ИКОНОМИЧЕСКИ ИЗСЛЕДВАНИЯ
ECONOMIC STUDIES
Volume 28 (5), 2019

Angel Sarov[1]
Krasimir Kostenarov[2]

AN EMPIRICAL APPROACH FOR OPTIMIZING THE PRODUCTION STRUCTURE OF A FARM OPERATING IN A MOUNTAIN AREA

This study analyses the effect and the impact of Common Agricultural Policy (CAP) subsidies on the production structure of a selected agricultural enterprise operating in a mountainous area. On the bases of mathematical model of the economy is to optimize the gross margin and the farm profit by allocating available resources according to the restrictions imposed. During the process of solving them, we considered into account many complex factors and dependencies. It is concluded that subsidies received under CAP have no impact on the structure of production. The article presents one case from which no general conclusions can be drawn about the effect of CAP subsidies on all farms. When applying the model in practice, it should be borne in mind that the model results have a number of conventions, which is a challenge for managers not to make hasty decisions based on the optimization of the task's solution.
JEL: C36; C54; C61; Q12; Q18

1. Introduction

The aim of this study is to test the mathematical model to examine the impact of CAP subsidies on optimizing the structure of production in the Bulgarian agricultural enterprise operating in a mountain region. Additionally, we want to check the level of applicability of linear optimization in studying the impact of the CAP subsidies. It should be stressed that only the effect of subsidies on the production structure of the farm is studied, not entirely from the CAP, which has many other mechanisms of impact on farms.

In the world's economic science literature there are publications in which linear programming is applied to optimize economics and mathematical models. Including: Dantzig, George (May 1987); Roger Fletcher (2000); Robert J. Vanderbei (2013); Piryonesi, S. M., & Tavakolan, M. (2017), etc.

[1] *Ch. Ass. Phd Angel Sarov, PhD, Institute of Agricultural Economics, Sofia, e-mail: angelsarov@abv.bg.*
[2] *Ch. Ass. Phd Krasimir Kostenarov, PhD, Department of Economics, New Bulgarian University, Sofia, e-mail: kraskostenarov@yahoo.com.*

Some of the first publications in Bulgaria related to economics models are in the planning of domestic trade. Later there are researches on planning the production (Георгиев, Т, 1973); for forecasting and planning the national economy (Владимирова, К., 1981); in trade (Младенов, З., кол., 1984), (Александров, Кр., 1986); linear optimization models (Аврамов, А., Грозев, С., 1991); in agriculture (Николов, Н., 1998), (Николов, Н., Иванов, Г., Стефанов, Л., 1994). In the more recent publications one can see Абрамова, Г, (2003); Ivanov, I. and Dobreva, J. (2007); Пушкарова, А. (2010); Добрева, Ю. (2011); Милкова, Михайлов (2016).

In regard to analyzes concerning CAP subsidies and productivity of the EU farms, some studies (Rizov, Pokrivcak and Ciaian, 2013) use a structural semiparametric estimation algorithm; Svobodová & Věžník, (2012); Bachev, (2013) – questionnaire survey; Galluzzo, (2016) using FADN Dataset. There have been studies, which analyze the effect of CAP subsidies according to the Econometric model (Arovuori, & Yrjölä, 2015). Some studies analyse marginal returns and level of subsidizing through stochastic models (Ivanov, 2016). Other (Křístková, Habrychová, 2011) analyze direct payments to agriculture by applying Computable General Equilibrium (CGE) models. Ciliberti & Frascarelli, (2015) – a critical assessment of the implementation of CAP 2014-2020 direct payments. Kaneva, et al. (2005) analyzes the efficiency of production structures in Bulgarian agriculture using the DEA model.

Agro-economic problems concern the group of the most complex (Николов, Н., 1998). During the process of solving them, we have to take into account the many complex factors and dependencies. This results in many possible solutions of the problems that can vary, depending on the goals set. However, with the help of the mathematical model, it is impossible to take into account the impact of all factors that affect the activity of agricultural enterprises. In practice, it is a hard task to find the best (optimal) solution. This is because reality is much more complex than what can be included into a model (Николов, Н., Иванов, Г., Стефанов, Л., 1994). More and more accurate (real) information is needed. Mathematics model does not allow to take into account informal relationships that do not have quantitative dimensions (habits, traditions, preferences).

2. Material and Methods

We constructed this task in a system of linear dependences. They should reflect the conditions to be taken into account when solving the task. The objective function expresses the optimality criteria (min, max):

$$A_{11}X_1 + A_{12}X_2 + \cdots + A_{1n}X_n \leq B_1$$
$$A_{21}X_1 + A_{22}X_2 + \cdots + A_{2n}X_n \geq B_2$$
.
.
$$A_{m1}X_1 + A_{m2}X_2 + \cdots + A_{mn}X_n = B_1$$

$$F = C_1X_1 + C_2X_2 + \dots + C_nX_n \to \max\ (min), \qquad (1)$$

Where:

- X_j – indicates the size (magnitude) of the activities or metrics,
- A_{ij} and C_j – indicate the activities that will be done,
- B_i – means the amount of available resources or the amount of activities (restrictions).
- The objective function F gives the optimality criteria.

The solution of the model will answer the following questions:

1. Establishing the optimum production structure according to the constraints and the optimality criteria;
2. Establishing the impact of the CAP subsidies on efficiency and production structure, depending on the chosen optimal criteria;

In order to establish the production structure of the selected agricultural holding, it is necessary to determine the area of the crops; the number of animals and other activities. When developing the model the optimality criteria will be (max Gross Margin). We will also study the influence of the CAP subsidies. Additionally, we will set another criterion for optimality – max profit (with and without CAP subsidies).

3. Exposition

3.1. Development of the model and an assessment of the impact of the CAP subsidies on the production structure of an agricultural farm operating in a mountainous area

According to established experts and researchers in agri-economic science, it is established that the agricultural farms in the mountainous regions have mixed specialization – agriculture and livestock.

Description of the farm

The necessary information was gathered with the assistance of specialists from the studied farm.

The farm is a legal entity registered under the Commercial Law as a solely limited liability company. Its activities are in a mountainous area on a territory of Sofia region. For this area are common cinnamon forest soils, falling in the group of infertile lands in the Bonity rating 0-20 ball, 10^{th} category. Climate conditions create prerequisites for growing the following crops of wheat, rye, vineyards, fruit trees, late vegetables.

The management is located in the lands of the former cooperative union. At the beginning of the 1990s, an agricultural cooperative for production and services was set up, but after 2010 it ceased agricultural activity.

The farm pays to the cooperative a rent, which is used for storage of grain – BGN 650 per year. The farm is equipped with modern equipment – John Deere tractors and harvesters.

Production

In its production activity, there is a mixed plant breeding specialization. The farm does not own land. It rents 2 thousand decares (da). It pays a rent of BGN 24/da. In addition, 1500 da of pastures / meadows are rented from the municipality for the feeding of the animals. They are used both for animal grazing (green food) and for hay. They are distributed as follows: 500 da of municipal land and 1 000 da of white spots. The municipality pays municipal rent of BGN 8 per decare per year. There is no additional opportunity for hiring land in the area because it is too organized as a production resource. There are no irrigation facilities built on the land.

Plant growing activity

On the rented land are cultivated wheat – 700 da; barley – 300 da; sunflower – 700 da; maize for silage – 300 da. Wheat, barley and sunflower are also grown for commodity crops, except for animal feed. The wheat could be sold at BGN 0.27 / kg, the barley – 0.26 BGN / kg, the sunflower – 0.65 BGN/kg. For the purpose of the model we assume that the products can be purchased at the same price. The yield of wheat is 400 kg/da; barley – 500 kg/da; sunflower – 200 kg/da. According to the studies, the amount of straw is about 40% of the yield. We assume an average of 180 kg/da. We do not apply the sunflower rotation requirement (1/6 of the area). The yield of silage maize is 1 tonne/da.

Livestock activities

The farm has the opportunity to grow up to 100 cows. At the moment there are 75 dairy cows with an average of 10 liters of milk per day or about 3600 liters per year. The breeds are the following: "Bulgarian Rhodope govedo" and "Iskarsko govedo". Due to the commitment because of the subsidy received, the farm is obliged to grow a minimum of 20 animals of every breed. Every day the produced milk is bought from a processing plant at a price of BGN 0.70 / l. At this stage, cows are fed on a level of 4000 liters milk per year. The necessary food for animal feeding is farms own production. Additionally for the ration of the animals can be bought concentrated fodder at the price of BGN 0.65/kg. On the farm, cows are fed according to a rationally determined by the zootechnics, in agreement with the farm manager.

The required Net Energy Lactation (NEI) per year for one cow will be determined according to the technical and economic standards. According to zootechnical requirements, we assume that the relative share of fodder to get the required NEI may vary within the following limits:

1. Concentrated Feeds from 20 to 40% from the necessary NEI;

2. Silage – from 30 to 48% of NEI;
3. Hay – from 5 to 12% of NEI;
4. Green fodder – from 10 to 20% of NEI;
5. Straw – maximum 10%.

The bred cattle are of the following breeds – "Bulgarian Rhodope Govedo" – 55. The milk of this breed is small, but due to commitments under Measure "Agroecology" and the subsidies taken are obliged to select them for 5 years. In addition there are 20 cows "Chernoshareno Govedo" breed.

<u>Labor resources</u>

There are permanently 9 people employed on the farm, distributed as follows: 3 mechanics with gross remuneration at 1100 BGN/monthly (13 200 BGN/year); 2 general workers with 1000 BGN (12 000 BGN/year); 2 breeders with 1100 BGN /month (13 200 BGN/year). These labor costs will be considered as variable costs because they depend on the amount of activity performed and may in practice vary. The salary costs of the administrative and managerial staff will be included in the column of permanent costs: 1 agronomist – BGN 1000 (12 000 BGN/year); 1 zootechnician – BGN 1000 (12 000 BGN/year); accountant (cashier and human resources) BGN 1,000 (12,000 BGN/year); manager – 15 000 BGN/year. Additionally, temporary support of 70 working days for general work and up to 90 working days for mechanized activities can be recruited on a monthly basis. Payments are BGN 30 per day for a general worker and 40 per day for a mechanic. Annually a single worker and mechanic can provide 240 working day, and one livestock breeder – 280 working days. The maximum number of permanent workers on the holding may not exceed 18 people. The months with the highest labor pressure are July, August and September. The number of days during which it is possible to carry out fieldwork in the months with high labor tensions are respectively: July – 26 working days; August – 26 business days; September – 24. When mechanics do not carry out mechanized activities, they can do a common job.

<u>Additional information</u>

According to the technological requirements, the following restrictions must be observed:

1. Autumn crops under non-irrigating conditions occupy not less than 45% and not more than 55% of the crop rotation area;
2. The sunflower does not occupy more than 17% of the crop rotation (1/6).

Since the aim is to assess the impact of the CAP on the efficiency and structure of production, information relevant to their application on this farm is needed.

The farm has received subsidies under 1 Pillar of the CAP for 2017 as follows:

1. 41 BGN/da, distributed as follows – BGN 19,50 under Single payment per area scheme, BGN 12.50 green payments, BGN 9 for disadvantaged areas;
2. 75 animals (419 BGN/animal) Scheme 11 for support for dairy cows and / or meat cows under selection control.

The development of feeding normative is an important step in collecting information. For different crops, livestock and other activities are developed a set of norms, depending on whether the activity is commodity or not. Commodities are the activities from which the final output is obtained, ie production for sale. These are wheat, barley, sunflower, cow's milk. Not commodity is the production that is used in the product cycle for producing milk like: 1 / fodder crops needed to feed the animals – wheat, barley, sunflower, silage maize; 2 / Animals for carrying out the reproduction process. For the different activities, norms are developed for 1 da or 1 tonne of production. The optimal ration is the one that satisfies the maximum zootechnical feed requirements of the respective group of animals. This includes obtaining the necessary NEI, energy, cost, etc.

3.2. Setting the model

In order to determine the production structure of the selected mountain farm, it is necessary to determine the area of the crops, the number of animals and other activities to achieve maximum economic impact. During the developing of the model, the criterion is to achieve the maximum gross margin with the inclusion of CAP subsidies and without applying them. The solution of the problem will also answer the questions regarding the most cost-effective production processes for crop production (for feed and commodities) and for livestock breeding (cows, feeding for 4000 l milk, ration: winter, summer). On the other hand, the model provides the opportunity to quickly and easily develop different options for optimizing the production structure in case of a change of production or some of the limiting conditions. Additionally, the decision will present the impact of CAP subsidies on the production structure and, accordingly, on the economic outcome. The production structure in the case at hand depends on the specifics of natural conditions and limiting factors. On the chosen farm, the organizational conditions are as follows:

1. The quantity and quality of the land (impossibility to rent more land, low bonitete estimate, non-irrigated conditions, etc.).
2. The amount of grazing meadows.
3. The quantity and quality of the main productions (breeds of selected animals, milking, presence of cowshed, warehouses, etc.).
4. Labor resources (number of permanently employed workers, plant breeders, stock-breeders, mechanics, zootechnics, agronomist, etc., a possibility for additional labor force hiring in periods of high labor stress).
5. Agrotechnical crop rotation requirements (minimum/maximum limits in which they may vary, green/dry weight ratio).

6. Zootechnical conditions regarding the feeding of animals according to the milking (ration/winter, summer, green, dry, concentrated, fodder).
7. Contracts to buy milk, sale of commodity crops.
8. Ability to purchase concentrated fodder.
9. Prices of marketed production and means of production.

For the purpose of optimization the objective function we use the Solver application in MS Excel. The solver is an application that can be used to find an optimal solution (minimum or maximum) of an equation that is subject to various constraints.

3.3. Development of the mathematical model

<u>Constraints on land use</u>

$$\sum_{j \in M_i} X_{ij} \leq B_i \qquad (2)$$

Where:

M_i – a set of indexes, denoting the area of the j-culture;
x_{ij} – the area j-th crop on the i-th rented land;
B_i – rented land from category i.

<u>Constraints on min / max size of the areas of the autumn crops</u>

$$\sum_{j \in M} X_j - k \sum_{j \in N} X_j \geq; \leq 0 \qquad (3)$$

where:

к – min / max relative share of areas of autumn crops;
M – a set of unknown variables x_j, describing the area of autumn crops със слята
N – a set of unknown variables x_j, expressing the area of crops in crop rotation.

<u>Constraints on agro-technological requirements of sunflower to crop rotation (1/6 of the crop rotation area)</u>

$$X_j - k \sum_{j \in N} X_j \leq 0 \qquad (4)$$

where:

к – a coefficient representing the crop rotation area of the j-th culture;
N – a set of unknown variables x_j, expressing the area of crops in crop rotation.

Constraints on labor resources

$$\sum_{j=1}^{n} A_{ij} X_j \geq; \leq B_2 \qquad (5)$$

where,

A_{ij} – the quantity of the i – th resource required to carry out one unit of j – activity or the quantity of the i – th product obtained by the one unit of j – activity

B_2 – labor resources.

Constraints for min / max number of dairy cows

$$\sum X_i \geq; \leq B_j \qquad (6)$$

i∈I

where,

I – a set of unknown variables, indicating the number of cows of the i-th breed

B_j – min / max number of dairy cows;

Constraints for min number of dairy cows under selection control

$$X_i \geq S_i \qquad (7)$$

i∈I

where:

I – a set of unknown variables, indicating the number of cows of the i-th breed

S_i – minimum number of cows of the i-th breed

Constraints on the feed balance

$$\sum p_{Mi} X_{Mi} - \sum d_{Mi} X_{Mi} - \sum d_{Mi} X'_{Mi} = 0 \qquad (8)$$

м∈M i∈I

where:

M is the sum of the indices of the unknowns of the different feeds in NEI

I – a set of unknown variables, indicating the number of animals

p_{Mi} – the need for the fodder in NEI for one animal

d_{Mi} – NEI of a M-th fodder, produced in the farm

x'_{Mi}- the amount of M-th fodder purchased to feed the animals

Constraints on the minimum and maximum limits of the NEI of a given type of feed

$$X_{dit} - k \sum X_{dit} \geq; \leq 0 \qquad (9)$$

d∈*S* s∈*U*

where:

S – a set of indexes of the variables Xdit, expressing the NEI of the d-th fodder required for animal feed

U – a set of indexes of the variables Xdit, expressing required NEI for one animal

к – minimum / maximum share of NEI of the s-th fodder

Linking activities (the amount of one depends on the amount of other activities)

$$\sum_k A_{ik} X_k \leq \sum_k A_{ir} X_r \qquad (10)$$

where,

$X_к$ is the amount of activities that depend on the amount of other activities,

X_r is the amount of activities that depend on the amount of other activities,

$A_{iк}$ and A_{ir} are coefficients, which determine the proportions between-group *k* activities and activities form group *r*,

Objective function

Fmax (gross margin/profit) = $\sum_{j \in T}^{n} C_j X_j$ (11)

where:

C_j is (gross margin/profit) from j-th unknowns;

T is the aggregate of the indices of the unknowns from which the gross margin / profit is obtained;

X_j – is the j-th unknown variables.

3.4. Creating unknown variables and limitations

To determine the impact of CAP policies on the economic efficiency of the farm, we define the following unknown:

X_1 – wheat (da)

X_2 – barley (da)

X_3 – sunflower (da)

X_4 – maize for silage (da)

X_5 – pasture meadows (da)

X_6 – hay for feed, own production (t)

X_7 – Purchased concentrated fodder (CF) for cows (t)

X_8 – own concentrated fodder for cows (t)

X_9 – green feed (m)

X_{10} – straw for feed, own production (t)

X_{11} – purchased hay for feed (t)

X_{12} – cows – 4 tons of milk (number)

X_{13} – rented land (dca)

X_{14} – general workers, permanent workers (number)

X_{15} – mechanics, permanent workers (number)

X_{16} – livestock farmers, permanent workers (number)

X_{17} – Revenue (BGN, thousand)

X_{18} – variable costs (BGN, thousand)

X_{19} – labor costs (BGN, thousand)

X_{20} – fixed costs (BGN, thousand)

X_{21} – Gross margin (BGN, thousand)

X_{22} – Profit (BGN, thousand)

X_{23} – NEI (number)

X_{24} – administrative costs (BGN)

X_{30} – wheat, commodity (da)

X_{31} – barley, commodity (da)

X_{32} – sunflower, commodity (da)

After determining the unknown variables, we develop the necessary constraints expressing in a mathematical form the different conditions and requirements that we need to comply with in the optimal plan.

The constraints are:

I. First group of constraints on land use requirements

1. Constraints on rented land (da)

$$X_{13} = 2000 \tag{12}$$

2. Relationship between agricultural crops and rented land

$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 = 2000 \tag{13}$$

3. Meadows constraints (da)

$$X_5 \leq 1500 \tag{14}$$

4. Autumn crops, at least 45% of the crop rotation area (da)

$$X_1 + X_2 + X_{30} + X_{31} \geq 900 \quad (15)$$

5. Autumn crops, max 55% of the crop rotation area (da)

$$X_1 + X_2 + X_{30} + X_{31} \leq 1100 \quad (16)$$

6. Sunflower, a maximum of 17% of the crop rotation area (da)

$$X_3 + X_{32} \leq 340 \quad (17)$$

II. A second group of constraints on the use of labor resources

7. workers, maximum (number)

$$X_{14} + X_{15} + X_{16} \leq 18 \quad (18)$$

8. workers, minimum (number)

$$X_{14} + X_{15} + X_{16} \geq 9 \quad (19)$$

9. general workers, maximum (number)

$$X_{14} \leq 6 \quad (20)$$

10. general workers, minimum (number)

$$X_{14} \geq 3 \quad (21)$$

11. mechanics, maximum (number)

$$X_{15} \leq 6 \quad (22)$$

12. mechanics, minimum (number)

$$X_{15} \geq 3 \quad (23)$$

13. livestock farmers, maximum (number)

$$X_{16} \leq 6 \quad (24)$$

14. livestock farmers, minimum (number)

$$X_{16} \geq 3 \quad (25)$$

III. A third group of constraints on animal feed

Balance of NEI needed to feed the cows (number)

$$489X_4 + 480X_6 + 1050X_7 + 1160X_8 + 170X_9 + 280X_{10} + 480X_{11} \geq 7100X_{12} \quad (26)$$

15. Silage, min 30% from NEI (number)

$$489X_4 \geq 2130X_{12} \tag{27}$$

16. Silage, max 48% from NEI (number)

$$409X_4 \leq 3400X_{12} \tag{28}$$

17. Concentrated fodder, min 24% from NEI (number)

$$1050X_7 + 1160X_8 \geq 1704X_{12} \tag{29}$$

18. Concentrated fodder, max 40% from NEI (number)

$$1050X_7 + 1160X_8 \leq 2804X_{12} \tag{30}$$

19. Green fodder, min 10% from NEI (number)

$$170X_9 \geq 710X_{12} \tag{31}$$

20. Green fodder, max 20% from NEI (number)

$$170X_9 \leq 1420X_{12} \tag{32}$$

21. Straw, max 10% from NEI (number)

$$280X_{10} \leq 710X_{12} \tag{33}$$

22. Hay, min 5% from NEI

$$480X_6 + 480X_{11} \geq 355X_{12} \tag{34}$$

23. Hay, max 12% from NEI

$$480X_6 + 480X_{11} \leq 852X_{12} \tag{35}$$

Processed Concentrated fodder which we feed the animals and the source from which we receive it (t)

$$0.4X_1 + 0.5X_2 + 0.2X_3 = X_8 \tag{36}$$

24. Relationship between straw and autumn crops

$$X_{10} \leq 0.16X_1 + 0.16X_2 \tag{37}$$

25. Balance between green fodder and hay that the farm can get from pasture meadows

$$4X_6 + X_9 \leq 2.2X_5 \tag{38}$$

26. Wheat, min. 20% of concentrated fodder

$$0.4X_1 \geq 20\%X_8 \tag{39}$$

27. Barley, min 20% of concentrated fodder

$$0.5X_2 \geq 20\%X_8 \tag{40}$$

28. Sunflower min 20% of concentrated fodder

$$0.2X_3 \geq 20\%X_8 \tag{41}$$

A fourth set of limitations for the minimum and maximum limits between which the specified crops and animals may vary

29. Cows, minimum (number)

$$X_{12} \geq 40 \tag{42}$$

30. Cows, maximum (number)

$$X_{12} \leq 100 \tag{43}$$

IV. Fifth group constraints, auxiliary

31. Income (BGN)

$$X_{17} = 108X_{30} + 130X_{31} + 130X_{32} + 2800X_{12} + 419X_{12} + 42X_{13} \tag{44}$$

Income (BGN) – 2-nd option without subsidies

$$X_{17} = 108X_{30} + 130X_{31} + 130X_{32} + 2800X_{12} \tag{45}$$

32. Variable costs (BGN)

$$X_{18} = 70X_1 + 62X_2 + 54X_3 + 50X_4 + 70X_{30} + 62X_{31} + 54X_{32} + 100X_6 + 650X_7 + 100X_{10} + 110X_{11} + 50X_{12} + 12000X_{14} + 13200X_{15} + 13200X_{16} \tag{46}$$

33. Labor costs (BGN)

$$X_{19} = 12000X_{14} + 13200X_{15} + 13200X_{16} \tag{47}$$

34. Administrative expenditure (BGN)

$$X_{24} = 40800 \tag{48}$$

35. Fixed costs (BGN)

$$X_{20} = 24X_{13} + 8X_5 + X_{24} \tag{49}$$

36. Gross margin (BGN)

$$X_{21} = X_{17} - X_{18} - X_{19} \tag{49}$$

37. Profit (BGN)

$$X_{22} = X_{17} - X_{18} - X_{19} - X_{20} - X_{24} \tag{50}$$

38. NEI – (number)

$$X_{24} = 489X_4 + 480X_6 + 1050X_7 + 1160X_8 + 170X_9 + 280X_{10} + 480X_{11} \tag{51}$$

39. Minimum contribution of fodder crops (dka)

$$X_1 \geq 20\% X_8 \tag{52}$$

40. Minimum contribution of fodder crops (dka)

$$X_2 \geq 20\% X_8 \tag{53}$$

41. Minimum contribution of fodder crops (dka)

$$X_3 \geq 20\% X_0 \tag{54}$$

In order to assess the impact of the policies implemented under the CAP, it is necessary to define the criterion of optimality. The gross margin will be used in this example. Additionally, the task will be solved with a maximum profit criterion.

$$F = 108X_{30} + 130X_{31} + 130X_{32} + 2800X_{12} + 419X_{12} + 42X_{13} - 70X_1 - 62X_2 - 54X_3 - 50X_4 - 70X_{30} - 62X_{31} - 54X_{32} - 100X_6 - 650X_7 - 100X_{10} - 110X_{11} - 50X_{12} - 12000X_{14} - 13200X_{15} - 13200X_{16} \rightarrow \text{MAX gross margin} \tag{55}$$

3.5. Solution of the task under different optimality criteria (gross margin / max profit, with and without subsidy)

The optimization was solved with the SOLVER software product.

Table 1

Parameters of the optimal solution with the criterion of optimum gross margin, with subsidy

Unknown Variables	Name	Da	Tonnes	Number	Thousand,BGN
x_1	Wheat	31			
x_2	Barley	275			
x_3	Sunflower	31			
x_4	Maize for silage		697		
x_5	Pasture meadows	514			
x_6	Hay for feed, own production		674		
x_7	Purchased concentrated fodder for cows		0		
x_8	Own concentrated fodder for cows		156		
x_9	Green feed		835		
x_{10}	Straw for feed, own production		0		
x_{11}	Purchased hay for feed		11		
x_{12}	Cows – 4 tons of milk			100	
x_{13}	Rented land	2000			
x_{14}	General workers, permanent workers			3	
x_{15}	Mechanics, permanent workers			3	
x_{16}	Livestock farmers, permanent workers			3	
x_{17}	Revenue				531,364
x_{18}	Variable costs				127,9
x_{19}	Labor costs				115,2
x_{20}	Fixed costs				*
x_{21}	**Gross margin**				**288,262**
x_{22}	Profit				*
x_{23}	NEI			710000	
x_{24}	Administrative costs				*
x_{30}	Barley, commodity	0			
x_{31}	Sunflower, commodity	656			
x_{32}	Wheat, commodity	309			

* are not taken into account

Source: Own calculations

Table 2

Parameters of the optimal solution with the criterion of optimum gross margin, without subsidy

Unknown Variables	Name	Da	Tonnes	Number	Thousand, BGN
x_1	Wheat	31			
x_2	Barley	275			
x_3	Sunflower	31			
x_4	Maize for silage		697		
x_5	Pasture meadows	514			
x_6	Hay for feed, own production		674		
x_7	Purchased concentrated fodder for cows		0		
x_8	Own concentrated fodder for cows		156		
x_9	Green feed		835		
x_{10}	Straw for feed, own production		0		
x_{11}	Purchased hay for feed		11		
x_{12}	Cows – 4 tons of milk			100	
x_{13}	Rented land	2000			
x_{14}	General workers, permanent workers			3	
x_{15}	mechanics, permanent workers			3	
x_{16}	Livestock farmers, permanent workers			3	
x_{17}	Revenue				531,364
x_{18}	Variable costs				127,9
x_{19}	Labor costs				115,2
X_{20}	Fixed costs				*
x_{21}	Gross margin				162,32
x_{22}	Profit				*
x_{23}	NEI			710000	
x_{24}	Administrative costs				*
x_{30}	Barley, commodity	0			
x_{31}	Sunflower, commodity	656			
x_{32}	Wheat, commodity	309			

* are not taken into account

Source: Own calculations

Table 3

Parameters of the optimal solution with the criterion of optimum maximum profit, with subsidy

Unknown Variables	Name	Da	Tonnes	Number	Thousand, BGN
x_1	Wheat	31			
x_2	Barley	275			
x_3	Sunflower	31			
x_4	Maize for silage		697		
x_5	Pasture meadows	514			
x_6	Hay for feed, own production		674		
x_7	Purchased concentrated fodder for cows		0		
x_8	Own concentrated fodder for cows		156		
x_9	Green feed		835		
x_{10}	Straw for feed, own production		0		
x_{11}	Purchased hay for feed		11		
x_{12}	Cows – 4 tons of milk			100	
x_{13}	Rented land	2000			
x_{14}	General workers, permanent workers			3	
x_{15}	Mechanics, permanent workers			3	
x_{16}	Livestock farmers, permanent workers			3	
x_{17}	Revenue				531,364
x_{18}	Variable costs				127,9
x_{19}	Labor costs				115,2
x_{20}	Fixed costs				46627,34
x_{21}	Gross margin				288,262
x_{22}	Profit				190, 635
x_{23}	NEI			710000	
x_{24}	Administrative costs				51,00
x_{30}	Barley, commodity	0			
x_{31}	Sunflower, commodity	656			
x_{32}	Wheat, commodity	309			

Source: Own calculations

Table 4
Parameters of the optimal solution with the criterion of optimum maximum profit, without subsidy

Unknown Variables	Name	Da	Tonnes	Number	Thousand, BGN
x_1	Wheat	31			
x_2	Barley	275			
x_3	Sunflower	31			
x_4	Maize for silage		697		
x_5	Pasture meadows	514			
x_6	Hay for feed, own production		674		
x_7	Purchased concentrated fodder for cows		0		
x_8	Own concentrated fodder for cows		156		
x_9	Green feed		835		
x_{10}	Straw for feed, own production		0		
x_{11}	Purchased hay for feed		11		
x_{12}	Cows – 4 tons of milk			100	
x_{13}	Rented land	2000			
x_{14}	General workers, permanent workers			3	
x_{15}	Mechanics, permanent workers			3	
x_{16}	livestock farmers, permanent workers			3	
x_{17}	Revenue				531,364
x_{18}	Variable costs				127,9
x_{19}	Labor costs				115,2
x_{20}	Fixed costs				46627,34
x_{21}	Gross margin				288,262
x_{22}	Profit				64, 735
x_{23}	NEI			710000	
x_{24}	Administrative costs				51,00
x_{30}	Barley, commodity	0			
x_{31}	Sunflower, commodity	656			
x_{32}	Wheat, commodity	309			

Source: Own calculations

3.6. Analysis of the results obtained

The results obtained from the optimization are shown in Tables 1-4.

On Table 1 are the parameters of the optimal solution for the gross margin target with a subsidy included. On Table 2 – the optimal solution of the gross margin target without a subsidy.

The objective function is designed to affect the area of different crops used for feed or for sale, cows and subsidies (when using optimization subsidies), the area of grazing grassland used and hay production, purchased fodder and labor costs.

In the management of the farm it is assumed that the rented land is 2000 decares and is used at its full capacity.

The solution of the optimization equation is expected to result in the area of the land to be sown with a particular crop, the optimal number of cows to grow. In determining the optimal structure of the farm, the requirements for an optimal ration of animals are taken into account by tracking the balance of the NEI.

The main effect on the results is the type of objective function, the constraints and the set price parameters. The type of the objective function is linear, as are linear and the constraints. Linearity influences the results in 2 ways:

- Maximizes the quantities produced from crops with a good price on the one hand.
- On the other hand, it minimizes the crops with a price disadvantage to the minimum.

That is why, the produced wheat for fodder is only 31 decares (the production costs of wheat are 72 BGN/da, while for barley and sunflower are respectively 62 BGN/da and 54 BGN/da) and the commodity wheat – 0. The latter results from the lower sales price of wheat set in the model – 108 BGN /da (130 for barley and sunflower).

The amount of land sown with sunflower fodder is also 31 decares. Although sunflower is financially profitable for cultivation at a cost of only BGN 54 per decares, its profitable market price is the reason for it to be sold as a commodity (309 decares) and for this reason the minimum quantity is set as a fodder according to the limitations introduced.

The moderate production costs and the good market price of barley cause it to be the optimal crop, both for feed (275 da) and for sale (656 da).

In fact, the difference between market price and production costs is greater for sunflower, which is why it is also mainly produced as a commodity crop.

The quantity of silage maize (697 t) is determined primarily by its low price and restrictions on its use for food.

In terms of the number of breeding animals (X_{12}), the function is maximized by maximizing the number of cows – 100 within our study. As already mentioned, the linearity of the gross margin objective function implies such a result when GM is positive.

It is interesting to note whether the availability of subsidies will change the results of optimization. The impact of the subsidies on the model is reflected by the animal subsidies of BGN 419 and the subsidies per unit area of BGN 42. The main result of the use of subsidies is the increase in the gross margin from BGN 162.32 thousand up to BGN 288.26 thousand (Tables 1 and 2). Accordingly, max profit is from BGN 64.735 thousand up to BGN 190.635 thousand (Tables 3 and 4).

All other parameters of the model – with regard to the structure of the areas for cultivation of different crops, grazing meadows, labor costs remain unchanged, whether or not subsidies are used.

The main conclusion from the optimization of the objective function of the gross margin is that the existence of subsidies does not affect the farmer's behavior with regard to the sown areas. His interest is to maximize the number of reared cows and maximize sown areas.

Table 3 and 4 show the results when the profit is taken for a target function. The results of the optimization conducted confirm the conclusions made so far. I.e. the addition of fixed costs to the model does not change the final conclusion for the optimum ratio of sown areas and the number of animals.

4. Conclusion

In this paper, we tested the impact of CAP subsidies on the production structure of an agricultural enterprise through a mathematical model. The main conclusion from the optimization model of the objective function of the gross margin/max profit is that the existence of CAP subsidies does not affect the production structure on the agricultural enterprises with regard to the sown areas and animals. The solution to the task gave the following answers:

1. The impact of CAP subsidies on efficiency and production structure has been established, depending on the chosen optimal criteria;
2. An assessment of the effects of CAP support on the market behavior of the agricultural precursor has been carried out;
3. The optimization model has been successfully adapted to the management of an agricultural enterprise, with the criteria for optimal gross margin and profit.

At the same time, we need to address some of the weaknesses we identified during the task development and after getting the possible solutions. The mathematical model is not able to take into account the influence of external factors (temperature, humidity, precipitation, atmospheric pollution, climate change), including current environmental, behavioral, social, etc. Also, the model cannot foresee the possible future changes in the market environment, the behavior of competition, the change in consumer requirements. The task's condition does not include the behavioral characteristics of managers, employees and stakeholders. The model would not identify the factors pertaining to threats to organization and potential imagination, and they are crucial criteria for making a decision.

References:

Абрамова, Г. (2003). Модел за оптимално функциониране на отрасъл млечно говедовъдсво /икономика-математически „симплексен метод“. – Икономика и управление на селското стопанство, 48, N 1, с. 54-58.

Александров, Кр. (1986). Икономико-математически методи и модели в търговията: Изследване на операциите. София: ВИИ.

Аврамов, А., Грозев, С. (1991). Математическо моделиране. Свищов.

Владимирова, К. (1981). Икономико-математически методи и модели за прогнозиране и планиране на народното стопанство. София: ВИИ.

Георгиев, Т. (1973). Икономико-математически модел и задачи за планиране на производството в АПК, ТКЗС, ДЗС. София: Земиздат.

Добрева, Ю. (2011). Оптимизационното моделиране при изследване на устойчивото развитие София: СУ “Кл. Охридски” (дисертация).

Николов, Н. (1998). Проектиране производствената структура на земеделското производство. София: изд. Стопанство.

Николов, Н., Иванов, Г., Стефанов, Л. (1994). Икономико-математическо моделиране на селскостопанското производство. София: Земиздат.

Милкова, Т., Михайлов, Д. (2016). Изследване на операциите. Варна: Икономически университет.

Младенов, З., кол. (1984). Приложение на икономико-математическите методи и модели във вътрешната търговия. София: ВИИ.

Николов, Н. (1998). Проектиране производствената структура на земеделското производство. София: изд. Стопанство.

Николов, Н., Иванов, Г., Стефанов, Л. (1994). Икономико-математическо моделиране на селскостопанското производство. София: Земиздат.

Пушкарова, А. (2010). Математически модели на икономически задачи за вземане на решения. Сборник на научна конференция. Велико Търново, с. 451-455.

Славов, З., Еванс, Х. (2014). Приложение на математиката в икономиката: хронология, знания, образование и професии. Варна: Варненски свободен университет.

Arovuori, K., Yrjölä, T. (2015, October). The impact of the CAP and its reforms on the productivity growth in agriculture. – In: 147th EAAE Seminar: "CAP Impact on Economic Growth and Sustainability of Agriculture and Rural Areas, pp. 1-14.

Bashev, H. (2013). Assessment of the impact of the EU CAP on agricultural cooperatives. – Bulgarian Journal of Agricultural Economics and Management, N 1, p. 22-36.

Ciliberti, S., Frascarelli, A. (2015). A critical assessment of the implementation of CAP 2014-2020 direct payments in Italy. Bio-based and Applied Economics, 4(3), p. 261-277.

Dantzig, G. (1987). Origins of the simplex method – Technical report sol 87-5.

Galluzzo, N. (2016). Analysis of subsidies allocated by the Common Agricultural Policy and cropping specialization in Romanian farms using FADN dataset. Scientific Papers: Management, Economic Engineering in Agriculture & Rural Development, 16(1).

Ivanov, B. (2016). Scenarios and Effects on Different Probabilities of Development of Bulgarian Agriculture: p. 22-33. Book of proceeding from IIIrd Applied science forum "Agricultural Development and Commodity Market Projection" (November 28-29, 2016, Sofia).

Ivanov, I., Dobreva, J. (2007). Application of the Optimization Model and the Slutsky Equation in the Supply of Public Goods. – Proceedings of the University of Rousse "Angel Kanchev", Vol. 46, book 4, Economics and Management, pp. 161-167.

Kaneva, K., Mladenova, M., Koteva, N., Bashev, H., Risina, M., Hadzhieva, V., Mitova, D. (2005). Efficiency, Sustainability and Competitiveness of Agricultural Holdings. – Bulgarian Journal of Agricultural Economics and Management, Vol. 5, pp. 44-54.

Křístková, Z., Habrychova, A. (2011). Modelling direct payments to agriculture in a CGE Framework – analysis of the Czech Republic. – Agric. Econ.–Czech, 57(11), p. 517-528.

Piryonesi, S. M., Tavakolan, M. (2017). A mathematical programming model for solving cost-safety optimization (CSO) problems in the maintenance of structures. – KSCE Journal of Civil Engineering, p. 1-10.

Rizov, M., Pokrivcak, J., Ciaian, P. (2013). CAP subsidies and productivity of the EU farms. – Journal of Agricultural Economics, 64(3), p. 537-557.

Robert J. V. (2013). Linear Programming: Foundations and Extensions, 4th Edition. Springer.

Roger, F. (2000). Practical methods of optimization. Wiley. ISBN 978-0-471-49463-8.

Svobodová, H., Věžník, A. (2012). Impacts of the Common Agricultural Policy of the European Union in the Vysočina region (Czech Republic) by the view of the farmers. – Journal of Central European Agriculture, 12(4).