Decision-Making Model to Support Agricultural Policies in Realizing Economic and Social Sustainability

Jaka Žgajnar, *Lidija Zadnik Stirn*
Biotechnical faculty, University of Ljubljana, Slovenia

Abstract

Background: Achieving economic and social sustainability is the goal of any policy when defining measures. We focus on the beef sector, where many challenges have arisen due to its structural characteristics, such as an unfavourable scale structure, high costs, low efficiency, and a low environmental footprint. This paper presents an example of the support provided by a mathematical programming model in the development of a Common Agricultural Policy Strategic Plan for the period 2023-2027. **Methods/approach:** It is a model based on linear programming that allows such an ex-ante analysis by calculating production plans at the farm level and aggregating the results at the sector level. **Objectives:** When defining the interventions, the question arose as to what the reform of the Common Agricultural Policy will bring and to what extent the sector should be supported in meeting these challenges. These were the concerns of agricultural policy that we sought to support by modelling different scenarios. **Results:** The results show that the situation of the sector will worsen, especially for larger farms, but they also show the great importance of production-related payments to mitigate the negative trend. **Conclusions:** The applied approach proves to be suitable for supporting the design of agricultural policy and achieving greater economic and social sustainability in the sector.

Keywords: decision-making model; farm model; mathematical programming; agricultural policies; CAP reform; beef sector

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Introduction

The Common Agricultural Policy (CAP) aims to support the EU agricultural sector in addressing local and global challenges and to drive the development towards a smart, sustainable, competitive, resilient, and diversified agricultural sector to ensure long-term food security (European Commission, 2023). The new programming period 2023-2027 therefore faces many challenges. In addition to the issue of income and a fairer distribution of direct payments among farms, climate preferences, etc., the environment plays a particularly important role (e.g. Avasiloaei, 2022). As various studies show, one of the ways to reduce the environmental footprint of EU agriculture can be achieved at the price of lower production and higher food prices (Petsakos et al., 2022), which has a significant impact on farms. The latter is even more pronounced in sectors that have been more strongly supported by production-related measures in the past, such as the beef sector. To achieve these goals, which are reflected in nine specific objectives, the CAP provides tailored support through national CAP Strategic Plans (CSPs). These documents are drawn up by each Member State and cover all agricultural policy measures for the next programming period, 2023-2027. The interventions and CSPs are, therefore, tailor-made solutions adapted to the conditions and needs of each Member State in terms of resource allocation and priorities related to agricultural structure and environmental, economic, and social challenges (European Commission, 2023).

When drafting the CSP, many questions arose as to how the general and specific objectives could be achieved most efficiently and how the instruments could be made as effective and financially sustainable as possible. Animal production poses a particular challenge, as it is a rather complex sector that accounts for 44% of the total value of agricultural production in the EU and provides many ecosystem services (van der Linden et al., 2020). Here, for example, the question arises as to which livestock farming model we want, whether it is economically sustainable, whether financial support through interventions is necessary and for whom and to what extent. On the other hand, there is also the question of how the efficiency of coupled income support (CIS) can be improved and how the target sectors can be made more profitable and less dependent on subsidies. Many of these solutions require the support of experts and tools, including the use of modelling. A review of the literature revealed a variety of models that have been developed to support decision making.

The use of various methods to support policymakers has a long history (e.g. Žibert et al., 2020, Kocjančić et al., 2016; Quendler, 2019). In reviewing the literature, we find various examples of their use, particularly for ex-ante analysis, ranging from macro-sectoral analysis (models based primarily on the partial and general equilibrium approach), which were particularly prevalent in the first phase of analysis by agricultural economists, to the microsimulation models that emerged in the latter phase (Langrell et al., 2013). These are a type of microsimulation model commonly referred to as farm models. Van der Linden et al. (2020) emphasise that operational models, once operational, enable relatively fast and cost-effective analyses, even though their development is often tedious and costly.

Farm models are often used to assess the economic situation of farms and to model the effects of various policy and market changes (Reidsma et al., 2018). Such models enable a better understanding of decision-making and management at the farm level and, on the other hand, give policymakers a better insight into what is happening on individual farms, enabling them to make better evidence-based decisions and thus achieve greater targeting accuracy. The need for farm-level models became more apparent after the 2013 CAP reform, which introduced greening as an additional level of conditionality for farm-specific obligations to receive direct payments (Kremmydas et al., 2022).

In most cases, these are models based on the optimisation potential of mathematical programming (Reidsma et al., 2018). These include, for example, the IFM-CAP model used by the European Commission in the EU. IFM-CAP is based on the Positive Mathematical Programming (PMP) approach and enables the assessment of different policy impacts on existing aggregates and groups of farms (Louhichi et al., 2015). Its main purpose is to assess and analyse the different impacts of the CAP on the economic and environmental performance of farms. Its main advantage is its EU-wide coverage. An analysis of the impact of the CAP at the farm level for the post-2020 period was also carried out with IFM-CAP (Petsakos et al., 2022). This model is based on FADN data. Van der Linden et al. (2020) mention some reviews of existing agricultural models that have also been used for policy analysis and support. In recent years, agent-based models (ABM) have also gained popularity to model the impact of policy measures (Huber et al., 2018). In addition, Britz et al. (2021) also mention life cycle assessments and agri-environmental simulations as examples of policy impact assessment models. These models naturally differ both in terms of the input data and the (accuracy of) the modelling assumptions.

In Slovenia, we also have a microsimulation tool based on mathematical programming, which was used for this analysis. It is the Slovenian model of typical farms (SiTFarm), which enables various analyses at the level of the agricultural production plan, whereby the results can also be aggregated at the sector level (Žgajnar et al., 2022). The main purpose of SiTFarm is to enable analyses from the perspective of income sustainability at the level of typical farms that are representative of a certain number of real farms. This model does not require FADN data and, therefore, allows a more detailed analysis also for smaller farms that would otherwise not be included in the sample. The model calculates different economic indicators and allows the inclusion of different CAP interventions at different levels and under different conditions (socio-economic context of the analysis). From this point of view, the model has also been used to support CSPs in Slovenia (e.g. Žgajnar et al., 2023).

In this study, we show an example of the use of SiTFarm to support the design of a CSP using the example of cattle fattening. In this paper, we focus on the cattle fattening sector, as it is of great importance in cattle farming from an economic, social, and environmental point of view. It is the second most important sector in Slovenian agriculture after dairy cow farming (Žgajnar et al., 2023). In addition, the beef sector is characterised by persistent economic challenges and has consistently received coupled income support (CIS) in all CAP periods since the introduction of the CIS mechanism, making it a sector with persistent problems. In the case of cattle fattening, the actual question in the CAP reform was in what form and at what level coupled support should be granted to the sector and whether it makes a significant contribution to improving the economic situation of the different beef farms (size, production intensity, breeding technology, etc.). In this way, we have modelled the impact of the CAP reform after 2023 on the selected economic indicators of typical cattle farms in an ex-ante approach.

The published models mentioned above were developed in different programming environments or based on different programming languages. Van der Linden et al. (2020) state in their study that the most used programs are MS Excel, GAMS and ModelMaker. MS Excel is often used in combination with other add-in tools such as @Risk. In terms of programming languages, models are most often developed in R, Visual Basic for Applications, C or C++, Fortran, Pascal, Python and Stella.

In the following, we briefly present the SiTFarm tool used, the types of farms for which the analysis was carried out, and the assumptions of the scenario. We then present the most important results and conclude the paper with the key findings.

Methodology

Farm model and aggregate analysis

The SiTFarm used in this study is a tool based on a mathematical programming approach that allows analyses of the impact of policy measures at the level of the agricultural production plan and the level of the aggregated sector. The model was developed in MS Excel in combination with Visual Basic for applications. The methodological background allows the use of different techniques to solve the production plan problem, which is the basic level of analysis in our example. It is a tool that follows modern trends in agricultural economic analysis in this field and enables analysis at the level of the Typical Agricultural Holding (TAH) (Žgajnar et al., 2022). TAHs are static models of the agricultural system that enable the simulation and analysis of various factors at the level of a farm's production plan. In this way, the production plan shows the situation in a specific type of farm, which is a typical representative of a larger number of farms in practice. It is, therefore, not a specific farm but a typical representative of a certain group of farms that can be identified with it.

The optimisation potential of mathematical programming is used to calculate the baseline (BL) and to simulate various scenario sequences at the level of a farm's production plan. In the present version of SiTFarm, deterministic LP is used. Although LP modelling has inherent weaknesses due to factors such as the assumed maximisation behaviour and the explicitly linear technology (constant input-output coefficients), the models provide a fairly accurate simulation of both the revenue and the production and cost structures of the farms.

For each TAH, a matrix of production possibilities is developed, which is an example of production planning where we focus on finding the optimal combination of production activities given production constraints to maximise the expected gross margin (EGM). GM is calculated as the difference between total revenue, including subsidies at the farm level, and variable costs. A separate matrix is created for each farm. In addition to production activities, the matrix also includes marketing activities, the combination of technological activities, decoupled payments and CAP interventions that apply to a specific scenario.

Mathematically, the LP model used in SiTFarm could be defined as in equations (1) to (4). The objective function is to maximise the EGM (1). However, the main purpose of using LP is not to optimise the overall production plan but mainly to reconstruct the baseline production plan (BL) and balance it according to the key information we had for each typical cattle farm. This includes not only the production activities but also the nutrient balances and other input flows at the farm level. We, therefore, refer to this process as partial optimisation. Partial optimisation means that we specify a certain part of the activities (x_f) and require the solver to include them in the optimal solution (3). In our example, for example, these are the number of cattle at the farm level. These are the variables that define the type of farm. So, the basic idea is to estimate or calculate the missing data – variables (x_j) using a linear programme, maximising the EGM. To obtain the optimal solution for the LP model, the Analytic Solver V2021 (21.0.0.0) from FrontlineSolvers® was used.

$$axEGM = \sum_{j=1}^{n} c_j x_j + \sum_{f=1}^{n} c_f x_f \quad (1)$$

so that

$\sum_{j=1;f=1}^{n;r} a_{ij}x_j + a_{if}x_f \le b_i$ for all $i = 1$ to m (2)

$x_f = b_f$ for all $f = 1$ to r (3)

$x_j \ge 0$ for all j (4)

Where: n – number of activities included in the production plan of the analyzed farm; m – number of constraints taken into account when drawing up the farm's production plan; r – total number of binding constraints on the inclusion of production activities in the production plan; those defining the type of farm - e.g. number of bulls, cows, etc.; j – sequential production activity, marketing activity, technological activity; i – sequential constraint in the model; b_i *– limitation of a single resource (e.g. ha of arable land);* b_f *– e.g. the number of bulls in the herd.*

As the main source of economic (c_j and c_f) and technological data (technological coefficients - a_{ij}) for the individual production activities, the model uses the budget calculations (model calculations) of the Agricultural Institute of Slovenia (AIS, 2023). According to Jones et al. (2017), they can be defined as component models. They include cropping models and livestock models and enable real-time adjustment of individual budget calculations in terms of technology, intensity, and price-cost relations to the conditions on the analysed farm (TAHx). This makes the system of model calculations an important reference source for analytical and economic data at the level of the individual production activities of the analysed farms. Thus, the production costs of individual agricultural products depend on the production technology, intensity, size of the plot, and some other technological parameters, which enable an adjustment to the analysed conditions of the individual TAHs.

In terms of time resolution, SiTFarm makes it possible to carry out analyses for different time scales (monthly, annual average, average of several years, etc.). When calculating the economic indicators, we included the average prices for the three years 2018-2020 in the analysis. In this way, we have reduced the impact of inter-annual fluctuations, which can otherwise have an important impact on (market) revenues, costs and, above all, the EGM. These are the three main indicators we use to measure the impact of changes in our analysis.

Typical beef farms

The analysis for the beef sector was carried out based on 12 typical beef farms. These are typical representatives of the beef industry in Slovenia and are representative of a different number of farms in each size group in Slovenia (Table 1). They were identified based on an in-depth analysis of available statistical data, standard output analysis and other sources at workshops with various experts (Žgajnar et al., 2022). According to national data, 3,630 farms in Slovenia predominantly raise beef, excluding those that also raise suckler cows and excluding the part of fattening that is carried out on dairy farms.

This is a rather heterogeneous group of farms (Table 1), both in terms of size (number of cattle), natural resources (available area and proportion of arable and permanent grassland), intensity and quality of feed produced, and intensity of breeding (with daily weight gains ranging from 850 g/day up to 1,400 g/day). Most of them (97 %) are small farms where part-time labour is required (< 0.5 FTE). This also has an important impact on decision-making and management. As Huber et al. (2018) emphasise, farmers' decisions in such cases are often influenced by non-agricultural activities, as most of these farms are both a household and a farm/business unit.

Except for the last farm (TAH12), which also produces hops in addition to fattening cattle, all other farms are typical fattening farms. As can be seen from Table 1, the farming technology varies considerably between the farms. First, in addition to the breeding technology and the scope of breeding, the breed structure of the herd also varies. Most small farms mainly breed Brown Swiss and Simmental cattle. On the larger farms, mainly beef breeds and a combination of Simmental and Charolais are bred. These farms usually also fatten heavier calves (240 kg) that come from suckler cow herds. On farms with larger herds and more precise breeding techniques, beef calves are also fattened to higher final weights and usually achieve higher daily weight gains (on average up to 1,400 kg/day).

In addition to the intensity of breeding, there are also differences in the areas under cultivation and, therefore, in the quantity and quality of the feed produced. Farms that grow most of their feed on permanent grassland also achieve lower average daily weight gains. However, the latter also depends on the number of mowing operations and thus on the quality of the forage produced on grassland (on the field) and permanent grassland (Table 1).

Table 1

Typical agricultural holdings specialise in beef farming in Slovenia.

TAHs		TAH1	TAH2	TAH3	TAH4	TAH5	TAH6	TAH7	TAH8	TAH9	TAH10	TAH11	TAH12[e]
Farms	(No)	600	600	600	400	400	450	250	250	30	30	18	2
Beef	(No)	1	2	3	6	8	12	17	25	60	75	150	150
Breed		Bro	Sim	Sim	Bro	Sim	SimBro	Sim	Lim	SimCha	SimCha	SimCha	SimCha
Beginning of fat.	(kg)	120	120	120	240	240	240	240	240	240	240	240	240
End of fat.	(kg)	680	700	700	680	700	680	730	730	750	750	750	750
FTE (1,800h)		0.13	0.15	0.17	0.20	0.22	0.24	0.32	0.41	0.54	0.82	1.33	1.85
Arable land	(ha)				1.27	2.38	3.49	5.29	6.91	6.13	19.54	42.00	42.00
Grass/Lucerne mixtures	(ha)				0.25[a]	0.48[a]	0.70[a]	1.06[a]	1.38[b]		3.91[b]	8.40[b]	8.40[b]
Barley	(ha)				0.25					2.45	4.88	6.57	6.57
Corn	(ha)				0.76	1.90	2.79	4.23	5.53	3.68	10.75	27.03	27.03
Permanent grass	(ha)	1.0[c]	1.54[c]	2.02[c]	1.84[c]	0.92[c]	0.92[c]	0.92[c]	1.38[d]	9.90[d]	3.68[d]	5.52[d]	5.52[d]
Average plot size	(ha)	0.5	0.5	0.5	0.5	0.6	0.8	0.8	1	1.5	1.5	1.5	1.5
Distance from the farm	(km)	1	1	1.5	2	2.5	3	4	5	8	5	5	5
Average slope	(%)	7	7	8	10	3	5	7	6	5	2	2	2
Machine line capacity	(1-3)	1	1	1	1	1	2	2	2	3	3	3	3
Entitlements	(€/ha)	153	182	192	257	303	332	350	345	242	387	382	378

Note: [a]*Three-cut silage-bale,* [b]*Four-cut silage-silo and bale* [c]*Three-cut grass (silage bale, hay bale),* [d]*Four-cut grass (silage bale & silo, hay bale),* [e]*Includes also 5 ha of hops production,* [f]*eligible only in BL 2024-2022. Bro – Brown cattle, Sim – Simmental cattle; Lim – Limousine cattle, SimCha – a mixed herd of Simmental and Charolais cattle; FTE – full-time equivalent;*
Source: Authors' work

Profitability is also influenced by the average distance and size of individual plots, which are larger on larger farms. As shown in Table 1, larger farms are in flat areas (lower slope), while smaller farms (with less than 25 cattle) can also be located in a hillier area. However, in most cases, fattening does not take place in hilly mountainous areas, as could be the case with a certain share of suckler cow husbandry. The profitability of land management and, above all, feed preparation for the animals is also influenced by the farm's equipment and investment in machinery. Here, "1" means poor equipment and "3" means excellent, modern, and powerful equipment (Table 1).

Scenario analysis

In the analysis, we simulated the expected effects of changes in CAP interventions for cattle farms in Slovenia. First, we simulated the situation of the baseline (BL) before the reform (MAFF, 2015). We considered Pillar 1 measures and LFA payments. In contrast, the inclusion in voluntary farm environmental measures (eco-schemes) was simplified and modelled based on the data available at the time of the analysis (MAFF, 2023). We only considered two eco-schemes (Table 2) that are of interest to cattle farms operating on permanent grassland in eligible areas. We have assumed that certain farms within the group opt for it and others do not. As a result, the proportion of support considered may vary depending on the TAH. Thus, not all farms (real farms) within a particular type (TAH) may be included in a particular eco-measure.

For this study, we conducted an additional impact assessment for the CIS for beef (annual payment per animal). The aim was to help policymakers determine what kind of impact direct payments have and whether it is justified to support the beef sector as a sector with certain difficulties. Therefore, in Scenario 1 (S1), we have considered all expected payments to which the farm would be entitled, while in Scenario 2 (S2), we have excluded coupled income support for beef. In doing so, we analysed the impact of the CIS for beef on the economic indicators of the cattle TAHs.

Table 2
Considered CAP interventions in baseline and CAP strategic plan scenarios.

Scenario		BL	S1	S2
Period		2014-2022		2023-2027
Coupled income support				
Cereals	EUR/ha	126.4	0.0	0.0
Beef	EUR/LU	51.4	56.65[b]	0.0
Protein crops	EUR/ha	0	175.37	175.37
Decoupled income support				
Entitlements (A+B)				
A - Basic payment[d]	EUR/ha	161.3	0.0	0.0
B - Greening[d]	EUR/ha	91.4	0.0	0.0
Basic income support for sustainability		0.0	184.2	184.2
Redistributive payment (8.2 ha[a])	EUR/ha	0.0	23.16	23.16
Eco-scheme on grasslands				
Extensive grassland	EUR/ha	0.0	30.0	30.0
Traditional use of grassland	EUR/ha	0.0	30.0	30.0

Note: [a]Farms receive payment only for the first 8,2 ha. [b]In order for the farm to be eligible, it must raise at least two beef. [c]Eco-scheme for the climate and the environment; [d]It is the average amount of payment. There are differences between individual TAHs due to historical payments and internal convergence. It is part of the value of the entitlement that the farm gets paid per ha of cultivated area. In the case of the analysed farms, this means that the amounts range from €152 to €387/ha. For more details per farm, look at Table 1; BL – baseline; S1 – scenario one, coupled income support for beef is included; S2 – scenario two, coupled income support for beef is not included.
Source: Authors' work

The basic assumption of the scenario analysis was that the production plan at the farm level could only be partially changed (xj) and to the extent that does not change the production activities that determine the farm type (e.g. the number of cattle) (fx). This means that due to certain (favourable/unfavourable) conditions that an individual scenario entails, the production plan can only be partially changed. These are either a slight change in the distribution of production resources (labour, land, capital), an increased implementation of certain market activities or a shift in the share of home-grown fodder and other harvesting methods.

In the final step, we extrapolated the results at the TAH level to the sector level. This is done in such a way that each farm is given its weight according to the number of farms (Table 1) and their economic and social importance in agriculture. In this way, changes at the farm level also affect the sectoral level and thus enrich the analysis at the sectoral level. However, it should be noted that SiTFarm does not allow analyses from the point of view of structural change or the effects of structural change. The analysis is static in this respect.

Results and discussion

The core economic results of the scenario analysis are presented below. Beef is the main production activity on about 7% of farms in Slovenia (Fig. 1). In the SiTFarm, the whole sector, represented by 12 TAHs, contributes 4.4% to the total income of the Agriculture sector.

As shown in Table 3, 98% of cattle farms are smaller than the average Slovenian farm in terms of available land. Small herds predominate. Therefore, poor economic results (BL) can be expected for these farms.

As shown in Table 3, only farms with more than 25 cattle achieve an EGM of more than 10 €/hour. The exception is TAH9, where the results are less favourable. As can be seen from Table 1, this farm relies predominantly on forage from grassland, where the cost per unit of production is higher than when the majority of the forage comes from arable land. Therefore, the GM/ha is also much lower and among the worst in the sector.

Very small farms (accounting for 84% of Slovenian cattle farms) with less than 6 cattle usually achieve less than 4€ per working hour. According to the results, the last farm (TAH12), which also produces hops, stands out in all economic indicators due to hop production. In this case, hops also represent an important part of the farm's total income, although beef production is still the main agricultural activity. However, this type of farm is typical of only one region in Slovenia.

The other farms can be found all over Slovenia and could be categorised as farming models at the regional level in terms of spatial resolution. As explained in the methodological part of the paper, we have required in the modelling that the production plan should not change between the scenarios (BL, S1 and S2). At constant prices (2018-2020), the CAP measures are, therefore, an important factor for change.

Table 3
Typical agricultural holdings specialised in beef farming in Slovenia and selected economic indicators.

TAHs	Farms	Beef	FTE	Field	Permanent grass	Budgetary payments	GM	GM/h	GM/h	GM/h
	(No)	(No)	(1 800 h)	(ha)	(ha)	(EUR)	(EUR)	(EUR)	(EUR)	(EUR)
				Baseline (BL)					S1	S2
TAH1	600	1	0.13	0.00	1.00	309	262	1.1	1.1	1.1
TAH2	600	2	0.15	0.00	1.54	537	883	3.2	3.3	3.0
TAH3	600	3	0.17	0.00	2.02	809	1,344	4.5	4.5	4.1
TAH4	400	6	0.20	1.27	1.84	1,478	1,115	3.1	2.8	2.1
TAH5	400	8	0.22	2.38	0.92	1,833	1,721	4.4	4.2	3.3
TAH6	450	12	0.24	3.49	0.92	2,520	2,546	5.9	5.1	3.9
TAH7	250	17	0.32	5.29	0.92	3,826	4,933	8.5	7.9	6.6
TAH8	250	25	0.41	6.91	1.38	5,258	8,136	11.1	9.7	8.3
TAH9	30	60	0.54	6.13	9.90	7,779	5,973	6.1	5.6	3.0
TAH10	30	75	0.82	19.54	3.68	14,143	17,810	12.1	10.2	8.5
TAH11	18	150	1.33	42.00	5.52	27,987	33,504	14.0	11.2	9.2
TAH12	2	150	1.85	42.00	5.52	30,088	75,401	22.7	20.8	19.4
Total	**3 630**	**32 145**	**796**	**7 689**	**5 341**					

GM – gross margin, FTE – full-time equivalent, TAH – typical agricultural holding, BL – baseline; S1 – scenario one, coupled income support for beef is included; S2 – scenario two, coupled income support for beef is not included.
Source: Authors' work

Subsidies are particularly important in the beef sector. Budget payments account, on average, for more than 80 % of the GM and, in many small farms, even exceed the GM realised. Therefore, the sector can be expected to be very sensitive to changes in CAP measures. As the results show, the reform of CAP interventions will lead to a deterioration (Fig. 1), especially for medium and large farms (GM/hour), and even more so if the CIS for beef is not available (S2) (Table 3). The positive effect of production-related support is recognisable in all TAHs (S1). If we compare the hourly rate (GM/h) in BL and after the reform of CAP measures in both scenarios (S1 and S2), the effect of CIS payments is obvious. On average, the farms achieve 15 % more GM per effective working hour (S1) if a CIS is available (S1). In the individual farms, however, this effect can range from a few % (in small farms and hopefully diversified farms) to over 40 %. This also raises the further challenge of whether it is necessary to differentiate the level of the premium for different herd sizes or breeding technologies. However, the expected retention of the CIS (S1) for this sector will only partially mitigate the negative effects of the total CAP reform (Table 4). Without it, there will be an even greater deterioration, as can be clearly seen in Figure 1 and Table 3. This is also primarily a consequence of the abolition of entitlements (Table 1), which comprised an important proportion of historical payments from previous CAP periods. It is, therefore, also to be expected that the result of this abolition, together with the possible simultaneous abolition (S2) of the CIS for beef, will further worsen the economic situation and, thus, the social sustainability of these farms. In the modelling, we have taken into account that these farms can only participate in ECO programs on permanent grassland (Table 1). Although we do not provide detailed results here, it appears that ECO schemes are not an important factor and, therefore, do not contribute significantly to improving the performance of cattle fattening farms. Since they are linked to permanent grassland, the effect is expectedly greater on farms whose fodder is mainly produced on permanent grassland, which is particularly the case on small farms.

Table 4.
Total budgetary payments per TAH and sector level.

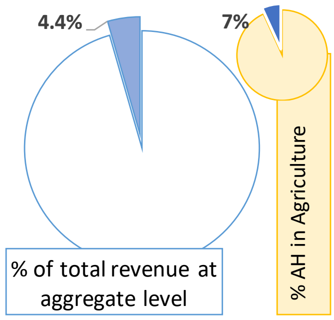
TAHs	Budgetary payments per TAH (EUR)		
	BL	S1	S2
TAH1	309	305	305
TAH2	537	559	474
TAH3	809	818	690
TAH4	1,478	1,359	1,104
TAH5	1,833	1,742	1,402
TAH6	2,520	2,162	1,652
TAH7	3,826	3,451	2,729
TAH8	5,258	4,233	3,171
TAH9	7,779	7,232	4,683
TAH10	14,143	8,759	6,529
TAH11	27,987	18,358	13,897
TAH12	30,088	19,691	15,230
Total per sector	**6,943,569**	**5,992,143**	**4,718,748**

BL – baseline; S1 – scenario one, coupled income support for beef is included; S2 – scenario two, coupled income support for beef is not included.
Source: Authors' work

Of course, the social sustainability of this sector is very important. It is closely linked to the milk production sector (mostly medium-sized farms) and suckler cow husbandry through the purchase and further fattening of calves, but nevertheless represents an important social aspect, as it employs almost 800 FTEs of the total effective labour force in the agricultural sector and accounts for 7% of all farms in Slovenia (Fig. 1).

Figure 1 shows that the CAP reform will bring only minor changes in revenue, which will be much more pronounced on the budgetary payments side. Since budgetary payments play an important role in the GM, it is to be expected that they will have a considerable influence on the GM achieved, given the production costs. Regardless, it is also clear from the results that simply monitoring the loss of budgetary payments does not give the same picture as monitoring the GM. This is also an important conclusion of our work. At the aggregate level, we estimate that GM has fallen by 10.3% (S1). If policymakers did not adopt a production-linked payment for beef (CIS), the deterioration at the aggregate level compared to BL would be up to 25 (S2) (Table 4). The overall decrease in budget payments would be 13.7% (S1) compared to the baseline of EUR 6.9 million, while production-related payments would amount to almost EUR 1.3 million (S2).

Figure 1
Summary of selected indicators for the beef sector in BL, S1 and S2.



	Gross margin	Gross margin per FTE	Gross margin per working hour	Scenario	Gross margin per working hour	Gross margin	Revenues	Budgetary payments	LFA
	(EUR)	(EUR)	(EUR/h)		(EUR/h)	Share based on baseline			
	Baseline (BL)			After the CAP reform					
Minimum	262	1,978	1.1	S1	1.1	0.758	0.948	0.619	0.712
				S2	1.1	0.482	0.930	0.462	0.712
Average	2,344	10,692	5.9	S1	5.3	0.897	0.981	0.863	0.942
				S2	4.5	0.747	0.956	0.680	0.942
Maximum	75,401	40,802	22.7	S1	20.8	1.024	1.006	1.040	1.267
				S2	19.4	0.986	0.998	0.988	1.267

LFA - Less-Favoured Area; AH – agricultural holding, BL – baseline; S1 – scenario one, coupled income support for beef is included; S2 – scenario two, coupled income support for beef is not included.
Source: Authors' work

Conclusion

Based on the analysis, we can conclude that the modelling approach used has proven to be effective in providing various business insights (indicators) in the scenario analysis, both at the farm level and at the sector level. The use of mathematical programming techniques allows us to balance the material balances. It flows at the farm level in a relatively simple way so that the production plan is technologically consistent and balanced.

However, it has been shown that the sensitivity of the LP model can be problematic when simulating different CAP measures, especially in marginal cases. This is indeed a problem of LP, where, in some cases, small (as well as larger) changes in conditions (CAP measures) can lead to completely different solutions. We circumvent the problem by including additional conditions in the model that make the model more static and consequently do not allow us to analyse possible structural changes.

Since the model is also static from the perspective of production technologies, as it does not include possible changes in production technologies in the modelling process, a limitation arises, namely that in this way, we can only analyse a certain part of CAP interventions that do not interfere with production and breeding technology. However, some interventions attempt to directly influence the change in a particular technology or management practice to reduce the environmental footprint, but this cannot be modelled due to the mentioned capabilities of the tool. In some cases, such dynamics may also mean that a different type of TAH occurs, which we also did not anticipate in this analysis.

While the results make an important contribution to the policy debate and the farm-level effects have generally been overlooked, an additional analysis at the farm level is needed. This is especially true in the development of CSPs, which should consider the national and local characteristics of Member States. CIS support for beef increases the resilience of the sector by supporting viable farm incomes. We have found that CIS is important for the beef sector anyway. On average, farms achieve 15% more GM per effective working hour when a CIS is in place. However, on individual farms, this effect can range from a few per cent to more than 40%. At an aggregate level, therefore, we estimate that total GM falls by 10%. If policymakers do not adopt a production-based payment for beef (CIS), the deterioration at the sector level would be up to 25% of total GM compared to BL (CIS payments thus represent this difference). The latter would certainly contribute to a deterioration in social sustainability, which is already bad for these types of farms.

An important conclusion of our work is also that it is not sufficient for policy impact assessment to look only at the level of budgetary payments and changes at this level, as is usually done by stakeholders, but that production costs and total revenues should also be considered. In such a case, we could obtain a significantly different picture.

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About the authors

Jaka Žgajnar, PhD is an Associate professor employed at the Biotechnical Faculty, University of Ljubljana (Slovenia). He teaches a course on farm management, animal health economics, and the utilisation of mathematical programming techniques in agriculture. In the field of research, he deals mainly with using various mathematical programming techniques in the analysis of decision-making in agriculture. He deals with farm-level modelling and conducting impact assessment analyses of Common agricultural policy. He is actively involved in several research projects. Since 2018, he has been a Council member of the International Farm Management Association (IFMA). The author can be contacted at **jaka.zgajnar@bf.uni-lj.si**.

Lidija Zadnik Stirn, PhD is a Professor Emeritus of Operations Research at the University of Ljubljana, Biotechnical Faculty, Slovenia, and an Associate Professor at the University of Tennessee, Knoxville, USA. Her research focuses mainly on deterministic, stochastic, dynamic, multi-objective and group decision-making methods for socioeconomic and environmental problems in natural resource management. Her work has resulted in more than 600 publications. She has been President of the Slovenian Society for Operations Research since 1997, Vice-President of the Slovenian Society INFORMATIKA since 2002, Slovenian representative in IFORS, EURO and IFIP TC7 and coordinator of the IUFRO group Managerial Economics and Accounting. The author can be contacted at **Lidija.Zadnik@bf.uni-lj.si.**