

Organic Transition in EU Agriculture: An Analysis of Environmental and Economic Outcomes

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Abstract

This study examines the impact of conversions from conventional to organic farming on environmental and economic outcomes in the European Union across main crops and livestock farming systems. Using a propensity score matching-difference in differences (PSM-DID) approach, we analyse a large sample of farms from the Farm Accountancy Data Network (FADN) between 2014 and 2021. We also find that the impact of organic conversions varies across different farm types, with fieldcrop specialists and milk and other grazing livestock specialists exhibiting the most pronounced environmental benefits. Our results show that organic farming conversions lead to significant reductions in fertiliser and plant protection product usage, as well as land re-allocation and increased farm net value added per annual work unit. Our study provides new insights into the effectiveness of organic farming policies in the EU and highlights the importance of considering farm-level heterogeneity in evaluating the impacts of agricultural policy interventions.

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Zelda Brutti, Marzia Freo

1. Introduction

The European Union (EU) recognises organic farming as crucial for sustainable agriculture, environmental protection, and human health, as outlined in the Farm to Fork and Vision for Agriculture and Food strategies, which prioritise long-term sector competitiveness and sustainability. Since the first introduction of an EU Regulation that defines organic farming (CoE 1991), the importance of support payments for organic production has increased over time. EU support is provided mainly through the second pillar of the common agricultural policy (CAP), and during the 2014-2022 CAP planning cycle, EU farmers received almost €12 billion to convert to organic farming or to maintain organic farming practices, while EU sales of organic products more than doubled during the same period (European Court of Auditor 2024). The substantial public investment in organic support and the significant policy effort towards promoting organic conversions underscore the need for a thorough understanding of their ecological impact. Quantifying the environmental and economic results of organic transitions, and comparing these to any associated economic support measures, ensures that organic policy initiatives are evidence-based and effective towards sustainable agricultural development.

While scientific agronomic evidence strongly supports the positive environmental effects of organic practices (see Guerrero et al. 2024 for a recent agronomic summary), a comprehensive ex-post evaluation of the effectiveness of policy-induced conversions, investigating the results of the practical implementation of organic practices, particularly from a EU wide perspective, is still lacking.

This inconsistency largely results from fragmentation in organic farming support, with variable delivery mechanisms, implementation intensity, and interventions across EU countries (see Brutti et al. 2023). Indeed, the CAP comprises several programs and measures aimed at promoting environmental sustainability, including agro-environment schemes, organic farming, as well as investment and greening measures, also complemented by interventions from single member states. In conclusion, the specific programs supporting organic farming vary significantly across countries and may be multiple even within individual countries, making it challenging to identify and isolate their effects.

Several studies employing counterfactual approaches evaluate the economic and environmental impacts of agri-environment schemes and payments for ecosystem services. However, for the scope of evaluating organic policies, their findings are constrained to a subset of member states where organic agriculture has been supported through agri-environmental measures. Because these schemes in the majority of EU countries support a broader range of practices, not exclusively organic production, the results cannot be directly attributed to the adoption of organic systems, but rather to the implementation of practices that are also common in organic agriculture.

This study aims to contribute to the research evaluating the effectiveness of organic interventions included in the CAP. To address the complexity of evaluating the diverse and fragmented interventions under the CAP umbrella, this study employs a focused approach, centering on the event of farm conversion to organic farming. By focusing on this event, the

study avoids the challenges of disentangling and attributing the effects of various programs supporting organic farming, which can vary significantly across EU countries. Instead, it examines the transition from conventional to organic farming practices, irrespective of the specific policy interventions implemented across countries, and subsequently assesses whether these transitions were facilitated by public support measures.

To estimate the impact of organic farming, we employ counterfactual methods because organic and conventional farms exhibit systematically different observable and unobservable confounding characteristics. These include, among others, the education and the societal preferences of farm managers (Riar et al. 2017), farm specialisation and sizes, workforce intensity or economic turnover (Koesling, Flaten, and Lien 2008, Benoit and Veysset 2003, Norton et al. 2009), location factors (Kujala, Hakala, and Viitaharju 2022), among which soil type, quality, and fertility (Davis, Abbott, et al. 2006, Treadwell, McKinney, and Creamer 2003), and parcel geometry and surrounding land uses (Parker and Munroe 2007, Norton et al. 2009).

We estimate a propensity score matching-difference in differences (PSM-DiD) model on a large sample of farms extracted from the Farm Accountancy Data Network (FADN) between 2014 and 2021. We evaluate several outcomes, including changes in land allocation, economic and environmental performance. As for the latter, we utilize the environmental data embedded in the FADN variables and notice that this information is somewhat indirect because it pertains to farming practices that influence environmental outcomes.

This strategy allows to contribute to the literature by concurring with increasing volumes of evidence about the impact of policy-induced organic conversions. Firstly, it provides a detailed analysis of the impact of organic policy for the entire EU. Secondly, the investigation provides in-depth findings on the relative performance of different organic farming systems, categorising them into main types of crop farms and livestock farming systems, and thereby accounting for the primary context drivers that influence their performance. In addition, tracking the performance of converting farms over time offers a more robust counterfactual framework with respect to the ones provided by several existing works relying on comparisons between already-organic and conventional farms, as it is documented later.

We can determine the short-term outcomes of conversion. The effects of transitioning to organic farming on the economic and environmental performance of farms vary significantly across different farm types. Specifically, fieldcrop specialists and milk and other grazing livestock specialists exhibit environmental benefits as early as the first few years after conversion, whereas specialists in permanent crops experience minimal or null effects. Furthermore, our analysis reveals statistically significant increases in farm net value added per annual work unit for fieldcrop specialists and other grazing livestock specialists. This increase is largely driven by support from the CAP, particularly through Rural Development funding. The CAP subsidies appear to have offset a decline in average farm net value added, thereby enabling the rise in net value added per annual work unit to be sustained.

The remainder of the article is structured as follows. Section 2 places this article amongst the related literature; Section 3 illustrates the methodological approach, and the data employed;

Section 4 details the concrete steps of the estimation procedure; Section 5 presents results and Section 6 concludes.

2. Related literature

The literature on the effects of organic farming on the environment and on farm profitability is extensive and heterogeneous, encompassing a wide spectrum of research designs and methodologies. The broad consensus in this literature is that organic farming has a better environmental performance per hectare of land when compared to conventional methods, although results are mixed when it comes to yield-adjusted environmental impacts and economic performance (Seufert and Ramankutty 2017, Clark and Tilman 2017, Rosa-Schleich et al. 2019, Meemken and Qaim 2018).

Restricting our focus to quantitative literature that employs causal methods yields a significant reduction in the number of relevant studies. A substantial part of studies is based on ad-hoc field experiments, such as the Swiss DOK long-term trial (Fließbach et al. 2024, Krause et al. 2024) or the German Pilotbetriebe project. By design, these studies, together with the other researches based on experimental settings (see Guerrero et al. 2024 for a recent agronomic literature review and summary), serve as valuable scientific evidence for evaluating outcomes of specific agricultural systems.

Another strand of literature analyses the ex-post effects of policy interventions targeted at organic farming, with a pivotal role for the CAP measures. This body of work aims at examining how various policy measures, such as regulations and/or subsidies, impact the economic and environmental sustainability of farms. Analysing the effectiveness of these interventions provides insights into whether and how policy frameworks can support the transition to organic agriculture and its sustainability, offering a complementary perspective beyond experimental field trials. Along this strand of literature, Grovermann et al. 2021 employ an instrumental-variable approach to quantify profit and efficiency impacts of organic certification in dairy farming across Europe; their study uses farm-level FADN data from 25 countries and finds substantial increases in gross margins and moderate ones in technical efficiency, as a result of certification. Norton et al. (2009) find that organic practices increase landscape complexity in England, pairing 88 non-organic and 73 organic farms over three cropping seasons between 2000 and 2004. Martín-García, Gómez-Limón, and Arriaza (2024) apply propensity score matching to a three-year-panel of fruit farms provided by the Spanish FADN, finding heterogeneous results in terms of both environmental and economic performance of organic farms, as compared to their conventional peers. Note that although the authors' claim is to be studying the effects of an "organic conversion treatment", no actual conversion events are observed or used in the analysis; the matching between conventional and organic farms is conducted, as in similar studies, at an unspecified time point after the conversion of the latter, assuming that a conversion event ever took place. Close to our article in terms of scope and methodology is Cisilino, Bodini, and Zanolini (2019), who study the effects of rural policy programs on the environment using FADN data between 2013 and 2015, on one Italian region. Similarly to our contribution, the authors identify program treatment effects through a combination of propensity score matching and difference-in-differences (PSM-DiD); their results indicate a better environmental performance of organic farms compared to conventional ones, without finding differences in income indicators. Even though this study exploits variation along the time dimension as we do, its matching exercise is performed between conventional and already-

organic farms, without observing the actual conversion event and remaining silent about the time of treatment. The fact that Cisilino, Bodini, and Zanolli (2019) find differences in the over-time evolution of outcomes between organic and conventional farms, despite not including the actual conversion in the observation window, suggests that organic practices may yield effects that reinforce over time and thus trigger outcome paths that diverge from those of conventional farms.

A related but distinct body of literature utilises counterfactual approaches to analyse the impact of agro-environmental schemes, which has a connection to the literature on organic farming. Specifically, in some countries, the CAP support for organic farming is provided entirely or partially through agro-environment-climate measures. The studies by Pufahl and Weiss 2009, Chabé-Ferret and Subervie 2013, Michalek 2022, Stetter, Mennig, and Sauer 2022, Uehleke, Petrick, and Hüttl 2022, and Ait Sidhoum, Mennig, and Frick 2024 examine the environmental effectiveness of agro-environmental schemes at the farm level, typically focusing on specific countries or regions. An exception is Arata and Sckokai 2016, who evaluate agro-environmental schemes' impacts across five distinct countries. However, despite some overlap in objectives, agro-environmental schemes and organic farming are distinct in principle, as agro-environmental schemes are generally accessible to both organic and conventional farms in most EU member states (Brutti et al. 2023).

In the end, there is a literature that has predominantly been centered on the motivations underlying conversion and the decision-making processes involved (Duram 1999, Koesling, Flaten, and Lien 2008, Home et al. 2019, Riar et al. 2017).

The outcomes of conversion processes have been the subject of attention of early case studies and meta-analyses, mostly targeting the evolution of yields (Stanhill 1990, Stolze et al. 2000) and the role of soil type (Liebhardt et al. 1989, MacRae et al. 1990, Martini et al. 2004). Among more recent studies, the most represented methodological approaches are structural modelling and site-specific experiments. Examples of the former category are Benoit and Veysset (2003), Kerselaers et al. (2007) and Kremmydas, Ciaian, and Baldoni (2023), who simulate the outcomes of organic conversion, respectively, for cattle farming in France; for arable farms, dairy and suckler cow farms in Belgium; and for both crop and animal farms across Europe. Among experimental studies, Sacco et al. (2015) present the effects of transition from conventional to organic methods on a single field in the Italian region of Piemonte, finding reduced SOC depletion and lower crop yield; Bouttes et al. (2019) surveyed a sample of 12 dairy farms in the French region of Brittany and find that their conversion processes resulted in higher economic efficiency and economic independence, although a number of vulnerability patterns are also uncovered.

This study offers a distinctive contribution to the existing literature by integrating a rigorous methodological framework with a comprehensive EU-wide perspective, disaggregated by farming specialisation, and shedding light on the organic farming impact. Further, the organic conversion events we observe between 2014 and 2021 speak strongly and directly to the outcomes of agricultural policy action. The CAP programming cycle that started in 2014 witnessed the establishment of dedicated, EU-wide support for organic practices, which triggered

a sharp expansion in organic areas; between 2012 and 2022, the increase amounted to 7.4 million hectares, or 79% (Eurostat 2024).

3. Data and Methodology

Our analysis leverages Farm Accountancy Data Network (FADN) data, which is a survey, harmonised at the EU level, sampling each year approximately 80,000 farms across EU Member States among commercial holdings above a minimum economic size¹. In the FADN, organic farms are specifically identified through a dedicated variable, starting from 2014.

To address the complexities of isolating the effects of organic farming practices, we leverage the FADN's longitudinal dimension in combination with the availability of the organic farming variable to implement a Propensity Score Matching (PSM) approach in conjunction with a Difference-in-Differences (DID) method, yielding a robust PSM-DID methodology. This approach has been successfully applied in various studies within the agricultural economics literature (e.g., Arata and Sckokai 2016; Mennig and Sauer 2019), albeit to distinct research questions. The superior performance of DiD matching estimators with respect to cross-sectional matching estimators has been confirmed empirically in seminal work such as Smith and Todd (2001), who show that different variants of simple propensity score matching are highly sensitive to subsample choice and to the set of variables included in matching procedures. More recently, Imbens and Wooldridge (2009) recommended leveraging the combination between matching and DiD methods as a way to increase robustness of results even under model misspecification, and Ho et al. (2007) suggested that matching can be viewed as a way to preprocess data to make identifying assumptions more plausible in subsequent parametric estimation, such as DiD. This combination requires the availability of panel data at the individual farm level, and focuses the attention on farms that convert from conventional to organic practices during the observation window. Converting farms (the treatment group) are matched to observationally similar conventional farms (the control group) in the pre-conversion period. Then, matched pairs are followed over time, while one farm converts and its similar peer does not. The effects of conversion are estimated as the differential change in outcomes that materialise between the the initial and the final period of observation in treated and control farms respectively, averaged across all matched pairs. Focusing on the change in outcomes of each farm with respect to its own past is likely to eliminate the confounding influence of those (time-invariant) unobservable characteristics that deteriorate the performance of simple matching estimators (Heckman, Ichimura, and Todd 1997, Heckman et al. 1998). The second advantage of the PSM-DiD approach lies in its ability to precisely date the treatment event. As elaborated in the subsequent section, our sample includes both organic converters and carefully matched conventional counterparts, all observed over a standardised three-year period. This design provides rigorous estimates of the short-term effects of organic conversion, eliminating potential biases from variability in treatment timing or imprecision in conversion dates.

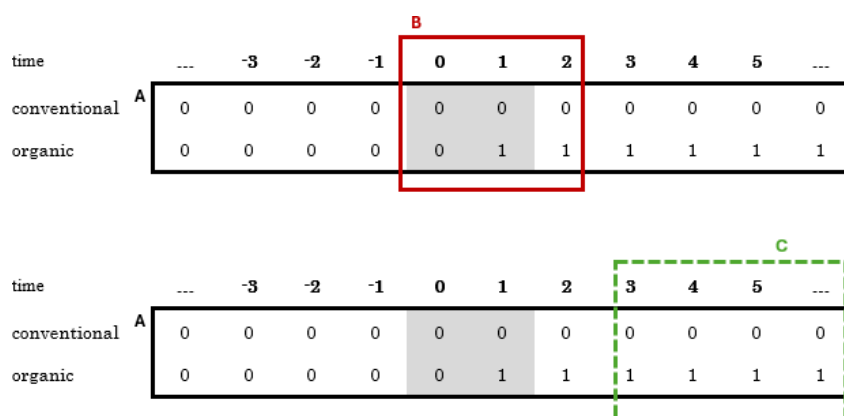
¹ More information on FADN data is available on the AgriFood Data Portal of the Directorate General for Agriculture and Rural Development.
<https://agridata.ec.europa.eu/extensions/FarmEconomyFocus/FADNDatabase.html>

Note that the DiD component of our approach yields estimate of the aggregate effect of being converted rather than not converted to organic farming for two years, after having been initially untreated units. This is consistent with estimate provided by a staggered DiD design over a balanced panel, where groups treated from 2015 to 2020 are averaged to compose the aggregate treatment effect methods while their control peers remain conventional. Average treatment effects on the treated (ATET) are obtained from this stage.

A key limitation of our study arises from the restricted pre-conversion observation period. Ideally, to comprehensively evaluate the longitudinal impact of organic farming, it would be desirable to observe cohorts of organic and conventional farms over an extended period including the intervention/conversion time, both before and after conversion, as depicted in Figure 1, Box A. In contrast, our analysis is confined to a three-year time window including the intervention/conversion time (Figure 1, Box B). Notably, our approach enhances existing research focusing on periods as represented by Figure 1, Box C, which typically exclude the conversion period and consequently weaken the causal inference.

The choice of the window length -three year- for tracking farms that convert to organic farming over time involved a deliberate trade-off. A longer time window would have led to a significant reduction in the number of farms observations, ultimately compromising our ability to causally examine the impact of organic farming across different farm specializations. To address potential biases arising from data limitations, we conduct a series of robustness checks in Subsection 5.1, which provide additional evidence in support of our methodological choices.

Figure 1: Example of ideal versus practically time windows for causal methods implementation.



Note: Values are equal to 1 if the farm at time t exclusively applies organic production methods, equal to 0 if it applies conventional production methods. The grey area indicates the conversion period.

Source: Authors' own elaborations.

4. Estimation procedure

The PSM-DiD estimation is set up by defining treated farms as those observed converting to organic farming during the window of observation. Next, the analysis unfolds in two stages. First, each treated farm is assigned a suitable control farm through the PSM procedure; importantly, the matching procedure is executed on pre-conversion characteristics, that is, while both treated and control farms are engaging in conventional farming methods. Second, a DiD model is estimated based on the previously defined treatment and control groups; over the period of observation, treated farms convert to organic methods while their control peers remain conventional. Average treatment effects on the treated (ATET) are obtained from this stage.

To identify treated and control groups, we construct an indicator variable taking value $D_{it} = 1$ if the i -th farm in year t exclusively applies organic production methods, $D_{it} = 0$ if it applies conventional production methods. In this analysis, the treatment group is composed of farms labelled as conventional in the first year of observation and as organic in the two consecutive years afterwards, that is, those characterised by the sequence $D_{i0} = 0, D_{i1} = 1, D_{i2} = 1$. The pool of potential control farms consists of farms that are conventional over three consecutive years, that is, those characterised by the sequence $D_{i0} = 0, D_{i1} = 0, D_{i2} = 0$. Farms using both organic and conventional production methods are excluded from the analysis to ensure interpretability of results. Because the effect of organic practices depends on the type of production (Clark and Tilman 2017), we run the analysis separately for the following principal types of crops and livestock farming systems: i) Fieldcrop specialists, ii) Wine specialists, iii) Other Permanent crops² among Crop farms, and i) Milk specialists and ii) Other grazing specialists³ for Livestock farms⁴.

Our final sample, drawn from the 2014-2021 FADN waves, consists of 1,241 crop farms and 668 livestock farms that converted to organic farming, whereas the number of conventional farms available as potential controls is substantially larger. Note that extending the treatment window to four or five years would have resulted in a significant reduction in the number of treated units, with losses of over 30% and 50%, respectively. This would have precluded the possibility of conducting a more detailed analysis by farm specialisation, thereby limiting the scope of our investigation. Similarly, we are unable to extend the pre-treatment period sufficiently to account for potential issues related to the preparation phase preceding conversion.

² Including specialists in fruit and in citrus fruit; specialists in olives; specialists in various permanent crops combined.

³ Including cattle, sheep, and goats.

⁴ The grouping of types of farming is based on the Farm Accountancy Data Network (FADN) classification, which categorizes farms into eight distinct types. However, certain categories, such as horticulture crop farms and granivores livestock farms, are not analysed because of the scarcity in observable farms (fewer than 80). Additionally, mixed farms are excluded to enhance the clarity and interpretability of the analysis, as their diverse operations could complicate the assessment of specific agricultural practices and outcomes.

Conventional farms were generally larger at the pre-treatment stage compared to those transitioning to organic methods. Specifically, for fieldcrop specialists, conventional farms cultivated an average of 136 hectares of arable land, whereas farms in conversion averaged 62.1 hectares. In terms of livestock units, conventional dairy farms reared an average of 127.4 dairy heads, and other grazing livestock specialists managed 86.5 heads. In contrast, specialist livestock farms converting to organic methods had averages of 95.1 and 71.9 heads, respectively (see Table A.1).

Organic holdings represent 2.7% of the EU-wide total of farms, and that they cultivate on average 41 hectares (ha) of agricultural area, which is more than double the average of conventional holdings (16 ha) (EC 2023). We find 8.5% of FADN holdings in 2020 to be either fully organic or converting; their average agricultural area measures 88 ha, versus the 106 ha of conventional farms. Despite the average differences in size, the FADN sample reproduces very well the typical land allocation profiles found in the overall population (see Table A.2). Additionally, FADN also represents correctly the main organic-producing countries in both crop and livestock specialisations, with the exception of Italy and Greece being overrepresented, and Czech Republic and Germany being under-represented (see Table A.3).

In our analysis, we focus on both environmental and economic outcomes. While the FADN survey does not record direct environmental outcomes such as greenhouse gas emissions, soil and water quality, or biodiversity at the individual farm level, it does provide variables that can serve as proxies for environmental outcomes. Agricultural systems that aim to reduce their environmental impact, such as organic systems, typically adopt specific farming practices. These include limiting the use of chemical fertilisers and plant protection products, adopting crop rotation; enhancing the cultivation of nitrogen-fixing crops, managing green and animal manure, leaving land fallow or maintaining it as grassland, limiting total stocking density, improving feed/seed self-sufficiency, and using a high proportion of fodder in animal feed (Kremmydas, Ciaian, and Baldoni 2023). Analysing FADN variables enables us to assess a farm's environmental performance and adherence to sustainable practices. This approach, supported by empirical research (e.g., Csilino, Bodini, and Zanolli 2019; Uehleke, Petrick, and Hüttel 2022) and theoretical frameworks (Rega et al. 2022), uses input usage as a proxy for environmental outcomes. These proxies include expenditures per hectare on fertilisers, plant protection products, fuel, and electricity. Additionally, we also examine the total values of purchased and own-grown seeds per hectare, the total values of purchased and own-grown feed per standardised livestock units (LSU), and veterinary expenditures both in total and per LSU. Regarding land allocation, we assess changes in the composition of agricultural land, expecting increases in nitrogen-fixing crops (e.g., protein crops), fodder, fallow, and permanent grassland. Finally, we evaluate the impact on a set of economic performance indicators. These are standardized either per hectare or per LSU, depending on the primary activity from which they are derived. For profitability, we use the farm net value added per average working unit. Additionally, we consider the total farm net value added and total CAP subsidies. Although subsidies are not outcomes in themselves, they are presented as key components of farm value added, thereby providing insights into their role in explaining average farm profitability.

4.1 Stage 1: Propensity Score Matching (PSM)

After defining the sample of analysis, we construct a PSM model to identify among the pool of potential control farms those that best resemble each treated unit. In the most commonly found approach of matching each already-organic farm with a similar conventional peer, the concern is to be working with farms whose characteristics and structure have already been modified by the adoption of organic methods. When such modifications are themselves outcomes of the organic adoption, the PSM procedure is invalidated through a violation of its conditional independence assumption, which translates into forming pairs between farms that are not truly comparable. The strength of our PSM setting is that pairings are formed at pre-conversion time $t = 0$, in which both treated and control units are applying conventional farming methods; this is considerably more demanding from a data point of view and represents a key advantage in terms of causal identification strategy.

We construct our PSM specification based on a standard logit function. We impose exact matching by country and year, to account for any variations in regulatory contexts and for differences related to the time in which controls and outcomes are measured. Additional control variables included in the model are altitude, to control for climate conditions, and land allocation shares, to ensure comparison between farming systems implementing broadly similar combinations of crops and livestock. More in detail, for crop specialists we include the shares of utilised agricultural area (UAA) allocated to arable land, vegetables, permanent grassland, and permanent crops; we add the number of LSU, to apply balancing on any secondary livestock activity.

For further robustness, pre-treatment outcomes found imbalanced after the first round of matching are included as covariates in the final matching specification, implementing what is known as a double-adjustment procedure (Rubin 1979, Abadie and Imbens 2011, Austin 2017). These are expenditures per hectare on fertilisers, plant protection products, seeds, fuel, and electricity, as well as the shares of UAA allocated to cereals and forage. These differences may reveal unobserved characteristics between treated and control groups depending by farmers' attitudes towards the environment, or also farmland allocated to mix of crops requiring specific inputs' intensities. Since these variables implicitly incorporate farmers' attitude towards organic practices already before the conversion, accounting for them in the matching model enables a more robust identification of the treatment effect. For livestock farms, land allocation shares are replaced by the number of units in the following classes: dairy (dairy cows, buffaloes, and cattle dairy cows calved and held principally for milk production), beef, sheep and goats, and granivores (including piglets, breeding sows, pigs for fattening, other pigs, table chickens, laying hens, and other poultry). Also the livestock farm PSM specifications for livestock farms were enhanced by including a selection of pre-treatment outcomes: expenditures per hectare on fertilisers, plant protection products, fuel, and electricity, and total veterinary expenditures.

After estimating the propensity scores, treated farms are matched to their most suitable control units based on a nearest neighbour algorithm (Abadie and Imbens (2006), Abadie and Imbens

(2011)), by imposing a caliper of one percentage point for each matched pair, to guarantee the common support.

The balance checks for the validity of assumptions (Austin 2009) indicate that the PSM procedure results in excellent reductions in Standardised Mean Differences (SDMs) in characteristics between treatment and control units. The post-matching standardized differences (SDMs) show that only four out of 73 variables exceed a threshold of 0.10, and none exceed 0.25, indicating that the matching process has successfully identified a well-balanced control group.

4.2 Stage 2: Difference in Differences (DiD) estimation

The DiD estimation consists in comparing over-time changes in outcomes between converting farms and their best-suited controls identified in Stage 1. Formally, we estimate:

$$\text{PSM-DiD} = \Delta\bar{Y}(1) - \Delta\bar{Y}(0) \quad (1)$$

where $\Delta\bar{Y}(1)$ indicates the average change in outcomes occurred in the treatment group between the pre-treatment period ($t = 0$) and the post-treatment period (either $t = 1$ or $t = 2$), and $\Delta\bar{Y}(0)$ indicates the same quantity for the control group that has been identified through the PSM strategy. That is, we compare the evolution of outcomes in farms that converted to organic management with the evolution of outcomes in farms that were statistically similar to these converters before their conversion, but remained conventional throughout the observation period.

Note that, although the explicit accounting for conversion timing and the matching on pre-conversion covariates can enhance the robustness of results, because of the inability to test the parallel trends assumption, we could reduce but not exclude at all residual influence from anticipation effects.

5. Results

Table 1 presents the main estimates of the effects of conversion to organic methods for EU crop farms. For each of the outcomes considered, the first column of the table provides the average outcome for converters (treated farms) before the conversion, at time $t = 0$. The second column indicates the difference in outcomes between treated and matched control farms at time $t = 0$, and its associated statistical significance. This column offers a diagnostic view on pre-treatment balance in outcomes of interest between treatment and control groups; none statistically significant at 5% differences are found. The third columns present average treatment effects on the treated (ATET) at time $t = 2$, estimated using the PSM-DiD specifications outlined in equation (1). The fourth column of the table presents the percentage size effects computed dividing each ATET by its average initial outcome. The outcomes of interest are grouped into three panels: inputs, land allocation, economic performance. We find impacts of organic conversion on the expenditure and quantities of fertilisers and plant production products per hectare of UAA.

In the second year following conversion, fieldcrop specialists, on average, achieve significant reductions in their expenditures on fertilisers and plant protection products per hectare. Compared to what they would have spent if they had not transitioned to organic farming, these farmers reduce their expenditures by 34.6 and 31.6 euro per hectare, respectively. These reductions correspond to relative decreases of 18.6% and 28.9% from their pre-conversion spending levels, they had not reached without conversion. The figures also indicate over 70% on average reductions in the quantities of synthetic fertilisers. Statistical significance is only achieved for plant protection products.

Wine specialist farms achieve reductions in the quantities of nitrogen-, phosphorus- and potassium-based fertilisers, statistically significant only for phosphorus-based ones. These farms, which typically use about three times more plant protection products than fieldcrop specialists, significantly decrease their expenditure per hectare—from 302 to 254 euro—resulting in a reduction of approximately 15.8%. In contrast, although other permanent crops show average reductions in these products, these changes are not statistically significant. Both fieldcrop and other permanent crop specialists significantly reduce their total seed purchases. In general, crop farms reduce their consumption of inputs that have negative environmental impacts, suggesting positive environmental impacts further along the line, and also indicates a shift towards lower dependence on external inputs.

Regarding land allocation, fieldcrop farms, on average, reduce the land dedicated to cereals and, to a lesser extent, roots and tubers, in favour of protein crops, whose share doubles within two years. Simultaneously, the share of land allocated to forage, both fodder and permanent grassland, significantly increases. No significant changes in land allocation are detected for permanent crop specialists, who, at the pre-treatment stage, cultivated few hectares of arable land, dedicating over 85% of their UAA to permanent crops, permanent grassland, and fodder.

Table 1. Impacts of organic conversion on Crop farms

	Fieldcrop farms				Wine farms				Other permanent crops farms				
	Y ₁ t=0	Y ₁ -Y ₀ t=0	ATET t=2	% size effect	Y ₁ t=0	Y ₁ -Y ₀ t=0	ATET t=2	% size effect	Y ₁ t=0	Y ₁ -Y ₀ t=0	ATET t=2	% size effect	
INPUTS per ha													
Fertilisers (value)	186.3	2.17	-34.67 ^{*a}	-18.6	151.9	-5.54	-11.96	-7.9	256.03	-23.68	-2.1	-0.8	
Nitrogen (quintals)	1.58	0.24	-1.16	-73.4	0.34	-0.14	-0.3	-88.2	1.27	0.24	-1.08	-85.0	
Phosphorus (quintals)	0.47	0.04	-0.41 [°]	-87.2	0.25	-0.04	-0.3 ^{*a}	-100.0 ^c	0.98	0.23	-0.7	-71.4	
Potassium (quintals)	0.4	0.03	-0.31	-77.5	0.27	-0.05	-0.55 [°]	-100.0 ^c	0.66	-0.1	-0.48	-72.7	
Plant protection products (value)	109.06	-2.78	-31.56 ^{*a}	-28.9	301.79	12.15	-47.65 [°]	-15.8	187.29	-15.88	-17.26	-9.2	
Fuel (value)	167.1	2.55	-2.68	-1.6	255.94	13.54	13.23	5.2	223.5	0.3	-17.47 [°]	-7.8	
Electricity (value)	39.68	-1.05	3.34	8.4	117.65	37.38 [°]	-5.5	-4.7	88.85	-7.88	-21.72	-24.4	
Seeds total (value)	178.03	-7.89	-40.03 [°]	-22.5	31.26	9.6	-5.26	-16.8	43.13	-1.72	-41.61 [°]	-96.5	
Seeds purchases (value)	171.8	-10	-39.21 [°]	-22.8	28.71	7.01	-4.92	-17.1	42.15	-2.23	-41.5 [°]	-98.5	
Seeds own (value)	6.23	2.12	-0.82	-13.2	2.56	2.59	-0.34	-13.3	0.98	0.51	-0.11	-11.2	
Purchased manure (value)	32.2	25.26	-3.46	-10.7	15.45	7.23	3.06	19.8	25.69	12.93	-0.48	-1.9	
LAND ALLOCATION (% of UAA)													
Cereals	40.1	0.87	-5.65 ^{*a}	-14.1	4.6	-0.03	-0.25	-5.4	4.42	0.81	0.02	0.5	
Protein crops	4.66	1	4.02 ^{*a}	86.3	0.86	0.63	-0.06	-7.0	0.81	0.46 [°]	-0.11	-13.6	
Roots and tubers	2.3	-0.44	-0.82 ^{*a}	-35.7	0.02	-0.05	-0.1	-100.0 ^c	0.19	-0.04	-0.09	-47.4	
Industrial crops	9.94	-0.87	-0.98	-9.9	0.71	-0.68	0.03	4.2	0.74	0.19	-0.26	-35.1	
of which Oil seeds	6.99	-1.5	-1.15	-16.5	0.58	-0.63	-0.11	-19.0	0.56	0.02	-0.13	-23.2	
Vegetables and flowers	5.97	-0.58	0.11	1.8	0.12	0.04	-0.12	-100.0	0.61	-0.01	-0.33	-54.1	
Fodder and fallows	22.36	-0.76	1.82	8.1	14.26	0.05	0.14	1.0	8.28	-0.3	0.71	8.6	
of which Fodder	15.62	-0.81	2.77 ^{*a}	17.7	4.47	0.04	-0.55	-12.3	3.06	1.43 [°]	0.15	4.9	
of which Fallows	6.76	0.02	-0.93	-13.8	9.83	-0.07	0.6	6.1	5.29	-1.67	0.49	9.3	
Permanent grassland	6.76	-1.16	1.26 ^{*a}	18.6	2.43	-0.49	-0.5	-20.6	2.78	1.23 [°]	-0.6	-21.6	
Permanent crops	9.18	1	-0.42	-4.6	81.34	1	0.98	1.2	84.34	-3 [°]	0.85	1.0	
Forage	22.36	-2	3.89 ^{*a}	17.4	6.85	-1	-1.05	-15.3	5.79	3 [°]	-0.67	-11.6	
ECONOMIC PERFORMANCE, SUBSIDIES (EUR)													
Output from crops per ha	2227	-234		1	0.0	9591	2374 [°]	-798	-8.3	5191	-677	-267	-5.1
Specific costs for crops per ha	293	-9	-72 ^{*a}	-24.6	336	24	-53 ^{*a}	-15.8	231	-17	-59 ^{*a}	-25.5	
Farm net value added per AWU	30914	3229	4413 ^{*a}	14.3	33112	2884	1902	5.7	28358	3821 [°]	2541 [°]	9.0	
Labour input in AWU	2.01	0	0.04	2.0	2.69	0	-0.01	-0.4	2.1	0	-0.1 [°]	-4.8	
Farm net value added	64354	9652	16259 ^{*a}	25.3	99948	13379	2974	3.0	62847	12302 [°]	367	0.6	
Total CAP subsidies ^b	34559	9464 [°]	7174 ^{*a}	20.8	10910	5041	-1777	-16.3	18772	9340 [°]	1276 ^{*a}	6.8	

Note: [°] p-value ≤ 0.10, ^{*} p-value ≤ 0.05, ^a adjusted p-value ≤ 0.20. ^b Total CAP subsidies are not an outcome. ^c Bounded as lower than -100.0.

Source: Authors' own elaborations.

The economic performance section indicates general statistically significant decreases in specific costs for crops per hectare. We find no significant impacts of organic conversions on average total output per crop per ha of crops farms, even if the change displays a positive sign for Fieldcrop, while negative sign for Wine and other permanent crops specialists. Note that an increase in crop output per hectare is not expected within the first 2 years after conversion, as products can only be sold under the organic label 2-3 years after the conversion process begins, and subsidies for organic farmers are aimed at alleviating transition costs.

On average, both farm net value added and total subsidies significantly increase for fieldcrop farms, with the increase in subsidies explaining 44% of the total increase in value added. Other permanent crop specialists exhibit an increase in subsidies without a substantial change in value added, suggesting that subsidies effectively sustained their performance, which might otherwise have declined. For wine crop farms, there are on average non-significant increases in farm net value added and decreases in subsidies.

In summary, among the crop farms, fieldcrops specialists appear to be the most benefited. All crops farms reduce their consumption of inputs with negative effects on environment, also showing a shift towards reducing their dependence on external inputs, but reductions are statistically significant overall for fieldcrops farms, which also reallocate land in favour of protein crops and forage. The conversion to organic positively affects fieldcrop farms' profitability in the second year, partly due to increased subsidies. This may be due to the higher amounts of subsidies directed at this group, or to the nature of their crops, which may allow them to respond in a more agile way to policy interventions.

Table 2 presents the impact evaluation results of converting to organic farming for EU livestock farms specialising in milk production and other grazing livestock, including cattle, sheep, and goats. Before conversion, these farms managed average UAA of sizes comparable to those of field crop farms (87.7 ha and 110.9 ha vs. 93.5 ha). However, their land use differed significantly, with approximately 85% of UAA dedicated to forage crops, such as fodder and permanent grassland, primarily for livestock feed. At this stage, milk and other grazing livestock accounted for 19.4% and 25.3% of their total farm output, respectively. As these livestock farms switch to organic practices, they typically significantly reduce both the expenditures and quantities of fertilisers and pesticides per hectare. Over a two-year period, the conversion does not significantly affect the total value of livestock feed per LSU, although the increase in the value of own-grown feed is higher than that of purchased feed, but this increase is not statistically significant. Additionally, there is a significant reduction in veterinary expenditures, with organic farms reducing total veterinary costs by 635 and 414 euro over the two years, although reductions per LSU are not significant. The conversion also results in a slight increase in the share of land dedicated to forage. Overall, we find that converting to organic farming results in reductions of output from livestock and crops. The significant increases in total subsidies are adequate to sustain positive but not statistically significant changes in farm net value added for other grazing livestock specialists, but not for milk specialists. Despite these challenges, the farm's net value added per Agricultural Work Unit (AWU) increases on average, partly due to a reduction in the average number of working units.

Table 2. Impacts of organic conversion on Livestock farms

	Milk farms				Other grazing livestock			
	$Y_{(1)}$ $t=0$	$Y_{(1)}-Y_{(0)}$ $t=0$	ATET $t=2$	% size effect	$Y_{(1)}$ $t=0$	$Y_{(1)}-Y_{(0)}$ $t=0$	ATET $t=2$	% size effect
INPUTS per ha								
Fertilisers (value)	45.13	1.85	-25.71 ^{*a}	-57.0	18.28	-0.34	-9.70 ^{*a}	-53.1
Nitrogen (quintals)	0.26	-0.01	-0.29 ^{*a}	-100.0 ^c	0.38	0.04	-0.15	-40.2
Phosphorus (quintals)	0.06	0.01	-0.05 ^{*a}	-90.6	0.06	0.03	-0.05 [*]	-90.7
Potassium (quintals)	0.07	0.03 ^o	-0.06 ^{*a}	-92.3	0.06	0.03	-0.06 ^{*a}	-95.2
Plant protection products (value)	13.63	-0.86	-9.93 ^{*a}	-72.9	5.84	-0.89	-2.96 ^{*a}	-50.6
Fuel (value)	134.3	-31.6	50.4	37.5	100.6	17.9	2.9	2.9
Electricity (value)	70.25	-14.5	14.13	20.1	22.86	0.27	-0.98	-4.3
Seeds total (value)	40.7	6.85 ^o	1.07	2.6	19.21	0.34	-0.99	-5.1
Seeds purchases (value)	39.65	6.80 ^o	0.49	1.2	17.88	1.17	-0.93	-5.2
Seeds own (value)	1.05	0.05	0.57	54.3	1.32	-0.83	-0.05	-4.1
Purchased manure (value)	0.91	0.83	0.73	80.4	0.74	0.75	0.22	30.0
Feed total (value per LSU)	552.3	15.7	38.9 ^o	7.0	337.9	-3.1	-3.2	-0.9
Feed purchases (value per LSU)	315.1	-32.8	16.4	5.2	125.0	-23.9	-16.9	-13.5
Feed own (value per LSU)	237.2	48.5 ^o	22.4	9.5	212.8	20.8	13.7	6.5
Livestock units	95.07	-5.92	-3.80 [*]	-4.0	71.86	-8.82	-0.32	-0.4
Veterinary expenditure (value)	4998	-37	-635 ^{*a}	-12.7	2158	-929 ^o	-414 ^o	-19.2
Veterinary expenditure per LSU (value)	48.32	-2.51	-0.23	-0.5	23.93	-5.16 ^o	-1.58	-6.6
LAND ALLOCATION (% of UAA)								
Cereals	12.43	2.51 ^o	-1.53 ^o	-12.3	10.51	1.28	-1.11	-10.5
Protein crops	0.7	0.68 ^o	-0.19	-27.3	0.76	0.34 ^o	0.08	9.9
Roots and tubers	0.18	-0.07	-0.11 ^o	-60.5	0.37	-0.01	-0.05	-13.3
Industrial crops	0.68	0.48 ^o	-0.26	-38.7	0.62	0.02	-0.16	-25.6
Vegetables and flowers	0.11	0.08	-0.03	-24.4	0.29	0.05	-0.03	-9.2
Fodder and fallows	30.82	0.99	0.94	3.1	26.65	5.98 ^o	-0.15	-0.6
of which Fodder	30.08	0.83	1.05	3.5	24.38	4.52 ^o	1.18	4.8
of which Fallows	0.74	0.13	0.01	1.7	2.7	1.65 ^o	-1.43 ^{*a}	-52.9
Permanent grassland	54.66	-5.15	1.61	2.9	60.75	-8.47 ^o	0.76	1.3
Permanent crops	0.44	0.28 ^o	-0.30 ^o	-68.1	2.25	1.24 ^o	0.13	5.8
Forage	84.78	-4.32 ^o	2.66 ^{*a}	3.1	84.38	-4.42 ^o	2.23 ^{*a}	2.6
ECONOMIC PERFORMANCE, SUBSIDIES (EUR)								
Output from crops per ha	328	33	-4.1	-1.3	300	48	-24	-8.0
Specific costs for crops per ha	55	6	-8.3 ^{*a}	-15.1	26	-1	-4	-15.4
Output from livestock per LSU	1646	-4	112 ^{*a}	6.8	903	76	-33	-3.7
Specific costs for livestock per LSU	666	16	40.0	6.0	386	-5	-4	-1.0
Farm net value added per AWU	29755	-1313	4258 ^o	14.3	30123	3016	4420 ^{*a}	14.7
Labour input in AWU	2.61	0.35	-0.17	-6.7	2.04	0.12	-0.12 [*]	-5.7
Farm net value added	72470	1628	-736	-1.0	65613	-838	7574	11.5
Total CAP subsidies ^b	42808	7072	10994 ^{*a}	25.7	42195	2448 ^o	8361 ^{*a}	19.8

Note: ^o p-value ≤ 0.10 , ^{*} p-value ≤ 0.05 , ^a adjusted p-value ≤ 0.20 . ^b Total CAP subsidies are not an outcome.

^c Bounded as lower than -100.0.

Source: Authors' own elaborations

5.1 Robustness checks

As support to the solidity of our empirical methodology, we run a set of validation and robustness checks. We contrast PSM-DiD estimates to the ones based on the PSM. Estimated confidence intervals at 95% from the two methods are largely overlapping for all outcomes, except few cases. Notwithstanding, when using the PSM approach instead of the PSM-DiD approach, a larger number of significant effects are obtained across all farm typologies (Tables A.4 to A.5). This comes at the cost of potentially overestimating the impacts. In contrast, the adopted PSM-DiD approach is more conservative, providing a more cautious estimate of the effects.

To address the concerns associated with multiple testing, we applied the Benjamini-Hochberg (BH, hereinafter) procedure (Benjamini and Hochberg 2018) to compute adjusted p-values⁵. In this more demanding inference method, we considered results significant if their adjusted p-value was below 0.20, which corresponds to set the false discovery rate (FDR) at 20%⁶. We also report results with non-adjusted p-values significant at 10% comparison under a less stringent setting. While the results in Tables 1 and 2 are commented in terms of standard unadjusted p-values, significant coefficients according to the BH-adjusted p-values are also indicated. We prefer to maintain coefficients that are significant according to unadjusted but not adjusted p-values, as they provide weaker but qualitatively relevant information. Overall, the findings do not change substantially by limiting the discussion to only adjusted results, providing a more cautious estimate of the effects. As a whole, in our opinion, the robustness checks support the methodological choices of the study.

⁵ The adjustment is made using the formula: adjusted p - value = p - value \times (m/k), where m represents the total number of tests performed (m = 176, resulting from testing hypotheses across 34 outcomes over the three types of crops specialised farms and 36 outcomes over the two groups of livestock specialised farms) and k is the rank of the p-value in ascending order.

⁶ The FDR is the expected proportion of false positives among all findings that are declared significant.

6. Conclusions

A first general takeaway from our study is that the impact of conversion to organic farming on the economic and environmental performance of holdings during the first years, as realised during the CAP programming period 2014 to 2022, is heterogeneous across farm types and effective overall on specific farm typologies. The number of significant impacts at 5% exhibits considerable variation across farm typologies, ranging from 12 significant effects for fieldcrop specialists to only 2 for permanent crop specialists, out of 29 analysed outcomes. Similarly, livestock specialists exhibit 11 and 9 significant effects, out of 35 analysed outcomes, highlighting the diversity of impacts across different farming systems. As a second conclusion of importance, our results support the hypothesis that conversion to organic farming enhances environmental performance already during the first years after conversion for all farm types analysed, with non-significant effects only for farms specialised in permanent crops other than wine. For permanent crops farms, this does not mean that conversion outcomes do not materialise at all, but may indicate that they need a longer time horizon.

As a whole, the positive impacts of organic farming on drivers of farm environmental performance per hectare feed strongly into the discussion of organic farming support measures, whereas in the past, these measures have often been criticised for their implementation strategy, which has frequently prioritised achieving target shares of organic land over delivering environmental or market outcomes. Specifically, we found statistically significant impacts per hectare for field crops and livestock farms, which, on average, are those with the largest extension of UAA and AL.

Thirdly, our results suggest that organic conversion does have an influence on economic performance. We observe moderate, although not statistically significant, reductions in specific costs for crop per hectare, along with generally statistically significant increases in farm net value added per annual work unit. On average, total net value added increases for fieldcrop farms, and displays positive not significant increases for all remaining types excluding specialist vineyards. It is important to highlight the central role played by CAP subsidies which increased over the period of analysis and appear to have contributed to curbing a decline in average farm net value added.

While an examination of long-term consequences of conversions would certainly be desirable, one inherent limitation of our study is its short time horizon; our specifications measure impacts up to two years after the conversion events and no further. This choice is dictated by the fact that samples extracted from the FADN survey face a severe trade-off between length of the observation window and numerosity, since the rotating-panel structure of FADN imposes a periodical update of interviewed farms (European Commission, DG AGRI 2021). As a consequence, it cannot be excluded that part of the impacts identified in our analysis characterise the transition process from conventional to organic practices rather than the stable, longer-run equilibrium that organic converters may reach. This constraint underscores the need for further research benefiting from longer observation periods.

The analysis developed in this study adds to the existing literature by offering new insights on the impact of organic conversions, featuring wider geographical coverage and a greater range of farm specializations with respect to previous related work. Moreover, this paper, by combining the PSM and DiD strategies, matching converters to comparable peers before conversion and subsequently following pairs over time, enhances the credibility of causal claims.

Our findings suggest that converting to organic farming systems has a generally positive impact, characterised by reduced per hectare use of fertilisers and plant protection products, decreased dependence on external inputs, and lower specific costs for crops for fieldcrops and livestock milk and other grazing specialists. Furthermore, the increase in total subsidies has been sufficient, on average, to offset potential losses in farm net value added, thereby maintaining farm profitability.

In terms of future research outlook, it would be desirable to acquire data on additional farms' and farmers' characteristics, such as individual attributes of farm manager, and characteristics and heritage of the economic and social community encircling the holding, to better control influent factors. In addition, a highly relevant but currently underexplored topic is the effect of organic policy measures on actual organic food production, rather than organic farm management in general. To the best of our knowledge, no ex-post evaluation has yet been conducted to explore this avenue, which may lend itself to the application of methodologies akin to those illustrated in this paper.

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List of abbreviations and definitions

Abbreviations	Definitions
ATET	Average Treatment Effect on Treated
AWU	Agricultural Work Unit
BH	Benjamini-Hochberg
DiD	Differences in Differences
EU	European Union
FADN	Farm Accountancy Data Network
FDR	False discovery rate
ha	hectare
LSU	Livestock Standardised Units
PSM	Propensity Score Matching
PSM-DiD	Propensity Score Matching-Differences in Differences
SMD	Standardised Mean Difference
UAA	Utilised Agricultural Area

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Annexes

Table A.1: Average Size of Conventional Farms (Before and After Matching) and Farms Converting to Organic, by Type of Specialization

	Utilised Agricultural Area (UAA)			Arable Land area (AL)		
	All Control	Matched Control	Treated	All Control	Matched Control	Treated
Fieldcrops	142.9	70.2	93.5	136.0	62.1	84.3
Wine crops	24.6	25.7	23.4	6.9	6.0	6.0
Other permanent crops	21.8	13.7	20.4	4.8	2.6	4.7
Milkcrops	99.0	83.2	87.7	61.0	41.3	52.9
Other grazing livestock	87.2	91.1	110.9	27.4	22.0	36.2
	Permanent crops area					
	All Control	Matched Control	Treated			
Fieldcrops	1.3	1.7	2.5			
Wine crops	17.1	19.3	16.6			
Other permanent crops	16.0	11.0	14.4			
Milkcrops	0.1	0.1	0.2			
Other grazing livestock	0.4	0.2	0.9			
	Livestock Standardised Units			Permanent grassland area		
	All Control	Matched Control	Treated	All Control	Matched Control	Treated
Fieldcrops	8.4	6.9	5.4	5.6	6.4	6.8
Wine crops	0.7	0.0	0.4	0.6	0.4	0.8
Other permanent crops	1.0	0.3	0.8	1.0	0.2	1.4
Milkcrops	127.4	129.0	102.6	97.2	41.8	34.7
Other grazing livestock	87.8	67.2	74.2	59.4	69.0	73.9

Source: Authors' own elaborations

Table A.2: Land use of conventional and organic agriculture, 2020, by crop (%)

	Conventional farms			Organic farms		
	EU^a	FADN farms		EU^a	FADN farms	
		simple	weighted		simple	weighted
Cereals	34	33.0	32.7	16	15.4	15.1
Protein crops	1	1.3	1.3	3	2.5	2.7
Industrial crops	8	6.7	5.3	4	2.4	2.0
Fodder	12	13.8	12.0	17	17.3	14.3
Permanent grassland	30	21.3	20.7	42	32.7	27.7
Permanent crops	7	13.1	18.8	11	22.8	31.8
Others	8	10.8	9.2	6	6.9	6.4

Source: Column ^a: EC 2023. Other columns: Authors' own elaborations

Table A.3: Comparison of Crop and Livestock Farms in main organic-producing countries

	Crop organic farms				Livestock organic farms		
	EU ^a	FADN			EU ^a	FADN	
	%	All %	Treated %		%	All %	Treated %
FRA	6.5	9.8	9.4	DEU	7.5	13.7	15.1
ESP	16	15.1	2.1	FRA	9.5	9.7	10.4
ITA	19.6	14.6	68.5	OST	3.9	3.8	10
DEU	2.9	7.7	4.3	ITA	8.2	8.6	37.6
OST	0.9	1.3	3.4	SVE	1.4	2.4	
SVE	0.5	0.6		CZE	0.6	1.3	1.1
CZE	0.4	1.5	0.3	DAN	0.7	2.9	1.4
ELL	9.7	7.4	1.4	ESP	8.8	10.5	1.2
POL	18.7	14	2.3	ELL	4.1	2.1	0.4
ROU	7.2	3.1		BEL	1.2	2	1.9
				LVA	0.9	1.4	3.5
				POR	2.9	2.9	1.8
Others	17.6	24.9	8.3	Others	50.3	38.7	15.6

Source: Column ^a: EC 2023. Other columns: Authors' own elaborations

Table A.4: Estimates from PSM and PSM-DID methods (1/2)

Outcome	Fieldcrop farms		Wine farms		Other permanent crops	
	PSM	PSM-DID	PSM	PSM-DID	PSM	PSM-DID
Fertilisers (value per ha)	32.50 ^o (19.3)	-34.67* (17.3)	-17.49 (34.2)	-11.96 (30.6)	-25.78 (24.1)	-2.10 (18.8)
Fertilisers- Nitrogen (quintals per ha)	-0.92* (0.4)	-1.16 (0.9)	-0.44* (0.2)	-0.30 (0.2)	-0.83* (0.2)	-1.08 (0.8)
Fertilisers- Phosphorus (quintals per ha)	-0.36* (0.2)	-0.41 ^o (0.2)	-0.33* (0.1)	-0.30* (0.1)	-0.46* (0.1)	-0.70 (0.7)
Fertilisers- Potassium (quintals per ha)	-0.28* (0.1)	-0.31 (0.2)	-0.60* (0.3)	-0.55 ^o (0.3)	-0.58* (0.2)	-0.48 (0.4)
Plant protection products (value per ha)	-34.34* (17.2)	-31.56* (8.7)	-35.50 (38.6)	-47.65 ^o (26.5)	-33.14 ^o (19.0)	-17.26 (12.0)
Fuel (value per ha)	-0.13 (14.7)	-2.68 (11.5)	26.77 (18.7)	13.23 (15.7)	-17.17 (13.4)	-17.47 ^o (10.3)
Electricity (value per ha)	2.30 (6.3)	3.34 (7.0)	31.88* (11.8)	-5.50 (10.9)	-29.59 (24.9)	-21.72 (25.2)
Seeds total (value per ha)	-47.92 ^o (24.7)	-40.03 ^o (21.9)	4.34 (8.9)	-5.26 (10.4)	-43.32 (26.9)	-41.61 ^o (23.5)
Seeds purchases (value per ha)	-49.21* (24.6)	-39.21 ^o (21.9)	2.10 (8.8)	-4.92 (10.3)	-43.72 (26.9)	-41.50 ^o (23.5)
Seeds own (value per ha)	1.29 (2.0)	-0.82 (1.8)	2.25 (1.4)	-0.34 (0.9)	0.40 (0.3)	-0.11 (0.6)
Purchased manure (value per ha)	21.79* (7.9)	-3.46 (12.8)	10.29 (12.3)	3.06 (11.8)	12.45 (8.5)	-0.48 (9.5)
Cereals (%)	-4.79* (1.8)	-5.65* (1.3)	-0.28 (1.4)	-0.25 (1.2)	0.83 (0.7)	0.02 (0.5)
Protein crops (%)	5.02* (0.8)	4.02* (0.8)	0.58* (0.3)	-0.06 (0.4)	0.35 (0.2)	-0.11 (0.3)
Roots and tubers (%)	-1.25 ^o (0.6)	-0.82* (0.4)	-0.15* (0.0)	-0.10 (0.1)	-0.13 (0.1)	-0.09 (0.1)
Industrial crops (%)	-1.85 (1.1)	-0.98 (0.8)	-0.65 (0.5)	0.03 (0.5)	-0.07 (0.2)	-0.26 (0.2)
Vegetables and flowers (%)	-0.47 (1.2)	0.11 (0.4)	-0.09 (0.1)	-0.12 (0.1)	-0.33 (0.2)	-0.33 (0.2)
Fodder and fallows (%)	1.06 (1.9)	1.82 (1.5)	0.19 (2.6)	0.14 (2.2)	0.40 (1.5)	0.71 (1.2)
of which Fodder (%)	1.96 (1.7)	2.77* (1.2)	-0.50 (1.3)	-0.55 (1.3)	1.58* (0.6)	0.15 (0.4)
of which Fallows (%)	-0.91 (1.0)	-0.93 (1.0)	0.53 (2.3)	0.60 (2.2)	-1.18 (1.4)	0.49 (1.2)
Permanent grassland (%)	0.10 (1.1)	1.26* (0.5)	-0.99 (1.3)	-0.50 (0.8)	0.64 (0.8)	-0.60 (0.7)
Permanent crops (%)	0.91 (1.1)	-0.42 (0.4)	1.93 (2.6)	0.98 (1.4)	-2.24 (1.5)	0.85 (0.6)
Forage (%)	2.27 (1.9)	3.89* (1.2)	-1.55 (1.8)	-1.05 (1.5)	2.00* (1.0)	-0.67 (0.8)

Source: Authors' own elaborations

Table A.5: Estimates from PSM and PSM-DID methods (2/2)

Outcome	Fieldcrop farms		Wine farms		Other permanent crops	
	PSM	PSM-DID	PSM	PSM-DID	PSM	PSM-DID
Total output from crops per ha	-233 (276)	1 (262)	1577 (1277)	-798 (503)	-944* (473)	-267 (305)
Specific costs for crops per ha	-81* (36)	-72* (27)	-29 (39)	-53* (27)	-76* (34)	-59* (25)
Farm net value added per AWU	7642* (2173)	4413* (1848)	4786 (4803)	1902 (3246)	6362* (1510)	2541° (1453)
Labour input in AWU	0.33° (0.2)	0.04 (0.1)	-0.15 (0.5)	-0.01 (0.1)	0.14 (0.1)	-0.10° (0.1)
Farm net value added	25912* (9241)	16259* (4901)	16352 (19083)	2974 (10423)	12670* (5535)	367 (3077)
Total significant at 5% (out of 29)	13	12	6	2	10	2

Source: Authors' own elaborations

Table A.6: Estimates from PSM and PSM-DID methods - Livestock farms (1/2)

Outcome	Milk farms		Other grazing livestock	
	PSM	PSM-DID	PSM	PSM-DID
Fertilisers (value per ha)	-23.86* (3.9)	-25.71* (4.0)	-10.04* (2.0)	-9.70* (1.7)
Fertilisers- Nitrogen (quintals per ha)	-0.30* (0.0)	-0.29* (0.1)	-0.11* (0.0)	-0.15 (0.3)
Fertilisers- Phosphorus (quintals per ha)	-0.04* (0.0)	-0.05* (0.0)	-0.02* (0.0)	-0.05* (0.0)
Fertilisers- Potassium (quintals per ha)	-0.03* (0.0)	-0.06* (0.0)	-0.02* (0.0)	-0.06* (0.0)
Plant protection products (value per ha)	-10.79* (1.5)	-9.93* (1.7)	-3.84* (0.8)	-2.96* (0.7)
Fuel (value per ha)	18.81 (16.7)	50.39 (35.3)	20.81 (27.8)	2.94 (12.1)
Electricity (value per ha)	-0.37 (5.9)	14.13 (14.8)	-0.71 (2.9)	-0.98 (2.6)
Seeds total (value per ha)	7.92* (3.8)	1.07 (2.9)	-0.65 (2.2)	-0.99 (1.7)
Seeds purchases (value per ha)	7.30 ^o (3.8)	0.49 (2.8)	0.24 (1.7)	-0.93 (1.4)
Seeds own (value per ha)	0.62 (0.5)	0.57 (0.5)	-0.89 (1.4)	-0.05 (0.9)
Purchased manure (value per ha)	1.56* (0.7)	0.73 (0.6)	0.98* (0.5)	0.22 (0.2)
Feed total (value per LSU)	54.56 (37.8)	38.86 ^o (23.4)	-6.25 (25.2)	-3.20 (19.8)
Feed purchases (value per LSU)	-16.37 (24.0)	16.41 (14.9)	-40.83* (17.5)	-16.94 (12.3)
Feed own (value per LSU)	70.93* (29.5)	22.45 (17.6)	34.57 ^o (18.8)	13.74 (15.2)
Total livestock units	-9.72 (12.7)	-3.80* (1.9)	-9.13 (8.5)	-0.32 (3.2)
Veterinary expenditure (value)	-672 839	-635* 265	-1343* 440	-414 ^o 246
Veterinary expenditure per LSU (value)	-2.75 (3.5)	-0.23 (2.9)	-6.74* (2.8)	-1.58 (2.1)

Source: Authors' own elaborations

Table A.7: Estimates from PSM and PSM-DID methods - Livestock farms (2/2)

Outcome	Milk farms		Other grazing livestock	
	PSM	PSM-DID	PSM	PSM-DID
Cereals (%)	0.98 (1.3)	-1.53 [~] (0.8)	0.18 (1.0)	-1.11 (0.7)
Protein crops (%)	0.49* (0.2)	-0.19 (0.2)	0.41* (0.2)	0.08 (0.2)
Roots and tubers (%)	-0.18 (0.1)	-0.11 [~] (0.1)	-0.06 (0.1)	-0.05 (0.0)
Industrial crops (%)	0.22 (0.3)	-0.26 (0.3)	-0.14 [~] (0.1)	-0.16 (0.2)
Vegetables and flowers (%)	0.05 (0.0)	-0.03 (0.1)	0.02* (0.0)	-0.03 (0.0)
Fodder and fallows (%)	1.94 (2.7)	0.94 (1.2)	5.83* (2.1)	-0.15 (1.1)
of which Fodder (%)	1.87 (2.7)	1.05 (1.2)	5.71* (2.0)	1.18 (1.1)
of which Fallows (%)	0.14 (0.4)	0.01 (0.4)	0.22 (0.6)	-1.43* (0.6)
Permanent grassland (%)	-3.54 (3.3)	1.61 (1.1)	-7.70* (2.5)	0.76 (1.0)
Permanent crops (%)	-0.02 (0.2)	-0.30 [~] (0.2)	1.37* (0.4)	0.13 (0.3)
Forage (%)	-1.66 (1.5)	2.66* (0.9)	-2.20 [~] (1.2)	2.23* (0.9)
Total output from crops per ha	28.75 (36.6)	-4.11 (20.0)	23.92 (21.5)	-24.09 (24.3)
Specific costs for crops per ha	-2.25 (4.8)	-8.30* (3.4)	-5.38 (3.5)	-4.00 (2.5)
Total output from livestock per LSU	108.27 (71.4)	112.41* (40.2)	43.24 (69.5)	-33.03 (41.6)
Specific costs for crops per ha	55.72 (39.8)	39.97 (24.7)	-8.85 (26.6)	-4.00 (21.0)
Farm net value added per AWU	2945 2881	4258 [~] 2273	7436* 2236	4420* 1794
Labour input in AWU	0.17 (0.4)	-0.17 (0.2)	0.00 (0.2)	-0.12* (0.1)
Farm net value added	892 13130	-736 7168	6736 7594	7574 5532
Total significant at 5% (out of 35)	10	11	17	9

Source: Authors' own elaborations