Farm model and analysis of typical agricultural holdings, case of arable farming in Slovenia

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Abstract

In this paper we present farm model applied to analyse arable farming sector in Slovenia. The rationale for the farm-level model is mainly based on the growing demand and need for a micro-simulation tools that can design and analyse different farm-level policies, capturing the heterogeneity of farms, both in terms of representation and impact of different policies. In this paper we focus on economic indicators that are extrapolated from farm level to the sector level. Approach is prepared to support national Strategic plan of the CAP. Preliminary results suggest that the developed approach allows such simulations, as it mimics the situation in the field well enough according to statistical and other available data. According to the results, 6% of farms with arable production contribute 9.6% of the total revenue generated in agriculture. Model results show that farms in arable sector could achieve good results, on average up to 24 EUR GM/h. The effects of economies of scale are particularly evident on larger farms, where results could range almost up to 40 EUR GM/h. However, the importance of subsidies is very high and, in most cases, exceeds the level of GM achieved. Thus, a more pronounced deterioration after the reform can be expected.

Key words: Farm model, typical agricultural holding, arable farming, strategic plan

Introduction

Recently there has been an increasing emphasis on models that allow simulation at the level of agricultural holdings or at the level of selected aggregate (Langrell et al., 2013). It is a type of micro-simulation models, commonly referred to as farm models. Such models allow us to better understand decision-making and management at the level of agricultural holdings, and on the other hand give policy makers a better insight into what is happening on individual types of agricultural holdings, thus enabling them to make better fact-based decisions. Namely, the approaches of result-oriented and data-based agricultural policy are gaining in importance, which is also reflected in the growing need for micro-simulation tools that enable the analysis of the impact of different policies at the level of agricultural holdings (Ciaian et al., 2013).

Even though the leading models for sector analysis until recently were, models based mainly on the partial equilibrium and general equilibrium approach, this shift towards farm-models is obvious. In most cases, however, these are models based on the optimization potential of mathematical programming (Reidsma et al., 2018). One of such is also IFM-CAP model used by the European Commission in the EU (Reidsma et al., 2018), which is based on the Positive Mathematical Programming (PMP) approach and allows assessments of different policy impacts on existing aggregate and groups of agricultural holdings (Louhichi et al., 2015). It is a model at the level of the

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agricultural holdings of the entire EU, based mainly on FADN data. Its main purpose is to assess and analyse the various impacts of the CAP on the economic and environmental performance of agricultural holdings.

As the policy impacts vary between types of agricultural holdings, the application of models that provide more reliable estimates is very important. It should be emphasized that both the possibility and the reasonableness of analysis carried out at individual farm level are practically impossible. Instead, it makes sense to classify agricultural holdings into groups, using techniques that allow the identification of groups with common characteristics (Robles et al., 2005). Namely, besides the key orientation, agricultural holdings differ in the degree of specialization, size, intensity, impact on their resources, constraints and objectives, and consequently in decision-making, and also in terms of economic, environmental and social impacts of individual scenarios and policies (e.g. Cortignani and Dono, 2015; Reidsma et al., 2015b; Viaggi et al., 2010a, cited after Reidsma et al., 2018). In such a manner typical agricultural holding (TAH) could be defined, that are representatives for individual groups of farms.

The Farm model applied in this study is a tool based on a mathematical programming approach and allows for diverse analyses at the level of the farm's production plan. It is based on a modular approach in the form of spreadsheets in MS Excel and connects with a complex system of Model calculations prepared by Agricultural institute of Slovenia (AIS, 2022) as a key reference source of analytical and economic coefficients at the level of production activities. It is a tool that follows modern trends in agro-economic analysis in this area and allows analysis at the TAH level (Žgajnar et al., 2021).

Further, we briefly present the applied farm model and the models of TAH oriented in arable farming. We summarize key characteristics of the analysed eleven farms, which are representatives of the arable sector in Slovenia. Following is a presentation of the results at the farm and sector level. The paper is concluded with key findings.

Material and methods

Farm model

For a comprehensive analysis of decision-making at the level of the agricultural holdings, which is covered by the presented approach, it is primarily important to be able to simulate the baseline situation. This is important especially in terms of the structure of production plan (which activities are included), and in further steps also from the viewpoint of the achieved economic results and various economic indicators at farm and also sector level. For this purpose, a farm model was used.

The farm model applied is based on the principles of mathematical programming with limited optimization. This allows the use of different techniques in solving the production plan, which is the basic level of problem solving. In the given model version, classical linear programming is used. The developed matrix of production possibilities is a classic example of production planning in which we focus on finding the optimum of one objective. In the case of the given analyses, we looked for the optimal production plan maximizing GM.

Since the analysis of TAH was basically grounded on the assumption of reconstructing the production plan, we used an approach that allows this. It's so called "partial optimization process", which is an upgrade of LP with a complex system of equations. These make it possible to search for the values of those variables whose values we do not know for certain and which we want to calculate in such a way that the production plan on the agricultural holding will be completed and also technologically consistent. Soo, the key purpose is not to optimize production, but try to present the current situation on the farm or to reconstruct the current situation.

The problem of reconstructing the production plan is based on the fact that we define all key production activities or at least the lower and upper limits. The values of unknown variables (x_j) are calculated based on the optimisation potential of LP. In such a way the solution is technologically appropriate (balances of nutrients and purchased fodder, balances of animals, balances of mineral fertilizers etc.). The partial optimization process is based on classical linear programming. Partial optimization refers to the fact that a certain part of the activities is fixed (x_f) and requires that the solver also include them in to the optimal solution to a given extent (b_f).

$$maxEZ = \sum_{j=1}^{n} c_j x_j + \sum_{f=1}^{n} c_f x_f \qquad \text{...(1)}$$

So that

$$\sum_{j=1;f=1}^{n;r} a_{ij} x_j + a_{if} x_f \leq b_i \qquad \text{for all } i = 1 \text{ do } m \qquad \text{...(2)}$$

$$x_f = b_f \qquad \text{for all } f = 1 \text{ to } r \quad \text{...(3)}$$

$$x_j \geq 0 \qquad \text{for all } j \qquad \text{...(4)}$$

All activities (x_f), the scope of which are known, are fixed with additional constraints (b_f). These activities are already defined in the calibration phase of TAH and do not change during further analyses. The basic guideline is that these are the activities that define the type of agricultural holding. In the analysed arable TAHs, the key were constraints related to land available and crop rotation where we defined the relationships of individual crops, as we encounter in practice on such farm types.

Analysed typical agricultural holdings specialised in arable farming

The analysis was performed on 11 typical farms (Table 1). These are typical agricultural holdings focused on arable farming. We summarize the key data for each TAH, which is representative for a certain number of farms. According to the statistical data, there are 3,161 pure arable farms in Slovenia. These were determined on the basis of an in-depth analysis of available statistical data, SO analysis, and other sources on workshops with different experts from the field (Žgajnar et al., 2022).

Table 1: Typical agricultural holdings specialised in arable farming in Slovenia

TAH's Code	Farms	Arable land	Labour	Wheat	Barley	Corn	Soybeans	Oilseed rape	Pumpkin	Potatoes	Buckwheat*	Set-aside
	(No)	(ha)	(FTE)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
TAH1	600	4	0.07	1.6	1	0.98	0		0.4	0.02	0.2	
TAH2	600	9	0.12	3.6	1.89	3.15	0.36				0.378	
TAH3	330	15	0.19	3.75	3	5.25	0		2.25		0.6	0.75
TAH4	60	15	0.15	5.25	4.5	3.675	0.75			0.075	0.9	0.75
TAH5	360	15	0.32	5.25	4.5	1.275	0.75			2.475	0.9	0.75
TAH6	330	15	0.14	4.5	3	3.75	0.75	2.25			0.6	0.75
TAH7	360	25	0.18	7.5	5	10	1.25				1	1.25
TAH8	300	40	0.30	10	8	14	2	4			1.6	2
TAH9	150	70	0.52	17.5	14	24.5	3.5	7			2.8	3.5
TAH10	60	150	1.01	40.5	34.5	52.5	7.5	7.5			6.9	7.5
TAH11	14	1,000	5.71	280	230	350	40	50			46	50
Total	3,161	78,425	719	22,701	17,178	25,628	3,360	4,138	981	906	3,436	3,531

*Legend: Code of the TAHs – first for numbers are ha of arable land, next two signs are main production activities, followed by expected wheat yield and location of the farm; FTE – full time equivalent; GC- grains and corn; Pa – potatoes; *Buckwheat is a subsequent crop after barley and wheat; TAH1 - TAH_0004_GC_4500_East; TAH2 - TAH_0008_GC_5000_East; TAH3 - TAH_0015_GC_6000_East; TAH4 - TAH_0015_GC_5500_C-North; TAH5 - TAH_0015_Pa_5500_C-North; TAH6 - TAH_0015_GC_6000_East; TAH7 - TAH_0025_GC_6000_East; TAH8 - TAH_0040_GC_6200_East; TAH9 - TAH_0070_GC_6500_East; TAH10 - TAH_0150_GC_6500_East; TAH11 - TAH_1000_GC_6500_East;*

For each farm we present various data. The first is for how many farms each TAH is a representative (No). Further, how many hectares of arable land (own and rented) it utilises and the main crop activities in the crop rotation. It is assumed that farms are mainly located in two regions, which are most favourable for arable production (eastern part (East) and central-northern part (C-North) of Slovenia). In Table 1 we present the crop rotation typical for such farms. However, the intensity of production (expected yield per each crop) is different and is summarized in the code of each TAH for wheat production, ranging from 4.5 tonnes up to 6.5 tonnes. Namely, wheat production is an activity that is present on all TAHs. In such a manner its yield (expressed in kg per ha – second number in the TAH's code) illustrates also the intensity of other activities. Based on the crop rotation, machinery, size, structure and distance of the arable land, we also estimated the need for effective working units (FTE) per each farm.

Results

Further we present the main results for the arable sector in Slovenia. In this analysis, we used price data for the three-year period 2018-2020 (AIS, 2022). The emphasis is mainly on the sector's contribution to the overall aggregate of agriculture, and the results achieved by arable TAHs. We briefly present the key results by individual TAHs. In the following, we present also the consumption of main production resources.

Given the average size of farms in Slovenia the arable sector is typically dominated by relatively large farms. Therefore, the production of market crops in areas, mostly smaller than 40 ha, is commonly only additional source of family income. As can be seen from Table 1, in such a case the need for effective labour is in most cases much less than 0.3 FTE.

Table 2: Selected economic indicators by each TAH

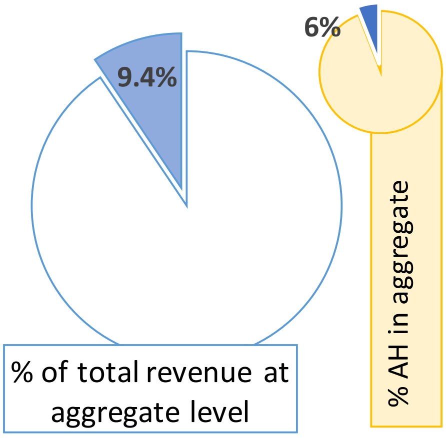
TAHs	**TR**	**BP**	**VC**	**GM**	**GM/ha**	**GM/FTE**	**GM/h**
TAH_ha_main crop_yield_region	(EUR)	(EUR)	(EUR)	(EUR)	(EUR)	(EUR)	(EUR)
TAH_0004_GC_4500_East	6,891	1,925	4,651	2,240	448	34,093	18.9
TAH_0008_GC_5000_East	13,905	3,975	10,266	3,639	364	30,526	17.0
TAH_0015_GC_6000_East	24,318	5,974	17,955	6,362	398	34,206	19.0
TAH_0015_GC_5500_C-North	20,209	6,205	15,991	4,218	281	28,372	15.8
TAH_0015_Pa_5500_C-North	41,697	6,026	24,526	17,171	1,145	52,919	29.4
TAH_0015_GC_6000_East	19,999	5,998	15,452	4,548	303	32,079	17.8
TAH_0025_GC_6000_East	35,707	9,850	28,238	7,468	299	40,827	22.7
TAH_0040_GC_6200_East	57,032	15,731	44,936	12,096	302	40,150	22.3
TAH_0070_GC_6500_East	103,682	28,057	81,448	22,234	318	42,856	23.8
TAH_0150_GC_6500_East	222,419	61,125	173,170	49,249	328	48,528	27.0
TAH_1000_GC_6500_East	1,503,815	384,869	1,216,877	286,937	287	70,849	39.4

Legend: TR- total revenue, BF – budgetary payments, VC – variable costs, GM – gross margin, FTE – full time equivalent, GC- grains and corn, Pa – potatoes, TAH – typical agricultural holding

As expected agricultural holdings achieve significantly different results. Small agricultural holdings are more efficient per unit area (GM/ha), while larger agricultural holdings are better off per unit of labour involved (GM/h). All this shows on great importance of work efficiency through machinery and economies of scale. As can be seen from the Table 2, budgetary payments are extremely important for arable farms. With the exception of the TAH_0015_Pa_5500_C-North, which is engaged in the production of potatoes, in all others they are close to the level of gross margin or even exceeds it up to 30%.

Arable farming is more important in the share of total output generated (9.4%) than in number of farms (6%). However, this refers to the contribution of only those TAHs, whose arable production is the main activity. Namely, arable production is very important also in other sectors such as dairy, beef, pig and also poultry. In the case of typical arable farms, most or all of the crop is tradable, while on other TAHs it is used mainly for animal feed. Only about 6% of all farms in Slovenia, including the largest agricultural companies with (several) thousand ha of arable land, are holdings with the main share of output coming from arable production (Table 3).

Table 3: Summary of selected indicators for the arable sector

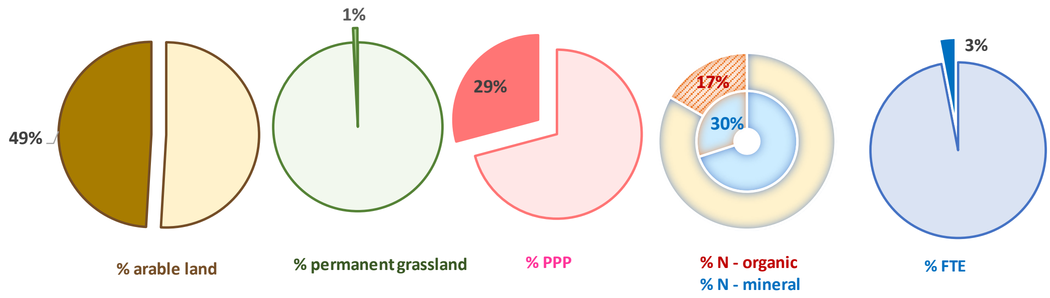


		Gross margin	Gross margin per FTE	Gross margin per working hour	Gross margin per working hour	Gross margin per working hour
		(EUR)	(EUR)	(EUR/h)	(EUR/h)	(EUR/h)
		Total sector			<0.3 FTE*	< 1.5 FTE**
Minimum		2,240	28,372	15.8	15.8	15.8
Average		9,540	43,343	24.1	19.8	22.3
Maximum		286,937	70,849	39.4	22.7	29.4
Number of agricultural holdings	(%)			100	81.6	99.6
Arable land of the sector	(%)			100	57.3	82.1
FTE of the sector	(%)			100	69.6	88.9

** Selected agricultural holdings whose labour demand is less than 0.3 FTE; ** Selected agricultural holdings whose labour demand is less than 1.5 FTE*

Production of arable farming could be in general characterized by rapid technical progress, which has led to higher labour productivity or low labour inputs per unit area. It is difficult to follow this trend, especially when managing smaller arable area. However, they have to compete on the market with crop prices of the best organized larger holdings. Effective labour inputs on smaller TAHs rarely exceed 0.3 FTE, unless slightly more demanding crops like potatoes, pumpkins, sugar beet or similar are included in the crop rotation. Given these reasons, it is understandable that the economic results achieved do not allow survival only from arable production activities on those agricultural holdings. On the other hand, GM per hour of labour is favourable, on average above 20 EUR/h, and on slightly larger TAHs and those that include also more commercially interesting crops, even above 30 EUR/h (Table 2). This is also reflected in the differences shown in the Table 3 according to the class of FTE in which the individual holding is classified. We can see that in terms of labour input, smaller farms (<0.3 FTE) represent almost 82% of all arable farms and cultivate almost 60 % of all arable land (Table 3). At the same time, it is clear that less than 0.4% of farms utilise larger areas (FTE > 1.5), and in total this represents 8% of all land cultivated by arable sector (Table 3).

Arable farms in Slovenia utilise almost half of all arable land (Figure 1). Due to intensive production, there is also a relatively high consumption of phytopharmaceuticals (PPP), expressed in monetary value. It should certainly be pointed out that the key consumers of PPP in Slovenia are permanent crops, therefore, the share seems low at first glance. This may be a problem in the near future, given the higher environmental emphasis. This sector is also important from the point of view of the consumption of mineral fertilizers (in this case expressed as nitrogen consumption), where 30% of the total annual consumption in agriculture is used. Based on the aggregate analysis, we can see that this type of agriculture represents 3% of the total effective labour force (FTE) in agriculture.



PPP - Plant protection products; FTE – full time equivalent; N - nitrogen consumption

Figure 1: Consumption of selected production resources at the level of the arable production

Conclusions

The approach used has proven to be effective, as it allows simulations both at the TAH's level and at the sector level. Both physical aggregates and key economic indicators show satisfactory coverage with comparable values in national statistics. Therefore, we can conclude that the model can be applied for monitoring development trends in Slovenian arable sector. This also makes it possible to support a CAP strategic plan and further simulations of different CAP scenarios.

Although the paper does not present more detailed production plans by typical farms, it is clear what results individual farms are achieving. There are quite large differences in efficiency. At the same time, smaller agricultural holdings achieve better results per unit of arable land, while larger farms achieve better results per unit of labour input. The latter difference would be even more obvious if we would consider the labour available and not just the effective labour.

The results here presented only in aggregate form, clearly show the great importance of budgetary payments on these farms. In principle, holdings oriented in arable farming are among those that have recently received the highest total budgetary payments per unit area. This is partly due to higher payment entitlements for arable land and coupled payments for grains, and partly also due to mostly high involvement in additional measures (Agri-environment-climate payments), as they have no problems with load of LU, as opposed to more intensive livestock farms, they are also not under pressure to provide certain feed for their animals. It is fact that basic payments for arable land will be reduced in the future, and production-linked support for grains is expected to abolish. It is therefore no surprise that one can expect a rather sharp decline in budgetary payments and strong decline in GM in arable farming in Slovenia.

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