of a given commodity producer if it has x production resources and organizing production activities as among the most efficient producers who are close in specialization and scale of production.
The level of technical efficiency of the i[th] commodity producer of the sub-industry (ТЭi) may be calculated using the following formula:

$$ТЭ_i = \frac{y^i}{f\left(x^i\right)} \quad (4)$$

The potential volume of production for all k producers of the sub-industry from their production resources and using similar technologies can be determined using the following formula:

$$Y_1 = \sum_{i=1}^{k} f\left(x^i\right) \tag{5}$$

where Y1 is the potential commodity production volume of all k producers.

The potential production volume of Y1 commodities is "limited from above" by the technological capabilities of the enterprises of the sub-industry and the production resources available to them, whose structures remain unchanged. However, restrictions on the volume and structure of production resources in the task (3) can be replaced by limiting the total cost of their set.

Let us assume that the operating activity k of the commodity producers of the analyzed sub-industry for a certain period is described by set P such that P={xt,yt,pt| t=1,…,k}, where pt=(p1t,…,pnt) is the vector of prices for production resources(pt∈ℜn+), and Ct=pt'xt is the amount of the production costs of the tth producer to produce the production volume of yt. Combination of production resources xt is optimal for production volume yt from the position of allocative efficiency if this combination is "in balance" with the price vector pt. Otherwise, there is a set xs such that f(xs)≥yt and Ct≥pt'xs.

If production is not allocatively efficient, a source of growth in its production volumes can be not only an increase in technical efficiency within the available production resources but also an adjustment of their structure. In this case, the potential output can be calculated using the following linear task (Afriat, 1972):

$$B\left(f(x), p^t, C_t\right) = \max_{\substack{\lambda=(\lambda_1,\ldots,\lambda_k) \\ x=(x_1,\ldots,x_n)}} \left[\sum_{i=1}^{k} y^i \lambda^i : \sum_{i=1}^{k} x_j^i \lambda^i \le x_j, \forall j, p^t{}'x \le C_t, \sum_{i=1}^{k} \lambda^i = 1, \lambda^i \ge 0, \forall i \right] \tag{6}$$

Evaluation of economic efficiency of production activities of the i^{th} commodities producer of the sub-industry (ЭЭi) can be calculated using the following formula:

$$ЭЭ_i = \frac{y^i}{B\left(f(x), p^i, C_i\right)} \tag{7}$$

Taking into account that the estimates of economic efficiency are the commodities of evaluations of its technical and allocative components, the allocative efficiency of the i^{th} producer of the sub-industry (АЭi) can be calculated using the following formula:

$$АЭ_i = \frac{ЭЭ_i}{ТЭ_i} \tag{8}$$

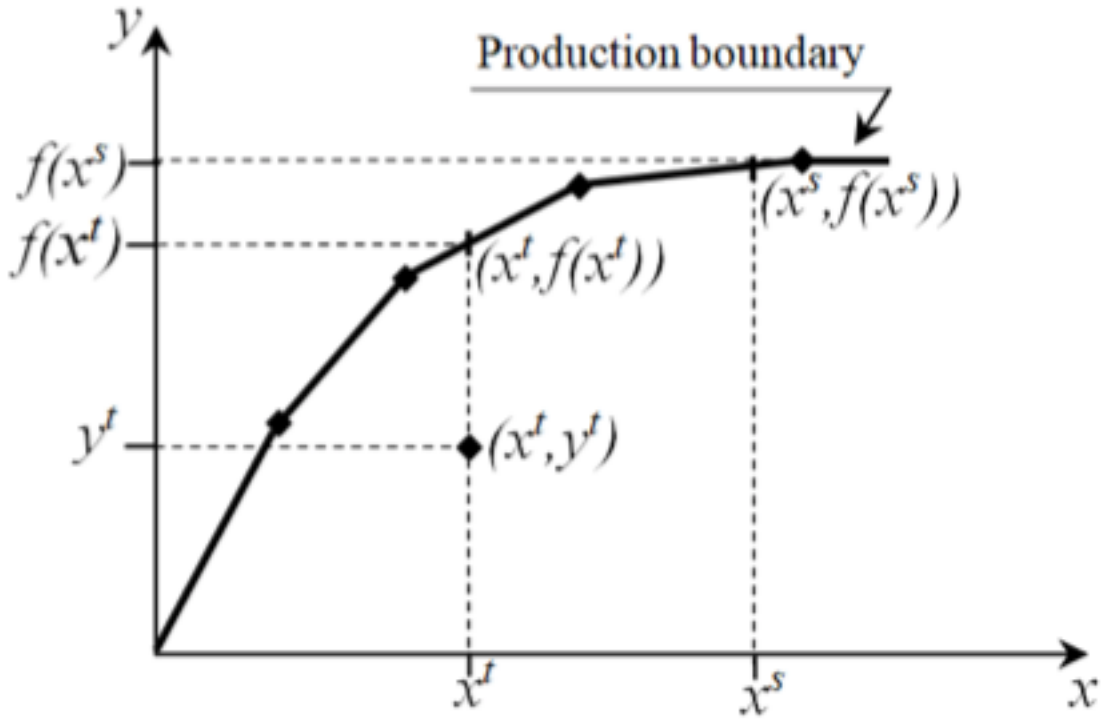
Equation (5), taking into account the allocative component of estimating the potential volume of production for all k producers of the sub-industry, will take the form of:

$$Y_2 = \sum_{t=1}^{k} B\left(f(x), p^t, C_t\right) \tag{9}$$

Figure 3 presents a graphical interpretation of the estimate of the potential production volume of commodities by producers, taking into account the allocative and technical components. The x-axis shows the resources x, which ensure the production of commodities y. Point (xt,yt) describes some production that has not reached the potential output f(xt). Every point of the boundary production function f(x) at given prices p has a corresponding certain minimum value of the set of resources C(p,f(x)), which is sufficient to achieve boundary output f(x), at that p'xt≥C(p,f(xt)) by default. Given that C(p,f(x)) is a non-decreasing function, and if p'xt>C(p,f(xt)), then there is f(xs)≥f(xt) such that C(p,f(xs))=p'xt. Then by replacing the set of resources xt with the set xs, the potential output may “move” along the production boundary to a point (xs,f(xs)).

Figure 3

Graphic interpretation of the assessment of the potential production volume, taking into account the technical and allocative components of economic efficiency



In the considered method, the potential for increasing the volume of production for individual producers is determined by the performance indicators of the leading producers in the sub-industry. The number of economic entities included in the sample under study affects the boundary characteristics of the best of them, shifting them in one direction or another. In the formation of samples of producers used to construct production functions, it is necessary to consider the following conditions: the assumption of the using the general production technology for all the producers included in the sample and the homogeneity of the production resources used by them.

The task (6) allows perfect elasticity of the supply of production resources in the region. However, when it comes to a sufficiently large group of producers or an entire sub-industry, then changes in the volume and structure of production resources used also cause changes in their prices in the market, and sometimes they may not be feasible due to the shortage of some of their species in the region.

To solve this problem, the authors propose to combine model (6) with a particular model of the market of productive resources, imitating their structural, dimensional and price changes (Bershitskiy and Sayfetdinov, 2016).

In this case, the potential production volume in the group of producers, taking into account the technical and allocative components of economic efficiency and available production resources, can be determined by solving the following linear problem:

$$B\begin{pmatrix} f(x), p^q, C_q, \\ q=1,\ldots,m \end{pmatrix} = \max_{\lambda,x}\left[\begin{array}{l} \sum_{j=1}^{m}\sum_{i=1}^{m} y^i \lambda^{ij} : \\ \sum_{i=1}^{m} x_n^i \lambda^{ij} \le x_n^j, \forall j,n,\ p^q x^j \le C_q, \forall q, j=q, \\ \sum_{j=1}^{m} x_n^j \le \sum_{q=1}^{m} x_n^q, \forall n, \sum_{i=1}^{m} \lambda^{ij} = 1, \forall j, \lambda^{ij} \ge 0, \forall i,j \end{array}\right] \quad (10)$$

The result of solving the problem (10) is potentially possible production volumes of m producers conducting economic activities in some territorial boundaries of the region, with the most efficient use of their production resources. It is assumed that business entities may have any other structural and volumetric composition of production resources under the current pricing environment. The correctness and adequacy of the developed methodology were tested in evaluating the effectiveness and substantiation of the directions for the development of beef cattle breeding in one of the leading agricultural regions of Russia - the Krasnodar Territory.

3. Results and discussion

The livestock of cattle in Russia in recent decades has demonstrated a negative trend: in 2017, there were 19.2 million heads, which accounted for 35% of the level in 1991 (Table 1). At the same time, the 90s of the transition to a market economy were the most destructive for domestic cattle breeding, when the number of cattle in farms of all categories of the country was halved. Since 2005, the rate of decline in livestock began to slow down, and in some years of this period, even its growth was noted.

In the same period, there were noticeable structural changes in the distribution of cattle livestock by groups of producers. Most of all, the livestock of this species has declined in agricultural organizations.

In the period from 1991 to 2017, the production of cattle live weight in farms of all categories of the country has more than halved to 2.8 million tons.

Table 1
Livestock and production volumes of
cattle live weight gains in Russia

					2017

Indicator	1991	2000	2010	2017	in % to 1999
Cattle livestock, thous. heads	54,677	27,520	19,968	19,253	35.2
Including: in agricultural organizations	43,911	16,509	9,257	8,295	18.9
in peasant (farming) economies	112	543	1,476	2,691	in 24 times
in population farms	10,654	10,468	9,236	8,267	77.6
Production volumes of cattle meat in live weight, thousand tons	6,361	3,212	2,968	2,826	44.4
Including: in agricultural organizations	4,551	1,374	1,003	938.5	20.6
in peasant (farming) economies	0	59	177	255.3	–
in population farms	1,810	1,780	1,789	1,632	90.2

Similar negative dynamics in the production of cattle meat was observed in the Krasnodar Territory. Cattle livestock in the agricultural organizations of the region from 2000 to 2017 decreased from 737 to 352 thousand heads or 2.1 times. During this period, the production of cattle meat decreased from 78 to 48 thousand tons or 1.6 times (Table 2).

The values of the principal specific production indicators in the region's beef cattle breeding remain low compared with the level typical for leading agricultural organizations in the country specializing in the fattening of animal meat breeds.

The insufficiently high level of these indicators is one of the main reasons for the loss of production of cattle meat in the region.

Table 2
Production and economic indicators of beef cattle in agricultural organizations of the Krasnodar Territory, 2000–2017

Indicator	2000	2010	2017	2017 in % to 2000
Cattle livestock, thous. heads	737	440	352	47.8
Including cows:	279	164	132	47.3
Production of cattle meat in live weight, thousand tons	78	64	48	61.5
The output of calves per 100 cows, heads	78	72	70	89.7

Average daily weight gain of cattle, g	437	619	642	146.9
Average live weight of sales of one head of cattle, kg/head	344	351	365	106.1
The production cost of cattle meat, rubles/kg	30	83	142	in 4.7 times
Unprofitable sales of commodities, %	-36	-26	-30	-

Calculations of indicators of technical, allocative and economic efficiency of production of cattle meat were carried out based on the results of production activities of 165 agricultural organizations of the Krasnodar Territory, engaged in 2017 in breeding and fattening cattle. For this, 652 linear programming tasks (3) and (6) were solved. The analysis of the results showed that a significant part of the agricultural organizations in each agro-climatic zone of the Krasnodar Territory is technically efficient (34, 32 and 11 producers in the North, Central and South Piedmont zones, respectively). The weighted average values of technical efficiency indicators indicate that the agricultural organizations of the Krasnodar Territory, engaged in the production of cattle meat, have the potential to increase production volumes.

Currently, in the region, more than 90% of cattle weight gain is produced from dairy animal breeds. At the same time, it has been established that even if the breed composition of livestock and the applied technologies of reproduction, rearing, fattening and the prevailing price situation are maintained, the production of cattle meat in the region may be increased by 11.4 thousand tons or by 22.5% due to livestock, optimizing the structure of feed rations of animals of different age and sex groups, as well as the complete mechanization and automation of production processes (Bershitskiy and Sayfetdinov, 2016).

Studies also showed that it is possible to significantly improve the efficiency of the cattle breeding of the region by providing the breeding stock and young animals in the early stages of the production cycle with cheap pasture feed. In this case, the cost of gains in live weight of cattle can be reduced by more than 25% (Bershitskiy and Sayfetdinov, 2017).

The experience of countries with developed beef cattle and selected advanced Russian agricultural enterprises engaged in cattle meat production has shown that to speed up the formation and reproduction of cattle herd, it is economically feasible to apply artificial insemination of cows by elite meat breeds, which allows up to 90% of male calves for subsequent rearing and final fattening. The calculations showed that insemination of up to 70% of cows using this innovative technology will not only accelerate the processes of formation and reproduction of a highly productive herd of cattle but also significantly reduce the amount of investment in the replenishment and renewal of brood-stock of expensively imported animals of beef breeds (Bershitskiy and Sayfetdinov, 2017).

Comparative evaluation of the effectiveness of various areas and forms of state support for animal husbandry in the Krasnodar Territory over the last 5–7 years has shown that the state budget funds have the highest return in compensating part of the industry's production costs, as well as subsidizing part of the interest rate on investment loans (Bershitskiy et al., 2016). Taking this into account, the government recommends partial reimbursement of expenses for the purchase of imported heifers and heifers of elite beef breeds divided by sex and bull seed for reproductive farms and complexes, as well as for subsidizing part of the interest rate on bank investment and short-term credits allocated to the construction and organization of the functioning of livestock production facilities.

The results of the research allowed performing calculations of the forecast indicators of the medium-term development of the sub-industry of specialized meat cattle breeding in the Krasnodar Territory, presented in Table 3.

Table 3

Forecast indicators of the medium-term development of the sub-industry of specialized meat cattle breeding in the Krasnodar Territory

Indicator	Value at the beginning of 2017	Forecast for 2026
Cattle average annual livestock in agricultural organizations, thous. heads	352	434
Including meat and cross-breeds, thous. heads	24	192
Of them breeding stock	8	40
fattening calves	3.8	74
The share of meat cattle in the total number of cattle, %	6.8	44.0
Production volumes of cattle meat in agricultural organizations, thousand tons	48	74.6
Including from fattening animals of meat and cross-breeds thousand tons	3.7	60.9
The average cost of production of cattle meat, rubles/kg	142	120
The average selling price of the live weight of cattle, rubles/kg	100	147
Production profitability, %	-30	22

Analysis of the forecast results shows that the practical implementation of economically sound organizational, economic and technological measures will increase the number of cattle from 20 to 192 thousand heads by 2026 and increase the share of meat cattle in the total livestock from 7 to 44%. This will ensure an increase in the production of cattle meat in the region by 26.6 thousand tons or 55%, a reduction in production costs by 15%, which, in turn, will allow overcoming the current unprofitability of production in the sub-industry and bring its profitability to 22%.

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4. Conclusion

In order to assess the economic efficiency of meat cattle breeding in the region, an author's methodical approach is proposed based on comparing the parameters of boundary production functions determined by the results of production and economic activity of the most efficient economic entities engaged in feeding cattle and having close to optimal scales of industry production and the structure of production resources the moment of calculation of price conjuncture.

An analysis of the state of the meat cattle breeding sub-industry in the Krasnodar Territory in 2017 showed that more than 90% of the production of cattle meat in the agricultural organizations of the region produces dairy breeds from livestock. Analysis of the parameters of the boundary production function, based on the results of economic activities of 165 agricultural organizations of various climatic zones of the Krasnodar Territory engaged in the production of cattle meat, showed that only in 17 of them the production of this type of commodity is cost-effective. The analysis also showed that even with the existing production technology and the prevailing price situation, the volume of production in the sub-industry

could be increased by 11.4 thousand tons or 22.5% due to a more rational use of production resources and optimization of their structure.

It is economically most efficient to organize the processes of formation and reproduction of the herd for the production of cattle meat using the technology of artificial insemination of cows with the bull-seed of elite meat breeds divided by sex. This will ensure the rapid growth of the livestock of highly productive animals of mixed and meat breeds for fattening and significantly reduce the amount of investment in the replenishment and repair of expensively imported breeding stock of animals.

Comparative evaluation of the effectiveness of various areas and forms of state support for livestock in the Krasnodar Territory allowed to justify the priorities of such support in the formation and development of the specialized meat cattle breeding sub-industry, which included targeted subsidies for the purchase of elite meat cattle breeds for reproductive farms and complexes divided by the sex of the seed bulls, as well as subsidizing part of the interest rate on bank investment and short-term loans, for the construction and organization of the operation of livestock facilities.

Calculations of indicators of the medium-term forecast of the development of the sub-industry of meat cattle breeding in the Krasnodar Territory, made using the results of the present study, showed that the implementation of the proposed and economically sound measures will increase the cattle stock of meat breeds from 2426 to 106 thousand heads and mixed breeds - up to 53 thousand heads. This, in turn, will ensure an increase in the production of cattle meat in live weight from 3.7 to 61 thousand tons at an average cost of 100–120 rubles/kg.

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1. Kuban State Agrarian University, 13 Kalinina Street, Krasnodar, Russian Federation

2. Kuban State Agrarian University, 13 Kalinina Street, Krasnodar, Russian Federation, marharyta.safonova@yandex.ru

3. Kuban State Agrarian University, 13 Kalinina Street, Krasnodar, Russian Federation

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