Research Article

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Efficiency of the European Union farm types: Scenarios with and without the 2013 CAP measures

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Abstract: The European Union Farm Accountancy Data Network (FADN) publishes data for the representative farms of several European Union (EU) farm types, regions and countries. In this database, the published data for the farm types allow us to assess several agricultural policies. In fact, the FADN publishes data for the EU farming types and there are not many studies about these fields in the whole European context. This study aims to bring novelty for the whole spectrum of stakeholder types in these domains. The analysis of these impacts may bring relevant insights, especially, for adjustments in the design of future strategies and plans. We analyse the evolution of the EU farm types in the last two decades with significant scenario changes like two large common agricultural policy (CAP) reforms (2003 and 2013) and suggest new approaches to the design for future measures. Statistical information from the FADN over the period 2004–2018 is considered. In addition, efficiency and productivity assessments are carried out, to assess the implications of the most recent instruments of the CAP. The results show that the policy instruments in the framework of the 2013 CAP justify the use of more inputs (or at least at higher costs) for the same level of output. In fact, the subsidies given to the farmers since 2014 mask the inefficiencies underlying some farm types. A significant decrease in the total factor productivity confirmed this trend, despite positive growth rates for the total verified output for several farm types over the period.

Keywords: farming systems, FADN, data envelopment analysis, Malmquist index

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1 Introduction

Climate change and global warming call for more sustainable practices in all economic sectors and in particular, more environment-friendly agricultural systems [1]. At the same time, the increasing trend in the world population is mostly responsible for global pressures to maintain high rates of economic growth [2]. Farming sustainability is a multi-dimensional concept that should be useful to the policymakers, capturing the complexities involved in the dynamics of agriculture [3]. Agricultural policies may have relevant contributions here, especially for the European Union (EU) member states and regions [4]. Eco-efficiency approaches may also play a relevant role because they aim at improving economic performance, minimizing environmental externalities [5].

Methodologies associated with data envelopment analysis (DEA) are often used to assess the efficiency of agricultural systems [6]. In some cases, DEA is complemented by other approaches [7], like fuzzy DEA [8]. The efficiency assessment of a farming system is crucial when aiming at enhancing profitability [9] and sustainability through a better use of resources including energy [10], which is a critical resource in the farm when pursuing economic and environmental values [11].

The main objective of this research is to analyse the evolution of the EU farm types over the last two decades, assessing the impact of several external shocks (financial and economic crises) and common agricultural policy (CAP) reforms on farm performance. It is also an objective of this study to make suggestions on new policy instruments for future CAP reforms. In fact, in the beginning, the CAP was focused on production. After the CAP reform of 1992, agricultural policies partly decoupled from production but remained focused on farming activities. Since 2003, aids became completely decoupled through a single payment conditional on criteria related to health and the environment [12]. Our questions here are the following:

- Do the new CAP instruments enhance efficiency in the use of farming resources?
- Can CAP measures be more effective for reducing inefficiencies by a focus on farm resources?

1.1 Literature review

Agriculture is a complex sector that depends on several factors and is called to respond to various challenges [13]. This often hinders the efficient use of the resources in the farms [14]. The education of the farmers, the location and size of the farms are variables, which sometimes, are found to influence agricultural efficiency [15] as well as the availability of land in specific contexts as those from the overseas islands [16]. The particularities of the agricultural systems and the characteristics of the farmers have been shown to impact farm efficiency [17].

Agricultural policies have implications on the use of resources and consequent outputs [16], including promotion of sustainable development [18], environmental efficiency [19], and organic farming which may bring interesting contributions [20]. The CAP measures have been designed to promote farm sustainability, reducing the environmental impacts [21]. The environmental impacts on agriculture in the EU is a concern for all stakeholders [22]. The relationship of agricultural sector with the environment is particularly relevant in the context of climate change [23] and its environmental consequences [24], where it is intended to meet the food needs and reduce the environmental impact [25]. Farm management through adjusted plans for better practices is another approach that contributes to more sustainable farming systems [26]. In addition, the limited number of studies in the EU context about the farm types hampers the analysis for this specific framework. In these plans, strategies of specialization/diversification [27], depending on the specific context [28], and dimensions associated with the farm design [29] should be considered in the decision-making processes.

In terms of methodology, to carry out an efficiency assessment at the farm level, the DEA is often considered [30] to define production frontiers [31] through benchmarks with the most efficient practices [32] and, in this way, identify the more profitable production patterns [33]. The DEA is considered to assess the relationship of several farm dimensions with efficiency, including the impacts from the CAP measures [31]. In some cases, the DEA is adopted jointly with other approaches to better address the specificities of the agricultural sector [34].

In general, researchers combining DEA with other methodologies aim to assess the environmental impacts [35] from farm activities [36], or at finding alternative activities [37] to deal with the consequences of climate change [38]. Another aim to identify new techniques of efficiency assessment is related to the needs to promote more eco-efficiency and sustainable intensification [39]. In particular, it is intended to make the systems more compatible with the increased requests for food [40] and the requirements to reduce the environmental implications [41].

Factor-cluster analysis is an example of approaches frequently used together with DEA [42] to assess the efficiency of agricultural systems [43]. Other examples are the policy analysis matrix [44], slack-based measures [45], life-cycle assessment [46], partial least squares structural equation modelling [47], and tobit models [48].

Usually, efficient use of energy in the farms deserves great attention [49], mainly because of its importance for agricultural performance [50] and its interrelationship with other dimensions [51]. The farms may also be an important source of renewable energies that may be produced with different resources and technologies [52,53]. Water is another farming resource, where efficient management is a determinant [54] for sustainable and integrated developments.

Using data at farm level from the European Union Farm Accountancy Data Network (FADN) database to assess the efficiency of the farming systems in the EU contexts through DEA approaches is rather rare, highlighting the relevance of this study. There are studies that consider some European cases [55], but there are not many studies considering the EU context as a whole.

2 Materials and methods

To achieve the objectives designed for this study and presented in Section 1, data publicly available in the FADN database [56] were considered for the period 2004–2018 for the whole EU. These data were taken into account for several EU farming types and presented in Table 1. The total farming type, with the designation “total,” represents not the sum of the 14 different farming types, but the representative farm type for the EU context and the respective statistical information was obtained from the FADN

Table 1: Trends (increasing or decreasing) over the period 2004–2018 for several farming system variables

	Labour input (h)	Total utilised agricultural area (ha)	Total LUs	Stocking density (LU/ha)	Total output/ total input (ratio)	Total crops output (€/ha)	Total livestock output (€/LU)	Specific crop costs (€/ha)	Specific livestock costs (€/LU)	Farm net value added (€/AWU)
Specialist COP	Increasing	Decreasing	Increasing	Decreasing	Increasing	Increasing	Decreasing	Increasing	Increasing	Decreasing
Specialist other fieldcrops	Decreasing	Decreasing	Decreasing	Decreasing	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing
Specialist horticulture	Increasing	Increasing	Decreasing	Decreasing	Decreasing	Increasing	Increasing	Increasing	Increasing	Increasing
Specialist wine	Increasing	Increasing	Decreasing	Decreasing	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing
Specialist orchards – fruits	Increasing	Increasing	Increasing	Decreasing	Decreasing	Increasing	Decreasing	Increasing	Increasing	Increasing
Specialist olives	Decreasing	Increasing	Decreasing	Decreasing	Decreasing	Increasing	Increasing	Increasing	Decreasing	Increasing
Permanent crops combined	Decreasing	Increasing	Decreasing	Decreasing	Decreasing	Increasing	Increasing	Increasing	Increasing	Increasing
Specialist milk	Decreasing	Decreasing	Increasing	Increasing	Decreasing	Increasing	Increasing	Increasing	Increasing	Increasing
Specialist sheep and goats	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Increasing	Increasing	Increasing	Increasing	Decreasing
Specialist cattle	Decreasing	Increasing	Decreasing	Decreasing	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing
Specialist granivores	Increasing	Increasing	Increasing	Decreasing	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing
Mixed crops	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Increasing	Increasing	Increasing	Increasing	Increasing
Mixed livestock	Decreasing	Decreasing	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing	Increasing
Mixed crops and livestock	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Increasing	Increasing	Increasing	Increasing	Increasing
Total	Decreasing	Increasing	Increasing	Decreasing	Decreasing	Increasing	Increasing	Increasing	Increasing	Increasing

Note: COP, cereals, oilseeds, and protein crops.

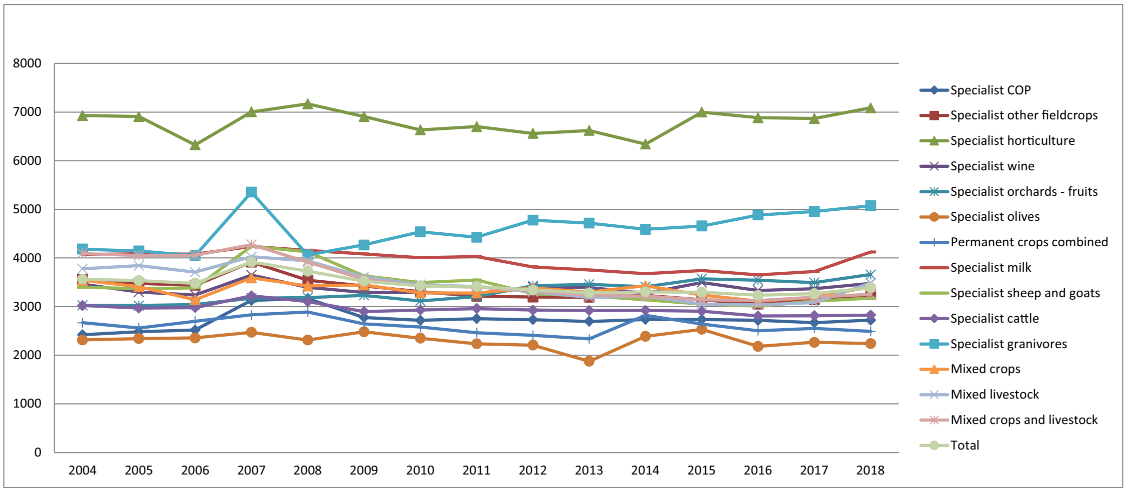

Figure 1: Labour input (h), per farm, for several farm types, for the period 2004–2018.

database. The variables chosen were considered to better reflect and assess the several impacts over the last two decades on the structure and competitiveness of the European farms. These variables have been chosen considering some of the most cited papers on farms' technical efficiency and farms' resources. The FADN focuses, for historical reasons, on financial rather than environmental (or social) farm/farmer attributes, and is restricted to "commercial" farm holdings – which of course accounts for the bulk of the EU's farm land and output, but exclude many EU farmers, and much ecology. However, given its recurrent use and the capacity of covering so many variables of European regions, FADN data have many potentialities for analytical use. This database publishes information for representative farms found through a weighting system to get average accounting values and data obtained in the farms of each country. This means that each farm type in Table 1, for example, is represented by average values for each variable obtained through a weighting methodology. In each farm type, there are changes only over the considered period (15 observations). Another limitation of the database is that the published data are in currency units rather than physical units (in volume). In any case, to deal with the different contexts that may influence the evolution of the variables considered (CAP reforms, financial crisis, and adhesion of new member-states), a shorter period (2014–2018) was considered for the models of efficiency assessment. For the period 2014–2018, the average producer price index (2014–2016 = 100) was around 0.1% [57] and the average Harmonised Indices of Consumer Prices (annual average rate of change, European Union – 27 countries) was about 0.8% [58]. This is a context of low

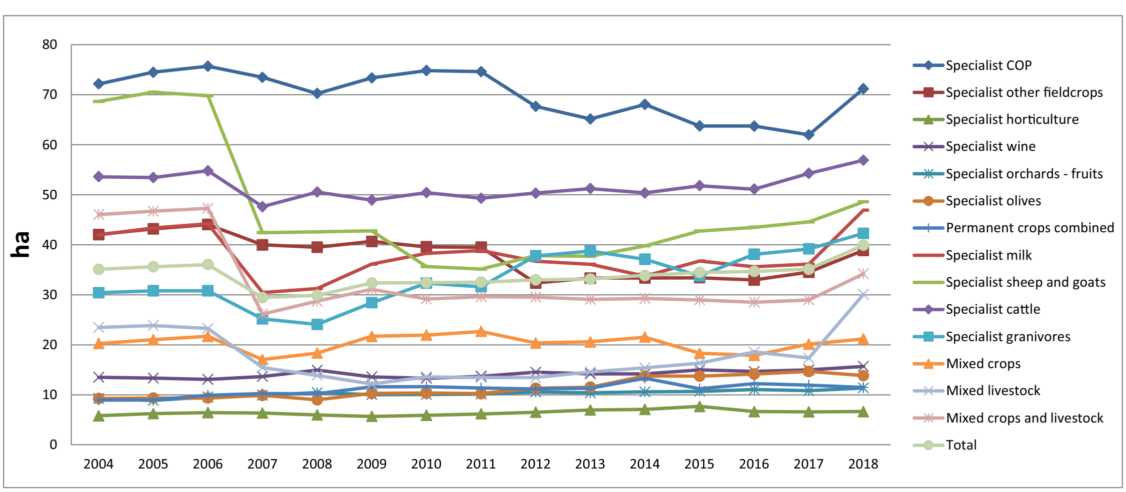

Figure 2: Total Utilised Agricultural Area (ha), per farm, for several farm types, for the period 2004–2018.

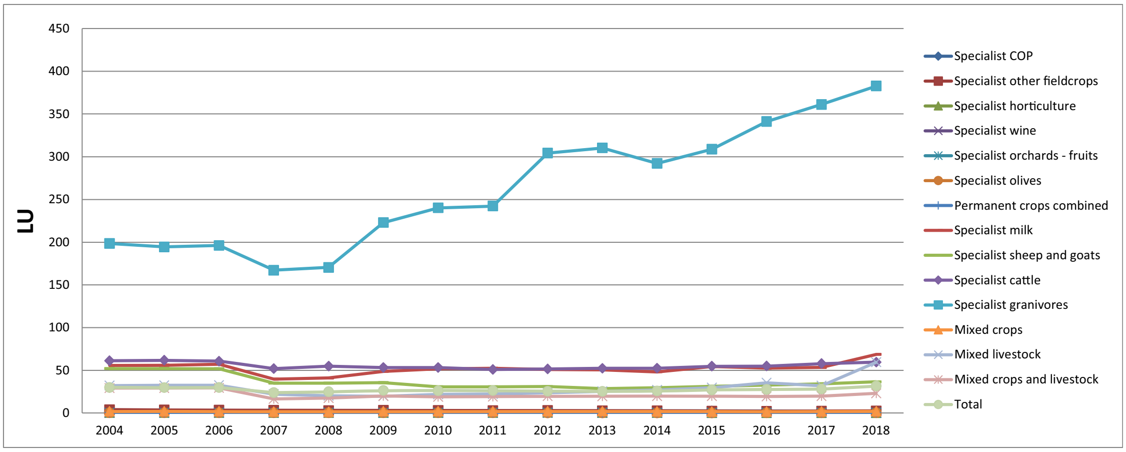

Figure 3: Total livestock units (LU), per farm, for the farm types, for the period 2004–2018.

inflation followed by the EU institutions [59] with residual impacts on the economic dynamics [60].

This statistical information was first analysed through descriptive approaches (to assess the evolutions over the entire period). Afterwards, the data were explored through DEA and Malmquist index methodologies using the DEAP software [61] and considering the Coelli [62] developments for the period 2014–2018 (after CAP reform of 2013) with and without subsidies (to analyse the effects of the policy measures adopted after 2013). DEA is an empirical method that considers linear programming methodologies to obtain nonparametric frontiers over the data in order to calculate any efficiencies. These approaches may be output- or input-oriented if the objective is to assess how the output can be expanded without changes in the inputs, or to analyse how the inputs could be reduced for the same level of output. The Malmquist index allows to work with panel data to calculate changes in total factor productivity [63]. Considering the literature, these methodologies are the most appropriate for the objectives proposed.

Section 3 will be organised to analyse the data for the period 2004–2018 and assess the impacts from the last reforms in the efficiency and competitiveness of the farms in the EU (considering data since 2014).

3 Results

3.1 Data analysis

The details shown in Table 1 were obtained by calculating the slope of a trend line that fits the different observations

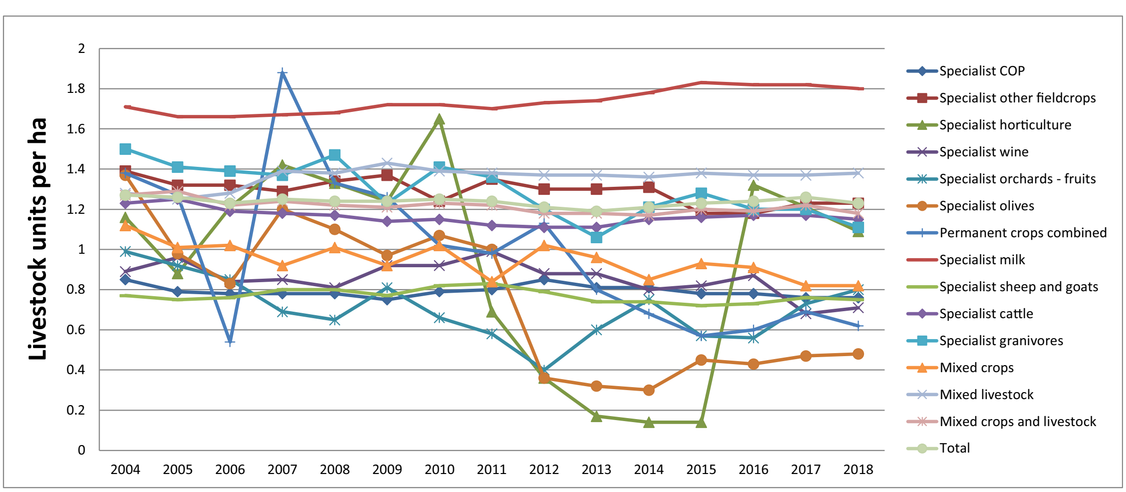

Figure 4: Stocking density, per farm, for several farm types, for the period 2004–2018.

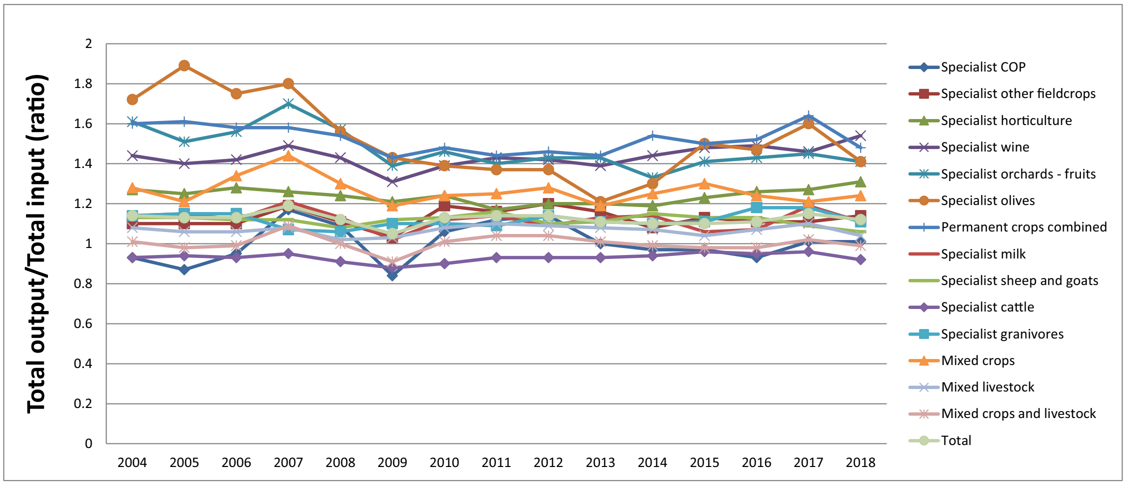

Figure 5: Total output/total input, per farm, for the several farm types, for the period 2004–2018.

of each variable over the period 2004–2018, for different farm types. To calculate the slope, it was considered as the coefficient of linear regressions. The results for these regressions were considered only to assess trends over the considered period, because regressions to find the marginal impacts call for time-series estimation approaches. This table shows that over the last two decades (2004–2018) there has been a trend in several farm types for increasing crop productivities of the area (total crops output (euros/ha)), as well as the specific crop costs per hectare. This means that the increase in crop production was supported by increase in the specific inputs costs (seeds, fertilizers, and crop protection products). Similar patterns were followed by the livestock activities, with increasing trends for the total livestock output per livestock unit (LU) and respective specific livestock costs (feed) per LU. These findings should be considered by the policymakers in future CAP reforms, in relation to sustainability and environmental concerns. Some exceptions to the increasing trends were found in the case of COP and orchards of fruit farming systems (in the productivities of the LU) and olive systems (in the specific livestock costs per LU). The competitiveness of the farms (farm net value added (euros/annual work unit, AWU)) also presents an increasing trend for several farm types, with the exception of COP, sheep and goat farms. The farm net value added is the output minus intermediate consumption, minus depreciations and plus balance current subsidies and taxes. This indicator is used to assess the remuneration of the fixed factors of production (work, land, and capital). AWU is the annual work unit.

In contrast, the total productivity (total output/total input), in general, presents a decreasing trend, with the exception (because they are fewer in the table, but it does

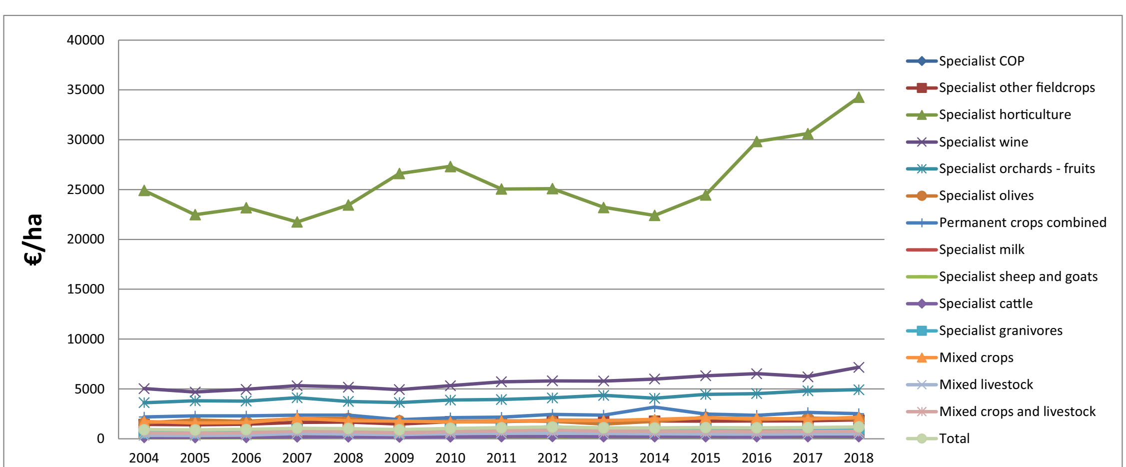

Figure 6: Total crops output (€/ha), per farm, for the several farm types, for the period 2004–2018.

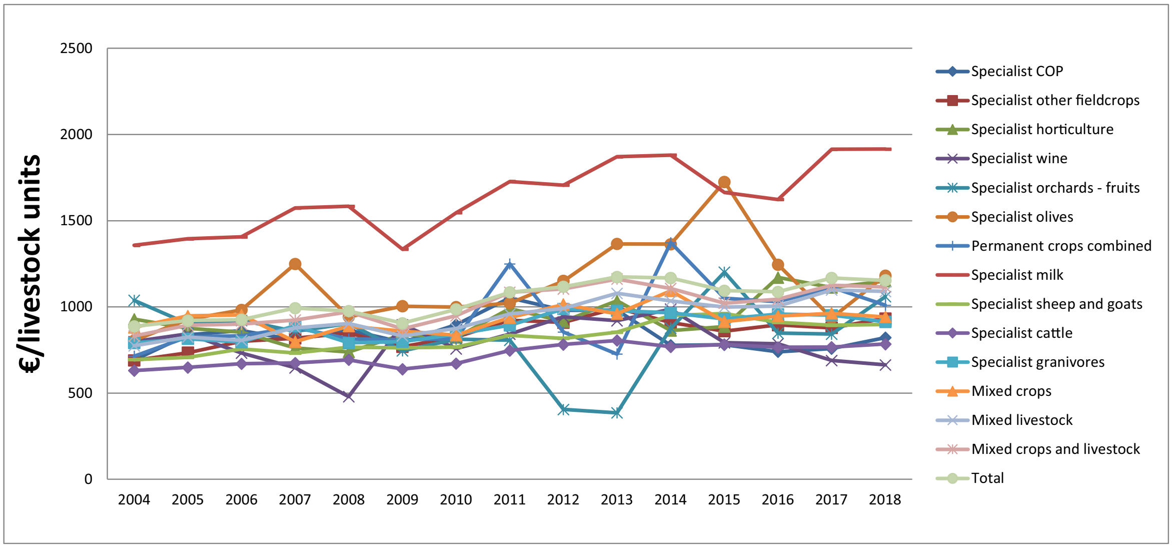

Figure 7: Total livestock output (€/livestock units), per farm, for the several farm types, for the period 2004–2018.

not mean that they are less important in the European context) of COP, other fieldcrops, wine, cattle, granivores (pigs, poultry, for example) and mixed livestock. The total output/total input is defined by the database as [56] (sales and use of crop and livestock + change in stocks of products + change in valuation of livestock – purchases of livestock + various nonexceptional products)/(specific costs + overheads + depreciation + external factors). The decreasing trends in the total productivity ratio verified for the majority of the systems reveal that, for example, the total output increased less than the total input. The stocking density (LU/ha) was also decreased with exception for milk and mixed livestock. The number of farm types with decreasing trends for the total LUs is greater than that of the total utilised agricultural area, explaining, in part, the decreasing trends for the stocking density. The labour input also presents a decreasing trend in the majority of the systems, especially in case of livestock systems (exception for granivores).

As expected, farms with horticulture are those that use most labour input, given the characteristics of horticultural farm types. However, there are signs that smart agriculture practices may improve the automatisation of the sector and reduce the dependency on labour [2]. In turn, for several systems analysed, 2007 and 2008 were the years with most labour used by the EU farms (Figure 1). The average agricultural area utilised decreased significantly after 2006, with some recovery in 2018. The farms

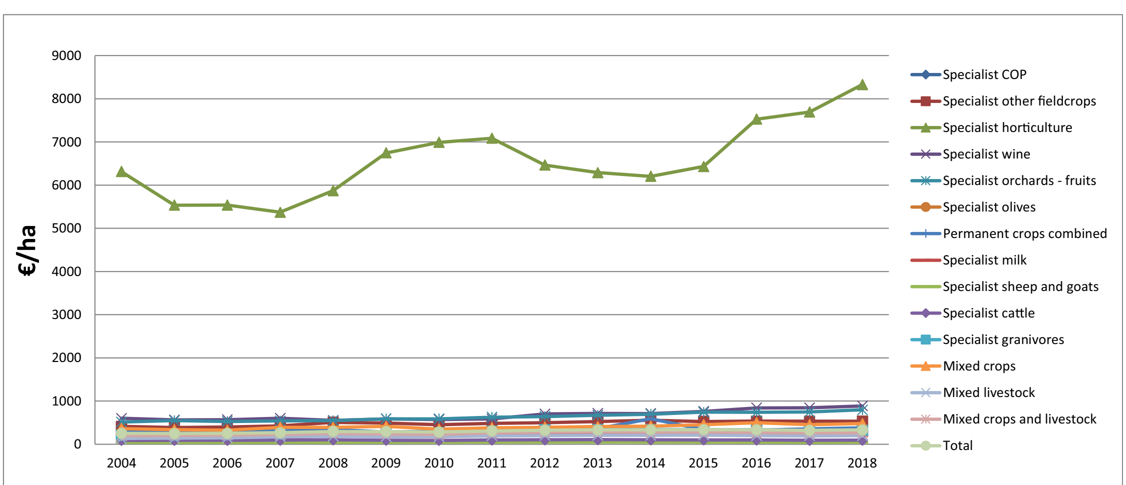

Figure 8: Specific crop costs (€/ha), per farm, for several farm types, for the period 2004–2018.

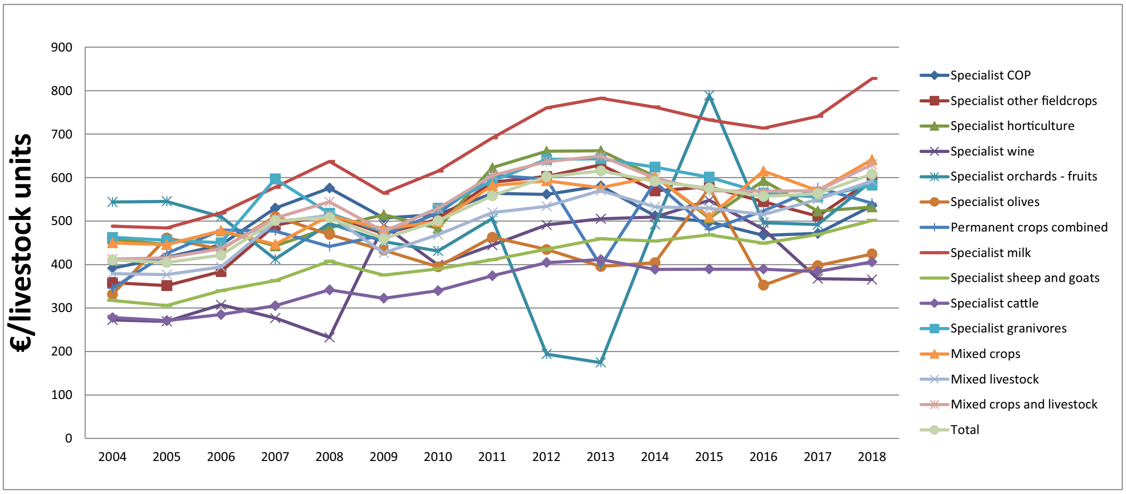

Figure 9: Specific livestock costs (€), per farm, for several farm types, for the period 2004–2018.

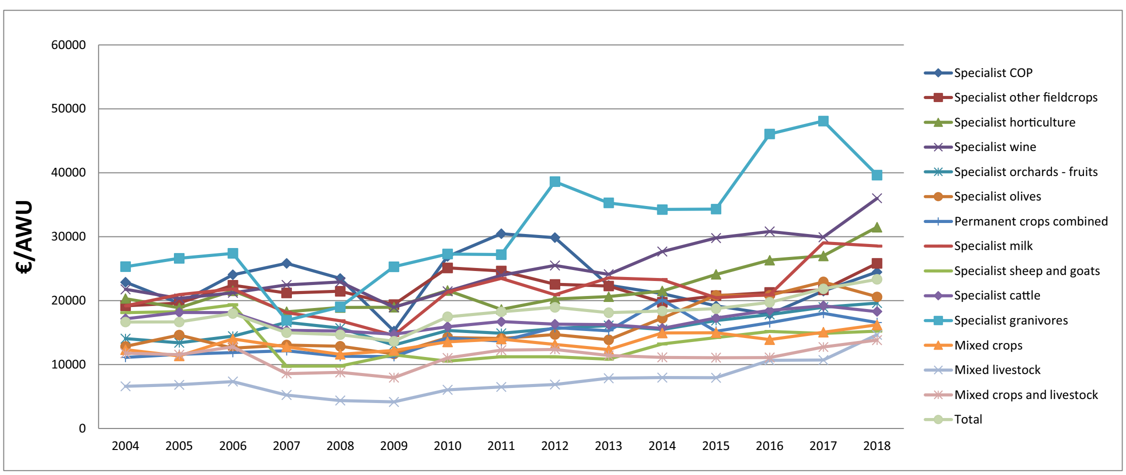

Figure 10: Farm net value added (€/AWU), per farm, for several farm types, for the period 2004–2018.

Table 2: Statistical summary of several variables considered (data on average for the period 2014–2018)

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
Total output without subsidies (€)	15	89,146	87,735	28,550	367,121
Total output with subsidies (€)	15	99,429	88,677	36,546	382,009
Labour input (h)	15	3,471	1,095	2,322	6,836
Total utilised agricultural area (ha)	15	29	17	7	66
Total LUs	15	38	85	0	337
Total inputs (€)	15	76,758	76,538	19,605	323,546
Total intermediate consumption (€)	15	53,530	61,874	10,056	260,890
Total specific costs (€)	15	35,379	51,188	4,257	212,317
Total farming overheads (€)	15	18,151	12,236	5,798	48,572
Total external factors (€)	15	13,479	11,302	4,296	43,707
Total assets (€)	15	358,114	175,440	179,807	855,609
Gross investment on fixed assets (€)	15	10,241	7,652	2,124	32,082

Table 3: Ratio (in %) between the projected values (obtained through input orientated DEA and using multistage method) and the original ones (data on average for the period 2014–2018)

	Total output	Labour input	Total utilised agricultural area	Total LUs	Total inputs	Total intermediate consumption	Total specific costs	Total farming overheads	Total external factors	Total assets	Gross investment on fixed assets
Specialist COP	100	100	100	100	100	100	100	100	100	100	100
Specialist other fieldcrops	100	97	42	100	76	67	55	80	100	89	79
Specialist horticulture	100	100	100	100	100	100	100	100	100	100	100
Specialist wine	100	100	100	100	100	100	100	100	100	100	100
Specialist orchards – fruits	100	100	100	100	100	100	100	100	100	100	100
Specialist olives	100	100	100	100	100	100	100	100	100	100	100
Permanent crops combined	100	100	100	100	100	100	100	100	100	100	100
Specialist milk	100	100	100	100	100	100	100	100	100	100	100
Specialist sheep and goats	100	100	100	100	100	100	100	100	100	100	100
Specialist cattle	100	100	100	100	100	100	100	100	100	100	100
Specialist granivores	100	100	100	100	100	100	100	100	100	100	100
Mixed crops	100	100	100	100	100	100	100	100	100	100	100
Mixed livestock	100	100	100	100	100	100	100	100	100	100	100
Mixed crops and livestock	100	93	54	93	84	83	84	81	93	93	69
Total	100	94	47	94	86	84	86	80	94	94	81

Table 4: Peer and peer weights (obtained through input orientated DEA and using multi-stage method) for the several EU farm types (data on average for the period 2014–2018)

	Order	Peers*					Peer weights**				
Specialist COP	1	1					1.000				
Specialist other fieldcrops	2	8	4	7			0.035	0.536	0.428		
Specialist horticulture	3	3					1.000				
Specialist wine	4	4					1.000				
Specialist orchards – fruits	5	5					1.000				
Specialist olives	6	6					1.000				
Permanent crops combined	7	7					1.000				
Specialist milk	8	8					1.000				
Specialist sheep and goats	9	9					1.000				
Specialist cattle	10	10					1.000				
Specialist granivores	11	11					1.000				
Mixed crops	12	12					1.000				
Mixed livestock	13	13					1.000				
Mixed crops and livestock	14	6	11	3	13	7	0.425	0.004	0.048	0.479	0.045
Total	15	7	11	3	8	4	0.628	0.060	0.019	0.100	0.193

*Peers are the farming types found to benchmark each type of farm; **peer weights are the relative importance in the benchmarking process of each farming type.

of the COP systems are large (Figure 2). The number of LUs also decreased after 2006; however, the recovery was more consistent. The granivore systems are those with, on average, more LUs (Figure 3). Despite the increase in the LUs after 2007, the stocking density decreased since this year, with some recovery in the last years (Figure 4). The information presented in these figures are for farm types where sometimes crops and livestock productions are combined. On the one hand, these data are for representative farms obtained through weighting approaches. It seems that the CAP reform of 2003 implemented since 2005 had an impact here, considering the findings described before. On the other hand, it seems that the CAP reform of 2013 overcame these implications, especially in the recent years, where there was some significant recovery in the variables analysed.

The total productivity remained, in general, without significant changes (Figure 5). Crop productivity of the area increased, in general, over the period, with farms with horticulture systems having, on average, higher productivities (Figure 6). A similar pattern was found for the trends, across the diverse farming types and over the considered period of the livestock productivity (Figure 7), specific crop costs (Figure 8), specific livestock costs (Figure 9), and competitiveness of the farms (Figure 10). The statistical information presented in these figures highlight that the CAP reforms of 2003, for the total decoupling of the subsidies, and 2013, with some adjustments relatively to 2003, had their impacts on the structures of the EU farms, but in inverse directions. The 2003 CAP reform allowed farmers to progressively receive subsidies from the first Pillar decoupled from production and activities, albeit with some constraints. The 2013 CAP reform adjustments seem to promote the recovery of some variables. In addition, the financial crisis of 2008 also had implications for the competitiveness of farms. These findings highlight the implications of the CAP reforms and international events on the European agricultural sector evolution.

3.2 Efficiency analysis

In this Subsection, a DEA was carried out considering an extended Cobb-Douglas [64] production function and the developments from Martinho [6,65]. The total output (total of output of crops, livestock, and of other output) was considered, while inputs were labour cost, total utilised area, total LUs, total inputs (total specific costs + overheads + depreciation + external factors), total intermediate consumption (specific costs + overheads) total specific costs (seeds and seedlings, fertilizers, crop protection products, other specific crop costs, feed for grazing stock and granivores, other specific livestock costs and specific forestry costs), total farming overheads (machinery and building current costs, energy, contract work and other direct inputs), total external factors (wages paid, rent paid, and interest paid), total assets, and gross investment on fixed assets. The main objective of considering these variables as input was to assess the main inefficiencies associated with several farming inputs and their respective

Table 5: Ratio (in %) between the projected values (obtained through input-orientated DEA and using multistage method) and the original ones (data on average for the period 2014–2018), considering the subsidies as additional output

	Total output + total subsidies – excluding on investments	Labour input	Total utilised agricultural area	Total LUs	Total inputs	Total intermediate consumption	Total specific costs	Total farming overheads	Total external factors	Total assets	Gross investment on fixed assets
Specialist COP	100	100	100	100	100	100	100	100	100	100	100
Specialist other fieldcrops	100	100	100	100	100	100	100	100	100	100	100
Specialist horticulture	100	100	100	100	100	100	100	100	100	100	100
Specialist wine	100	100	100	100	100	100	100	100	100	100	100
Specialist orchards – fruits	100	100	100	100	100	100	100	100	100	100	100
Specialist olives	100	100	100	100	100	100	100	100	100	100	100
Permanent crops combined	100	100	100	100	100	100	100	100	100	100	100
Specialist milk	100	100	100	100	100	100	100	100	100	100	100
Specialist sheep and goats	100	100	100	100	100	100	100	100	100	100	100
Specialist cattle	100	100	100	100	100	100	100	100	100	100	100
Specialist granivores	100	100	100	100	100	100	100	100	100	100	100
Mixed crops	100	100	100	100	100	100	100	100	100	100	100
Mixed livestock	100	100	100	100	100	100	100	100	100	100	100
Mixed crops and livestock	100	97	63	97	91	91	93	89	97	97	79
Total	100	97	63	97	95	95	97	93	97	97	95

Table 6: Peer and peer weights (obtained through input orientated DEA and using multi-stage method) for the several EU farm types (data on average for the period 2014–2018), considering the subsidies as additional output

	Order	Peers*						Peer weights**					
Specialist COP	1	1						1.000					
Specialist other fieldcrops	2	2						1.000					
Specialist horticulture	3	3						1.000					
Specialist wine	4	4						1.000					
Specialist orchards – fruits	5	5						1.000					
Specialist olives	6	6						1.000					
Permanent crops combined	7	7						1.000					
Specialist milk	8	8						1.000					
Specialist sheep and goats	9	9						1.000					
Specialist cattle	10	10						1.000					
Specialist granivores	11	11						1.000					
Mixed crops	12	12						1.000					
Mixed livestock	13	13						1.000					
Mixed crops and livestock	14	13	6	3	1	7		0.530	0.157	0.053	0.053	0.207	
Total	15	3	13	8	4	11	6	0.057	0.056	0.330	0.027	0.020	0.511

*Peers are the farming types found to benchmark each type of farm; **peer weights are the relative importance in the benchmarking process of each farming type.

costs. To deal with the structural breaks from the several shocks associated with the CAP reforms and the financial crisis, only data for the period 2014–2018 were considered.

Table 2 presents the statistical summary of the several variables related to the 15 farm types, and Table 3 reveals that the several farm types considered are efficient (with values of 100%) in the use of the diverse inputs, except for the following farming types: other fieldcrops, mixed crops and livestock, and total. The main inefficiencies in these farm types are associated with the total area utilised for agriculture where could be possible to reduce about 50% of the area without affecting the level of output. The other fieldcrop system should be benchmarked, especially with the wine farming types, mixed crops, and livestock with the mixed livestock and total with permanent crops combined (Table 4). The permanent crops combined appear here with an interesting balance among output, inputs, and respective costs. In these tables, the total farming type, with column head "total," represents not the sum of the 14 different farming types, but the representative farm type for the all EU context.

The consideration of the EU subsidies from the CAP framework eliminates the inefficiencies verified for other fieldcrops and improve the efficiency of mixed crops, livestock and total farm types (Table 5). In other words, the subsidies given to farmers since 2014 imply the use of more inputs, at least the use of inputs with higher costs, with consequences on the sustainability. In addition, these subsidies make the milk system as a better benchmark for the total EU systems (Table 6). These are interesting findings that deserve special attention by several stakeholders, especially by the policymakers, considering that the current world's endeavour is to achieve more output with less resources.

3.3 Productivity and output growth

Considering the similarities between the levels of technical efficiency for several farm types verified in Subsection 3.2, it is important to go further and understand whether this pattern is followed by the evolution of competitiveness (total factor productivity). In this perspective, an analysis of total factor productivity and total output evolution was carried out, its results are presented in Tables 8 and 9 and Figure 11 (summary statistics are presented in Table 7). These results are based on the growth rates for the period 2014–2018, including, and not, the current subsidies (excluding those on investments). The data considered were obtained from the FADN [56] database and were explored with DEAP [61] software, following the procedures proposed by Coelli [63] for the Malmquist Index (input oriented) to obtain total factor productivity changes.

On an average, total factor productivity, for the period 2014–2018, decreased for several farm types, except for horticulture that grew by 1.4% (Table 8). The worse performances were verified for the granivores, milk, and mixed livestock. In addition, there are great similarities among the total factor productivity changes with and without subsidies. The only slight differences are verified

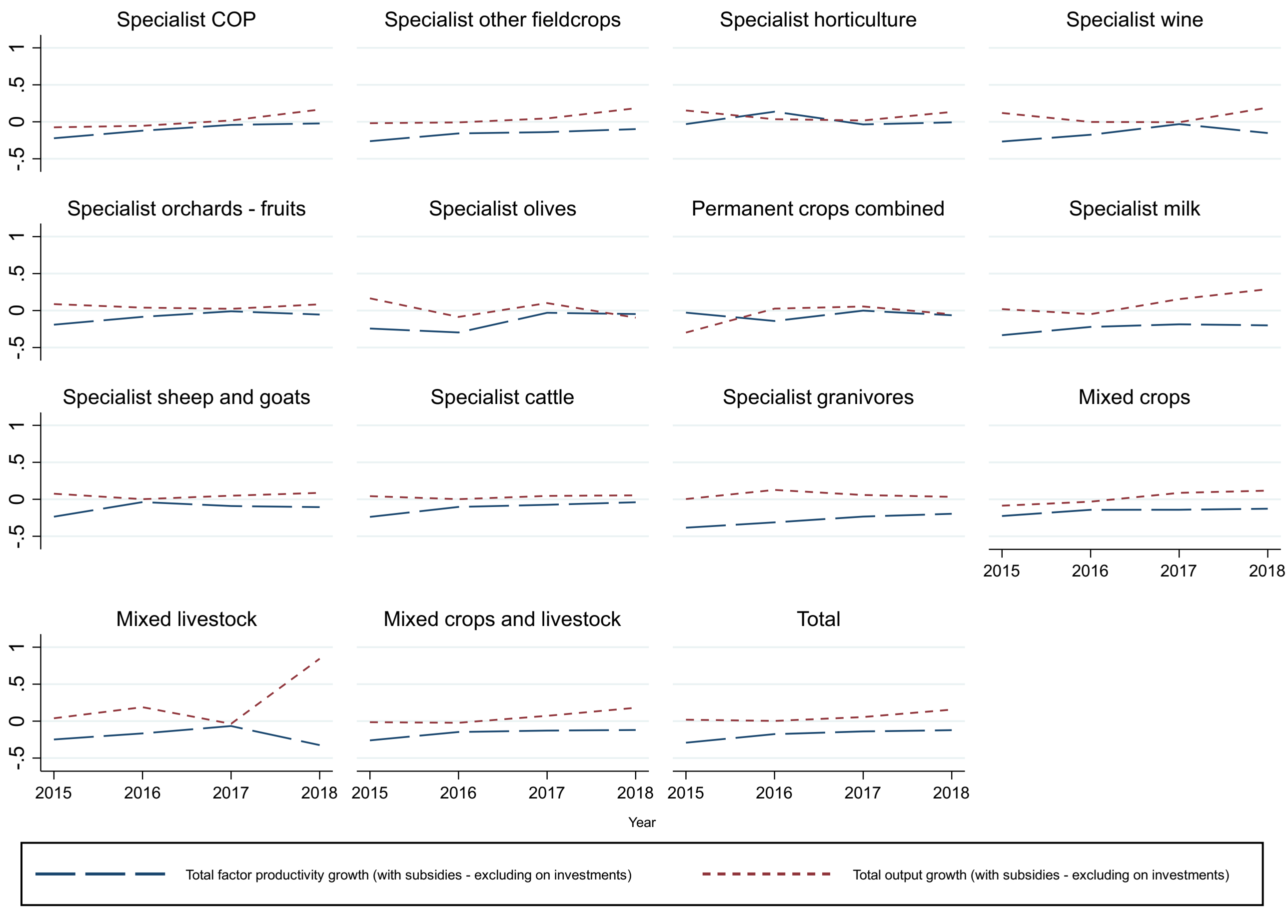

Figure 11: Evolution of the total factor productivity (Malmquist index) and total output growth rates (including subsidies), over the period 2014–2018, for several EU farm types.

for the following systems: olives, permanent crops combined, and mixed crops and livestock. In these cases, total factor productivity growth rates became slightly worse with the subsidies. These findings confirm the results obtained above from the efficiency analysis. In fact, the subsidies from the CAP measures increase the use of inputs (or at least increased the costs with the use of inputs), in some cases, and worsen the performance and competitiveness of the farms (or at least do not improve them), which in a context of environmental impact

Table 7: Statistical summary for the several variables considered over the period 2014–2018

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
Total output (€)	75	89,146	86,263	25,257	407,477
Labour input (h)	75	3,471	1,072	2,182	7,088
Total utilised agricultural area (ha)	75	29	17	7	71
Total LUs	75	38	83	0	383
Total inputs (€)	75	76,758	75,123	18,815	368,701
Total intermediate consumption (€)	75	53,530	60,659	9,332	297,629
Total specific costs (€)	75	35,379	50,086	3,905	241,170
Total farming overheads (€)	75	18,151	12,114	5,343	56,458
Total external factors (€)	75	13,479	11,144	4,060	50,537
Total assets (€)	75	358,114	175,798	138,829	996,464
Gross investment on fixed assets (€)	75	10,241	7,692	964	39,604
Total subsidies – excluding on investments (€)	75	10,283	5,447	2,607	22,835

Table 8: Total factor productivity (Malmquist index) and total output growth rates, in percentage (without and with subsidies), on average over the period 2014–2018, for the several EU farm types

	Total factor productivity growth (without subsidies – excluding on investments)	**Total factor productivity growth (with subsidies – excluding on investments)**	**Total output growth (without subsidies – excluding on investments)**	**Total output growth (with subsidies – excluding on investments)**
Specialist COP	−11	−11	1	1
Specialist other fieldcrops	−17	−17	6	5
Specialist horticulture	1	1	9	9
Specialist wine	−16	−16	8	8
Specialist orchards – fruits	−9	−9	6	6
Specialist olives	−16	−16	3	2
Permanent crops combined	−6	−6	−8	−7
Specialist milk	−24	−24	10	10
Specialist sheep and goats	−12	−12	4	5
Specialist cattle	−12	−12	3	4
Specialist granivores	−29	−29	6	6
Mixed crops	−16	−16	2	2
Mixed livestock	−21	−21	26	26
Mixed crops and livestock	−17	−17	5	5
Total	−19	−19	6	6

Table 9: Total factor productivity (Malmquist index) and total output growth rates in percentage (without and with subsidies), on average across the several EU farm types, for the period 2014–2018

Year	Total factor productivity growth (without subsidies – excluding on investments)	Total factor productivity growth (with subsidies – excluding on investments)	Total output growth (without subsidies – excluding on investments)	Total output growth (with subsidies – excluding on investments)
2015	−24	−24	2	2
2016	−15	−15	0	1
2017	−9	−9	5	5
2018	−12	−12	16	16

mitigation deserves special attention. On the other hand, the total output increased, on average over the last five years, except for the permanent crops combined systems. The higher growth rates were verified for the milk and mixed livestock farming types. The values of 2018 were determinant for the average higher changes of the mixed livestock system (Figure 11). In general, the growth rates for the total output are higher without subsidies than with subsidies. These values reveal that the total output grew at greater rates than the level of subsidies.

As shown in Table 9, presenting the results for the period considered, on average, over the different farming types a similar trend is observed with that described in Table 8. It is worth observing that the negative growth rates verified for the total factor productivity improved from −23.6% in 2015 to −11.5% in 2018. The total output growth rates followed an inverse pattern, with 2016 as the worse year for the output growth.

4 Discussion and conclusion

This research analysed the implications of several CAP reforms and external shocks (financial and economic crises) on the evolution of various variables related to EU farm types. Data from the FADN were considered for the period 2004–2018 and for variables associated with the farming outputs, inputs, and subsidies. Technical efficiency was assessed, as well as the competitiveness of the EU farm types over the period 2014–2018 (after the last CAP reform). In this case, DEA and the Malmquist index were considered.

The data analysis, for the period 2004–2018, highlights that the crops and livestock productivities (by hectare and LU, respectively) increased, although these increases were accompanied by higher specific costs. The increase in agriculture intensity has impacts on biodiversity and ecosystem quality [66]. Furthermore, relevant improvements were identified in farm labour competitiveness. In addition, total productivity (total output/total input) decreased in a majority of farm types. On the other hand, the stocking density (LU/ha) decreased, as well as the labour input. Looking deeper for each one of the farming types, horticulture systems are those that use more labour and have higher crop productivities by area; COP farms are the largest in terms of agricultural area utilised; and granivores are the systems with more LUs per farm. Despite EU policymakers' intention to promote agricultural sustainability through improved farm efficiency and mitigation of environmental impacts [67], in practice, there is much work to do.

The analysis of the efficiency, considering the labour, utilised agricultural area, LUs, total assets, and associated costs as inputs, shows that several farm types are technically efficient with similar results. This reveals that the farms have similar management approaches and technologies [68]. The exceptions to this framework were other field-crops, mixed crops, and livestock farms. The main inefficiencies in these cases are associated with the utilised agricultural area. In turn, when the current subsidies (excluding those on investments) are included in the total output, the levels of inefficiencies found are lower. In any case, there is field to improve the efficiency in the use of the agricultural factors of production, namely the fertiliser, with benefits for sustainability [69], where innovation may play a determinant role in improving the competitiveness of the farms [70].

The results for the Malmquist index show that the total factor productivity decreased (negative growth rates) in several farm types (exception for horticulture farms) and over the period 2014–2018. These contexts were accompanied by positive growth rates for total output. These findings are slightly worse when the subsidies are included as output. This shows that improvements in the competitiveness of the European farms are needed [71] and the CAP measures may bring relevant contributions.

In general, the EU farm types became larger in recent years, despite reductions in the number of farms and total area used by the agricultural sector (meaning that the decrease in the number of farms was supported mainly by the smaller ones). Also, in the recent years, the outputs as well as the productivities of the area and the LUs increased, followed by increases in the specific costs (at least), with the consequence of a reduction in total factor productivities (confirmed by the data analysis and Malmquist index). In addition, the subsidies (excluding those on investments) justify the use of more inputs (at least at higher costs) by the farmers (because of the reduction of inefficiencies in the use of inputs for the same level of output). In any case, the impact of the subsidies on technical efficiency and total factor productivities is marginal. In fact, it seems that the CAP measures are disconnected from the efficiency [72]. These findings are confirmed by the results of the horticulture farm types. These farms are, despite reduced subsidies, those with the greatest productivities of the area, with higher use of inputs but with a good competitiveness level for the use of total factors. Of course, this is one of the main aims of the CAP instruments (totally decoupled). However, if the environmental impacts from the agricultural sector are to be efficiently mitigated, this should receive more attention from the efficiency and competitiveness point of view.

In general, our results offer an original view both on the dataset and the issues discussed. Several previous studies agree with our findings. For example, Braito et al. [73] focused on the complexity of the results of the CAP reform in different agricultural productions. Studies such as those by Quiroga et al. [74] were also convergent in approximating the levels of technical efficiency observed in this period in European agriculture. The delay in recovering the shocks felt between in the various agricultural sectors converged with the findings of Martinho [75]. Finally, the study by Kobus [76] meets ours in relation to the role of subsidies in promoting the productivity of the sector.

We suggest two main implications. First, the role of subsidies in driving agricultural productivity across different European sectors. At a time when, for various reasons, the role of subsidies is questioned, this work emphasised its relevance in terms of conducting a common agricultural policy. Second, the need to recognise the heterogeneity of agricultural sectors and agricultural activities requires a more detailed analysis of the associated specificities. In terms of policy implications, it is suggested the design of more adjusted policy instruments and measures, in the CAP framework, promoting a more efficient use of the resources. In other words, the subsidies should be decoupled of the output (to avoid oversupply, for example) and should become more input-directed (to reduce the carbon footprint from the several agricultural activities). It is important that subsidies are more closely linked to the level of efficiency in the use of resources.

For future research, it could be important to carry out a similar study for several EU countries and regions to assess the symmetric/asymmetric impacts from the most recent tendencies over different agricultural realities of the European geographical context. In methodological insights, there are new emerging contributions which may be used for these purposes – from the use of Stochastic Frontier analysis to dynamic panel data methods.

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