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National organic action plans and organic farmland area growth in Europe

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A B S T R A C T

The expansion of organic agricultural production methods has been tendered as a critical factor in the development of a sustainable global food system. The European Union has led efforts to expand organic farming, with a current target share of 25% organic farmland area by 2030 through the Farm-to-Fork strategy. Many member states have set organic area targets through the initiation of organic action plans, but systematic, quantitative, empirical research into the effectiveness of such organic policies is lacking. This study analyses the effect of four different national organic action plans - the 1st French Organic Action Plan (2008 to 2012), the 2nd Swedish Organic Action Plan (2006 to 2010), the 2nd Czech Organic Action Plan (2011 to 2015) and the 5th Austria Organic Action Plan (2011 to 2013) - on organic farmland area extent. This was achieved using a balanced country-level panel dataset consisting of 26 OECD states between 2001 and 2019 (N = 494). The synthetic control method was applied systematically to predict the counterfactual organic area growth paths, enabling the quantification of the treatment effects for the selected action plans. The model specifications were vigorously tested with leave-out-one robustness tests and in-space placebo tests. The results indicated robust, large, positive and significant effects for the French and Swedish organic action plans on organic farmland area. However, the Czech and Austrian plans were found to be ineffectual. Whilst organic action plans appear useful agenda-setting tools, caution is advised in relying on them to produce consistent results, particularly if numerous plans have been previously implemented and the organic area share is already high. This finding is also likely indicative of decreasing marginal returns to action plans. A deeper understanding of the effectiveness of previously implemented plans is critical for the optimisation of future interventions.

1. Introduction

The world is facing a looming biodiversity, climate and food security crisis (Hertel, 2011; Tilman et al., 2011; Wheeler and von Braun, 2013). Critical to meeting these challenges is the sustainable adaption of food production systems. Organic agriculture has been outlined as one key component of the overall solution as it is able to mitigate some of the negative externalities resulting from intensive agricultural practices (Lee et al., 2015; Muller et al., 2017; Squalli and Adamkiewicz, 2018; Stolze and Lampkin, 2009; Fuller et al., 2005; Pe'er et al., 2020). Organic agriculture is explicitly orientated towards sustainable food production via the maximisation of biodiversity, soil fertility and food quality (EU, 2018; Gomiero et al., 2011; IFOAM, 2008). These aims are achieved through the implementation of agroecological management practices that have been linked with advantages over conventional agriculture that include; lower environmental impacts, greater soil carbon capture and improved profitability (Cisilino et al., 2019; Gabriel et al., 2013; Scialabba and Müller-Lindenlauf, 2010; Smith et al., 2019; Tuck et al., 2014; Tuomisto et al., 2012). There has been a large policy focus on promoting organic agriculture in the European Union (EU) over the last 30 years (Stolze and Lampkin, 2009), which has contributed to a higher area share in the EU of ~8.5% compared to the global average of ~ 1.5% (EC, 2021; Willer et al., 2021). Nevertheless, the sector still requires significant growth given the ambitious target for 25% of the farmed area to be managed organically by 2030 through the Farm-to-Fork strategy (EC, 2021; Montanarella and Panagos, 2020; Moschitz et al., 2021).

While governments across Europe commit to organic targets, the extent to which past organic policies have had an impact on organic conversion at the country scale has been largely unexplored empirically. If the full benefits of organic agriculture are to be brought to fruition and targets are to be met, it is critical to develop insights into how organic policy can be formulated to efficiently and effectively drive its proliferation. National and EU-wide action plans are a frequently used policy intervention both within and outside of the agri-environmental setting. Organic action plans specifically aim to strengthen the organic sector in

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the EU, both on the demand and supply-side. Whilst demand-side effects have been studied (e.g. Sørensen et al., 2016; Lindström et al., 2020), supply-side effects of these action plans on organic farmed area are largely not verified empirically.

We here contribute to fill this gap and analyse the effectiveness of four national organic action plans (France, Sweden, Czech Republic and Austria) at stimulating organic farmland expansion. To this end, we use a balanced panel country-level dataset consisting of 26 OECD states between 2001 and 2019 (N = 494), and use the synthetic control method to quantify the treatment effects for the selected action plans on the respective organic farmland areas.

Whilst a large number of studies have looked at drivers of organic agriculture adoption at the farm level (e.g. Allaire et al., 2015; Khaledi et al., 2010; Läpple and Kelley, 2013; Läpple and Rensburg, 2011; Malá and Malý, 2013; Musshoff and Hirschauer, 2008; Mzoughi, 2011; Pietola and Lansink, 2001; Schmidtner et al., 2012; Serebrennikov et al., 2020), setting the scope at this juncture limits the ability to quantify the effectiveness of any particular country scale policy intervention. Furthermore, the relatively more abundant qualitative and descriptive research efforts that investigated organic policies at a country level, such as organic action plans (e.g. Sanders et al., 2011; Sanders, 2013; Jahrl et al., 2016), are also limited in their ability to precisely measure the effect of a particular policy on the organic sector. To complement the existing literature, rigorous counterfactual analysis is needed, hence the approach adopted in this study. Previous studies clearly show that quantitative econometric research into understanding the effects of policy on organic adoption at a country level is generally underdeveloped (Daugbjerg et al., 2011; Lindström et al., 2020 being amoung the most recent examples).

This study seeks to make a novel contribution to the organic policy discourse through the assessment of the conversion effects of four selected national organic action plans implemented in four EU member states between 2001 and 2019. We test whether and how the acreage under organic farming was affected by the national action plan and apply the synthetic control method to model to this end. The method is especially relevant for our analysis as it enables the quantification of the effect of organic action plans by predicting the counterfactual year-on-year development of organic area using a weighted combination of untreated units – from a sample of multiple units known as the donor pool – to manufacture a single control unit. The synthetic control method is also appropriate due to its ability to perform accurate causal estimations with small sample sizes. This is especially pertinent for our country-level analysis which focuses on action plans in Europe. We use a donor pool of 26 OECD member states[1] with which to estimate the counterfactual (details are available in Sections 3 and 4). The rational for including some non-EU OECD members was to obtain a sufficiently large sample of countries.[2] For each iteration of the model, the treated country was excluded from the donor pool to avoid self-contamination. We also made sure that none of the remaining three treatment units were used in the calculation of any other synthetic control estimation that we conducted. Through this analysis, we find mixed results that indicate that the success of organic action plans is highly context specific. For instance, our analysis provides robust evidence of large, positive organic area increases resulting from the implementation of plans in France and Sweden. However, the Austrian and Czech plans are found to be ineffectual at stimulating growth. Reasons for this are discussed in the sections that follow.

The remainder of this paper is structured as follows. Firstly, the theory and mechanisms of the empirical method are further elaborated within the background and methodology sections (Sections 3 and 4). Here, the robustness tests applied to verify the results are also outlined. The methodology is followed by a section covering the empirical application of the model that details the data and policy setting that characterises this analysis. The results are then presented, which are contextualised and critically assessed in the discussion. The paper concludes by drawing the key policy implications from the study and by outlining areas for further development.

2. Background

Organic action plans are defined as an overarching policy instrument operating at the national or regional scale that frequently combine a mix of both supply and demand side interventions (Sanders and Metze, 2011) and are commonly used as an agenda-setting tool. For example, interventions can be in the form of direct farm support payments, laws for purchasing organic food and investment into research and development, all of which are combined to meet the stated targets of the plan. However, given that the definition is very broad, the exact design, targets and level of political backing are often diverse (Sanders and Metze, 2011). Therefore, it was important to consider a representative sample of action plans, which is why we analyse the effects of four different national organic action plans. See Fig. 1 for an illustration of the running periods of the different national organic action plans employed by EU member state, that stated and quantified area growth targets (dark grey bars). This considers the period of data available for this study which was from 2001 to 2019. We also highlight the four studied action plans (light grey bars with shaded vertical black lines)[3] that were selected on the basis of the following criterion:

I) Plans were chosen that fell within the 2nd and 3rd quarters (the period 2006 to 2015) of the full time period covered by the available data. It was necessary to have a reasonable number of pre and post-treatment periods for the quantification of the effect of the policy interventions. Plans of states that joined the EU in 2004 were only considered if they fell in the 3rd quarter so as to minimise confounding effects associated with entry into the EU. This left six potential action plans that could be analysed. These plans were the 1st French action plan, the 2nd Swedish action plan, 2nd Czech action plan, 1st Irish action plan and the 4th and 5th Austrian action plans (see Fig. 1 for the timelines of these plans).

II) Only plans that set out clear targets for the expansion of organic area were considered.

III) Plans were then selected from geographically, economically and politically different areas. This was to minimise the crossover of donor countries within the pool of countries used to construct the synthetic control. We did not consider the Irish plan in the main text because we had to interpolate one of the values of the organic area due to a very large outlier. However, we performed the same analysis and included the results in the supplementary material for completeness. It was also of high value that the four country cases had very different starting organic area shares in the year of the intervention to generate insights into action plan effectiveness at different stages of the organic adoption cycle. For this reason, we chose the 5th Austrian organic action plan over the 4th Austrian action plan because this gave a good example of a plan

[1] The 26 countries included in the donor pool were Austria, Belgium, Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Ireland, Latvia, Lithuania, the Netherlands, New Zealand, Norway, Poland, Slovakia, Slovenia, Spain, South Korea, Sweden, Switzerland, Turkey and the United Kingdom.

[2] Specification tests showed that re-running the analysis on a donor pool of only EU countries had little effect on the magnitude of estimation. However, the constrained sample size reduced the precision and accuracy of the estimations.

[3] For more information on the specific details of the action plans considered in this analysis, please consult González et al., (2011); Lampkin and Sanders, (2022); Sanders, (2013); Sanders and Metze, (2011); Sanders and Schmid, (2014); Schmid et al., (2008).

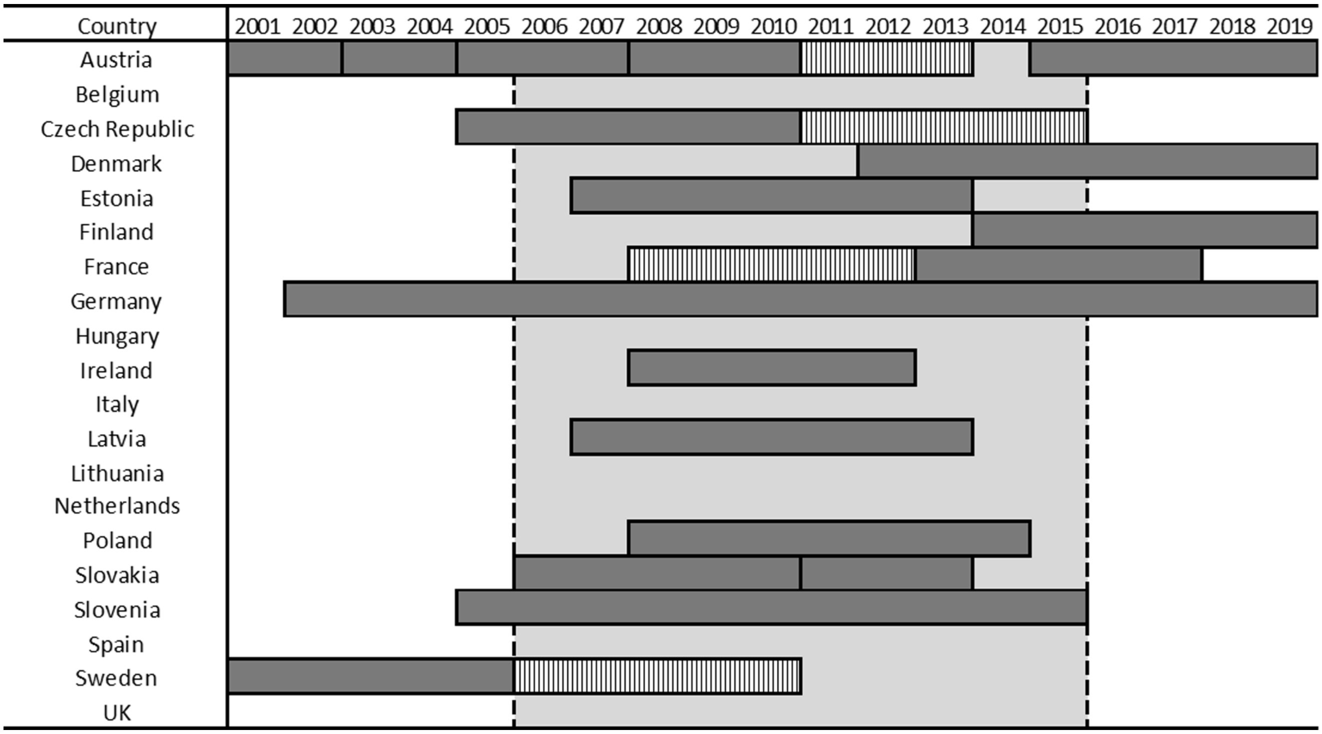

Fig. 1. Graphic showing the running periods of the organic action plans with specified organic area growth targets initiated in the EU countries that are included in the donor pool of this analysis. Note: Solid dark grey bars show the organic action plans that outlined area share targets according to selection criterion 2, light grey bars with shaded vertical lines represent the action plans tested in this analysis. The medium grey section represents the time constraints laid out under inclusion criterion 1. Sources of information for the action plans were: González et al. (2011), Sanders and Metze (2011) and Sanders and Schmid (2014).

with rather unambitious targets in a country with an already high organic area share. However, as in the Irish case, we also include an analysis of the 4th Austrian action plan in the supplementary material for further insight[4].

The French action plan (2008–2012), the Swedish action plan (2006–2010), the Czech action plan (2011–2015) and the Austrian action plan (2011–2013) were selected because they best satisfied all the conditions stipulated above. The starting organic area shares in the first year of the action plan were very heterogeneous, with the shares being as follows: France 2.0% in 2008, Sweden 7.2% in 2006, Czech Republic 13.8% in 2011 and Austria 19.7% in 2011. Additionally, the area targets were also quite different, with France targeting 6% by 2012 (tripling of area), Sweden targeting 20% by 2010 (2.75 times increase in area), the Czech Republic targeting 15% by 2015 (1.09 times increase in area) and Austria (1.02 times increase in area). See the supplementary material for further background information on the implementation of these plans.

3. Methodology

3.1. Problem definition

In this study, we ain to isolate the impact of the four selected policy interventions. To that effect, we henceforth use the term "treatment effect" to refer to the effect of the implementation of an organic action plan on the development of a country's organic farmland area. More specifically, the treatment effect that this study seeks to quantify is known as the average treatment effect on the treated (*ATT*). Application of this represents the additional organic area caused directly by the initiation of an organic action plan in the country in which the plan was initiated (e.g. France, Sweden, Czech Republic and Austria), which can be illustrated in the equation:

$$ATT = E[\Delta Y_1 - \Delta Y_0 | D = 1] \quad (1)$$

Here, the *ATT* is measured at the end of the action plan and is calculated by subtracting the change in organic area between the beginning and end of the plan for the non-treated – "control" – unit(s) (ΔY_0) from the change in organic area of the treated unit(s) (ΔY_1). A key assumption that is necessary for *ATT* calculation is signified by the term $\Delta Y_0 | D = 1$. This implies that, in equation (1), ΔY_0 represents the counterfactual – i.e. the change in organic area that would have happened in the country where an action plan was initiated in the event that this specific treatment did not actually occur. Therefore, accurate estimation of the *ATT* is only credible providing that the pre-treatment organic area trends between the treated and untreated units are as similar as possible. The treatment and control units must also replicate each other closely on key drivers of organic area growth. This is critical to exclude the possibility that the treatment effect observed was caused by anything other than the organic action plan.

The quantification of these treatment effects in comparative case studies using standard regression methods is often complicated by the relatively small sample size, lack of randomisation of the data, an inability to use probabilistic sampling (Abadie et al., 2015) and also by the assumptions underpinning regression methods. In order to quantify the treatment effect of a policy intervention in a given country (*ATT*), there must be a counterfactual control unit to indicate what would have

[4] The results after all robustness checks for these plans indicated that no significant treatment effect was detected (p-value 0.1364 and 0.3636 for the estimate +3.868 percentage point and −8.783 percentage point differences versus the counterfactual of Austria and Ireland respectively). However, there was also a much higher level of control bias than in the four main models presented below which further warrants the exclusion of these action plans from the analysis. Check Figures SM5 and SM6 in the supplementary material for the results of the robustness tests for these plans. Consult Tables SM11 and SM12 for information on the control bias inherent to these two cases which influence their exclusion from this analysis.

happened in the absence of the treatment ($\Delta Y_0|D = 1$) in Equation (1). However, due to the country-level scale of this analysis and small sample size, no single untreated unit could be utilised independently for an accurate counterfactual comparison of the treated country. Therefore, the synthetic control method was selected as the more appropriate alternative to the traditional difference-in-difference approach.

Our estimation approach was thus to select cases that met a strict inclusion criterion, to which the method could be applied for the detection of a treatment effect of the initiation of an organic action plan on the development of the extent of organic farmland area. In such cases, these predictions were then subjected to a series of different robustness tests to assess the sensitivity, precision and accuracy of the predicted results. The theory underpinning the model calculation is highlighted in the subsection below, which is followed by an explanation of the different robustness tests that we employed. Information on the form and variables used to achieve this strategy can be found in the Empirical Application section (Section 4).

3.2. Econometric modelling approach

The synthetic control method calculates the *ATT* by simulating the counterfactual with a synthetically constructed control unit, which is unique to each case in which it is calculated, built through the assignment and combination of variable inclusion weights to a group of potential control units (Abadie and Gardeazabal, 2003; Abadie et al., 2010). Formally, this mechanism can be represented as follows. Take a sample of $I+1$ units, where i is representative of an individual unit, such as an EU member country, that is repeatedly present in the panel data ($i = 1, \ldots, I+1$). Now suppose that the country where $i = 1$ is the treatment unit, i.e. the country where the organic action plan of interest took place. The countries from $i > 1$ to $i = I+1$ can be used as a donor pool for the estimation of the counterfactual (Abadie et al., 2015). As the *ATT* is measured over several time periods, t represent the time of the observation ($t = 1, \ldots, T$). It is necessary that the number of pre-treatment time periods, represented by T_0, as well as the number of post-treatment time periods, represented by T_1, are both ≥ 1. The intervention must have no effect on $i = 1$ from periods $t = 1, \ldots, T_0$. Country $i = 1$ is then only exposed to the policy intervention from periods where $t = T_0 + 1, \ldots, T$ (Abadie et al., 2015).

However, in creating a realistic synthetic representation of the development of organic area for country $i = 1$, all individuals from the donor pool are not arbitrarily fed into the counterfactual (Abadie et al., 2015). Their inclusion in the estimated counterfactual is weighted on the basis of similarity of a vector of pre-treatment response and control variables X_1 from the treatment unit $i = 1$ and a vector of response and control variables X_0 from the donor pool $i > 1$ to $i = I+1$. The control unit is thus represented as a vector of weights W, for all i from $i > 1$ to $i = I+1$. Therefore, let $W = w_{i>1}, \ldots, w_{I+1}$. Additionally, any weight w_i must be bounded between 0 and 1 with $\sum w_{i>1}, \cdots, w_{I+1} = 1$. The synthetic control is constructed from the minimisation of the difference between all the variables in the above vectors as represented in the equation $X_1 - X_0W$ (Abadie et al., 2015).

The treatment effect is calculated through a final step. Here Y_{it} is representative of the outcome observed for a given individual at a given time which is equivalent to Y_0. In this study, it is the relative organic farmland area at a given time. Conversely, $Y_1 = (Y_{T_0+1}, \ldots, Y_T)$ represents a vector of the observations of the response variable in the treatment country. It is assumed that $Y_1 = Y_0$ during the pre-treatment period and that the treatment had no effect on either Y_0 or Y_1 before the intervention was implemented. It is also assumed that the observed outcome for the units that constitute the synthetic control unit are not affected by the policy intervention applied to the unit of interest (Abadie et al., 2010). The estimated treatment effect during any time within the period T_1 between the treatment country Y_1 and the synthetic control country Y_0 is summarised in equation (2):

$$ATT = Y_{1t} - \sum_{i>1}^{I+1} w_i^* Y_{it} \tag{2}$$

3.3. Robustness tests

In the country specification robustness test, the donor pool was condensed from all 26 OECD countries to just the 18 EU member countries.[5] This was to develop insights into how the inclusion of non-EU states in the donor pool affected the results. Secondly, variable specification robustness tests were carried out, whereby different combinations of variables were tested. The results of both specification tests are presented in the Supplementary Material (Table SM2, Figs. SM1-SM4).

Further model robustness tests were carried out using the synth2 package in stata17.[6] This was done on the full 26-country dataset using the variable specification outlined in the next section (Tables 1 and 2). These tests were conducted to verify the results and to determine the confidence attributable to the predictions. “Leave-one-out” robustness checks, as suggested by Abadie et al. (2015), were employed first. These tests systematically removed members of the donor pool where $w_i > 0$ and then iteratively re-estimated the model. Comparisons between the models for the full and restricted donor countries show to what extent the predicted observations for the synthetic control are driven by events in any particular country. Leave-one-out robustness tests sacrifice some of the quality of fit but, providing that the predicted outcome is similar to that of the initial synthetic control, one can assume that the treatment effect is not biased by the countries selected for the control. This test also would provide an indication of the implications of the contaminated control group on the reliability of the detected treatment effect, with large variations in predicted calculations indicating that the contaminated control group may be driving large biases in the estimations.

A subsequent robustness test employed was the “in-space” placebo test, whereby the “true” treatment unit was iteratively substituted for a “fake” treatment unit, as outlined by Abadie et al. (2010). This was performed across all members of the donor pool that did not have a similar intervention in the same year to reduce the effect of confounding treatments on the estimated treatment significance. This was done to enable the quantification of the probability of attaining an estimated treatment effect of the magnitude obtained through the initial calculation of equation (1) in the “true” treatment country. The confidence in the estimated synthetic control would be considered unreliable if the estimation obtained a treatment effect of similar or greater size in a country where the intervention should not have an effect (Abadie et al., 2015).

4. Empirical Application

4.1. Data and descriptives

The dataset included observations covering all 19 years between 2001 and 2019 for a sufficiently large donor group, namely the 26 OECD member states previously mentioned. This yielded 494 observations for analysis. Complete sets of the response and all relevant control variables were only available within this timeframe. All data utilised in this paper takes the form of secondary data. Data covering country-level organic agricultural area was utilised for the construction of the outcome

[5] Canada, New Zealand, Norway, South Korea, Switzerland and Turkey were dropped. Latvia and Lithuania were also dropped here due to missing variables that were used in some of the other specifications tested on the EU-only dataset. See the supplementary material for further detail.

[6] The synth2 was developed by Guanpeng Yan and Qiang Chen of Shandong University. This is a wrapper for the synth package and enables the specification of placebo and robustness tests.

Table 1
Variables included in the final models and motivations supporting their inclusion.

Category	Variable	Unit	Inclusion Motivation
Land Use	Agricultural Land Area	[Ha]	– To enable the synthetic controls and treatment countries to be of comparable agricultural area. Controlling for industry size effects.
	Cropland Proportion	[0–1]	– To control for the relative focus of the agricultural sector on crop and livestock proportion which provides information on the dominant farm systems. This is also a proxy for land quality.
Agricultural, Inputs, Outputs and Investment	Number of Farm Workers	[#]	– To control for the farm labour force use intensity when combined with agricultural land area. Proxy for both labour requirements for cropping systems as well as degree of mechanization.
	Value Added (Agriculture)	[USD]	– This variable accounts for the relative profitability of the agricultural sector as it indicates the difference between the total sale value and total cost of inputs for the industry as a whole.
	Net Investment (Agriculture)	[USD]	– This variable captures the acquisition and disposal of fixed assets used for the food production process. This also accounts for changes in the value of non-produced assets, such as land quality or productivity improvements.
	Net Capital Stocks (Agriculture)	[USD]	– This captures the total value of all fixed assets used in the production process such as machinery, equipment and farm storage facilities.
Macroeconomic	Gross Domestic Product	[USD]	– To match countries on their relative economic size and trajectory. Wealthier countries would be expected to be able to invest more into organic agriculture, both in terms of policy and purchases of food products.
Demographic	Total Population	[#]	– This variable was included in the absence of consumption-based variables to control for the domestic market size for agricultural products.
	Urban Population Proportion	[0–1]	– To control for the distribution of the population, with higher proportions of rural inhabitants hypothesized to be a proxy for higher public connection to the land and local products.

Note: sources motivating the variable selection are incorporated in the text.

Table 2
Descriptive statistics of the variables included in the final model specification. Log-transformed.

Variable	Unit	Mean	SD	Min	Max
Agricultural Land Area	[Ha]	15.352	1.265	13.104	17.944
Cropland Proportion	[0–1]	0.638	0.230	0.040	0.989
Number of Farm Workers	[#]	12.341	1.254	9.965	15.906
Value Added (Agriculture)	[USD]	22.594	1.299	19.203	24.967
Net Investment (Agriculture)	[USD]	21.455	1.158	17.469	23.615
Net Capital Stocks (Agriculture)	[USD]	23.975	1.225	19.982	26.249
Gross Domestic Product	[USD]	26.532	1.463	22.557	29.012
Total Population	[#]	16.306	1.230	14.090	18.241
Urban Population Proportion	[0–1]	0.742	0.109	0.508	0.982
Number of Observations	494				

Note: All non-proportion-based variables were transformed into their natural logarithms. Data source: FAOSTAT.

variables and was extracted from the FiBL World of Organic Agriculture database (FiBL Statistics, 2023). For each organic action plan, the organic area was transformed to reflect the percentage change in organic area relative to the year of the intervention (i.e. the outcome variable equalled 0 for all observations in the year the respective intervention took place) to make a direct comparison between countries possible. Whilst other organic-specific variables were available, such as the value of organic retail sales, there were large data gaps in the panel which precluded their use in this analysis as either response or control variables. Furthermore, inclusion would lead to additional problems resulting from possible reverse causality and endogeneity of demand origin.[7] Because the focus of this paper is to isolate the supply-side impacts on the treated units alone, notwithstanding feasibility constraints, methodologically it is appropriate to leave this out. Furthermore, we include GDP and total population, with GDP per capita at least being highly correlated with food expenditure in monetary terms.

Publicly available data sources were screened via internet search to gather the available control variables into a dataset. The variable specification presented in this study was finalised on the basis of; I) variable relevance, indicated from the literature (e.g. Fuglie, 2012; Grovermann et al., 2019; Lindström et al., 2020; Mekonnen et al., 2015) and expert advice (see supplementary material), as well as II) the resulting model's ability to consistently minimise both mean squared predicted error and control bias over the four case studies. The final variables controlled for factors that impact structural development in the agricultural sector (Kirchweger and Kantelhardt, 2015; Neuenfeldt et al., 2019; van Neuss, 2019) as well as influencing the market for consumption of organic products. All control variables used in this paper originated from the FAOSTAT database (FAOSTAT, 2023). This source provided the most relevant variables with the fullest panel coverage, see Table 1 for the motivation behind including each variable. All non-proportion-based variables were transformed into their natural logarithms. See Table 2 for summary statistics of the variables used. Note that the relatively small standard deviations imply a reduced potential for the occurrence of interpolation biases.

4.2. Donor pool

The donor pool was set at the OECD level rather than the more constrained EU level to ensure an adequate number of donor units with complete and reliable observations. In defining this set, 11 of the total 38 OECD members were not included due to highly volatile organic agricultural area trends. Additionally, Luxembourg was excluded due to its relatively small size. The ability of the model to realistically estimate a counterfactual for the analysis of the treatment effect of the organic action plans would be compromised if these 12 states had been included.[8] The observed volatile trends could not feasibly be captured by the model and this and would lead to biased estimations. As outlined by Abadie et al. (2010), restricting the units in the comparison group to

[7] Reverse causality is a major endogeneity concern in econometric analysis and inclusion of factors that are suspected to cause reverse effects should be avoided. Furthermore, considering that we look at the treatment effect on the treated, to account for the demand side without introducing endogeneity into the model it would require that we only consider domestically produced products that are consumed domestically. This is not feasible in practice considering the cross-border nature of the European market for food products. To illustrate this, according to FAOSTAT for 2021, the EU as a whole produced 965 million tonnes of agricultural products. At the same time 480 million tonnes of agricultural products were exported outside of the EU and 475 million tonnes were imported into the EU.

[8] The 12 OECD countries not included in the analysis due to lack of data availability and or data concerns were: Australia, Chile, Colombia, Costa Rica, Greece, Iceland, Israel, Japan, Luxembourg, Mexico, Portugal and the United States of America. This left the remaining 26 OECD member states for use as the donor pool in this analysis. These states were Austria, Belgium, Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Ireland, Latvia, Lithuania, the Netherlands, New Zealand, Norway, Poland, Slovakia, Slovenia, Spain, South Korea, Sweden, Switzerland, Turkey and the United Kingdom. See Table 4 in the text for the different unit weights assigned to the 26 OECD countries across each model of our analysis.

countries that are more or less similar is important to reduce the scope of interpolation bias. This also reduces, but does not eliminate, omitted variable bias from missing time-invariant variables. Conceptually, the donor pool should also be free of units that experienced similar treatment. However, as is evident from Fig. 1, many countries introduced organic action plans over the studied period. Therefore, the donor pool is contaminated to a certain degree. This problem could theoretically be managed by removing all other countries where an organic action plan occurred. However, as countries similar to the EU member states are finite in number, this would require the inclusion of less-similar countries as control units. As highlighted by Abadie et al. (2003, 2010 and 2015), that would result in greater problems being induced from interpolation and omitted variable bias. Therefore, we followed the recommendation of Abadie et al. (2003, 2010 and 2015) and accepted that we could not increase the sample size which meant that the contamination had to be worked with in the construction of the synthetic controls within this study. Nevertheless, contamination was carefully managed when calculating the significance of the treatments. Furthermore, to make sure that the counterfactual predicted by the synthetic control method was appropriate to the given organic area developments, the donor unit weights were separately calibrated for each of the four cases.

5. Results

5.1. Treatment predictions

The gaps between the observed and predicted development of the relative extent of the organic area for the four cases provide an indication of the estimated treatment effects of the organic action plans (Fig. 2). The values of the relative changes over the plan periods for each case are highlighted in Table 3. The estimation for France predicts a large difference between the synthetic control relative to the observed outcome, which is 68 percentage points greater by the end of the action plan in 2012 (see Table A1 in the appendix for absolute change statistics). This corresponds approximately to an additional 397 thousand hectares of organic farmland compared to the estimated no-intervention scenario (Table A1). The Swedish model also predicts a large gap of 75 percentage points for the treatment unit over the synthetic control by the end of the action plan in 2010 (Fig. 2). This would imply an additional 169 thousand hectares of organic farmland as a result of the 2006 intervention relative to the counterfactual (Table A1).

In general, the models resulted in a very good fit for the pre-treatment organic area growth trends between the treatment and respective synthetic controls over the length of the pre-treatment period (Fig. 2). This is supported by the pre-treatment R^2 of 0.186, 0.924, 0.961 and 0.939 for the French Swedish, Czech and Austrian cases respectively. See the supplementary material for greater detail on the goodness of fit of these models. Specifically relating to France, Table SM2 and Fig. SM1 show the robustness of the treatment effect calculation under different degrees of model fit. In the French model, which we present here, the fit underperformed relative to the other French model specifications (see Table SM2), generating a relatively large mean squared predicted error of 23.825. However, the pre-treatment predicted growth of the synthetic control still matched the actual pre-treatment development in France very closely (Fig. 2, Fig. SM1 and Table SM2). The reason that the best model in each individual case from Table SM2 is not presented is because we only show the results for one model specification, specifically the one that minimised control bias across the four cases.

All country weights selected by the models provide sensible country matches and, importantly, in no instance were any of the four studied countries involved in the synthetic control of another case. For details on the variable weights calculated by the models to allocate the donor unit weights (presented in Table 4) for the construction of the synthetic controls, please consult the appendix Tables A2-A5. These tables show very high degrees of matching on observed variables when comparing the respective treatment unit with its synthetic control unit. This signifies very low degrees of control bias which fall within the range of those presented in the previous synthetic control method literature.

5.2. Robustness tests

5.2.1. Leave-One-Out robustness tests

When leave-out-one tests were run for France (Fig. 3), the test showed that the outcomes are very similar to that estimated by the initial model (red lines versus black-dashed line). However, it indicated that the treatment gap (Table 3) may be overestimated by approximately 10%. The same test for Sweden indicates a very similar result when most countries are excluded but, there are some exclusions that result in a lower estimated treatment effect.[9] However, the differences are not large during the treatment period (2006 to 2010). These tests also show that the predictions following the Czech and Austrian action plans are not heavily driven by the countries that are included in the control (Fig. 3).

5.2.2. In-Space placebo tests

In-space placebo tests allowed the assessment of treatment effect significance.[10] Right-sided $p-values$ are reported to test the null hypothesis of no positive treatment effect. The probability of having obtained a treatment effect as large as that predicted for the French organic action plan by 2012 was 0.046 which indicates that the null hypothesis of no positive treatment effect should be rejected. See Fig. 4 for a comparison of the "true" versus "fake" treatment units. In the Swedish placebo tests, the probability of having observed a post-treatment growth in the organic area as great as that of the treatment unit by 2010 was 0.040, with an unusually large treatment effect relative to the placebos (Fig. 4). The placebo test is also significant below the 5% level meaning the null hypothesis in the Swedish case can also be rejected. The right-sided $p-value$ of 0.696 calculated by the end of the Czech organic action plan in 2015 provides evidence that supports the null hypothesis of no positive treatment effect on organic area in the Czech Republic. The treatment effect is not remarkably different from most countries but the majority have a placebo effect greater than that of the Czech Republic (Fig. 4). The insignificance of the result in both directions supports the notion of no treatment effect. It was a similar story for the Austrian action plan where the right-sided $p-value$ for the probability of having a treatment effect greater than that of Austria was 0.870.

[9] This difference in predicted counterfactual is because key donor countries for the construction of the synthetic control in this case had been excluded through this robustness test. The model iterations are run using the same variable weights, which means that, while key donor countries are removed, the accuracy of the predictions is also reduced. However, the aim of the robustness test is to test how the counterfactual is affected under increasing levels of restrictions. In the case of Sweden, one leave-one-out counterfactual prediction included South Korea with a non-zero weight. However, this donor unit did not make it into the original model.

[10] In-space placebo tests refer to the fact that the placebo tests are implemented across the geographical units, by re-assigning the treatment to the units that did not receive the true treatment iteratively. This is a similar concept to placebo treatments in medical sciences, that seek to account for the bio-physical effect of a medicine on patients that received the treatment versus those that actually received no treatment, to exclude psychological confounding factors and sample selection bias. In our study, this translates to the process of testing for an effect of a country-specific organic action plan in countries that did not (or should not) have received any treatment effects from its implementation. In-time placebo tests would be rather a temporal reallocation of the true treatment rather than a spatial reallocation. However, these temporal tests were not possible to perform meaningfully in this analysis as we would have needed a longer period of data coverage before the interventions were launched.

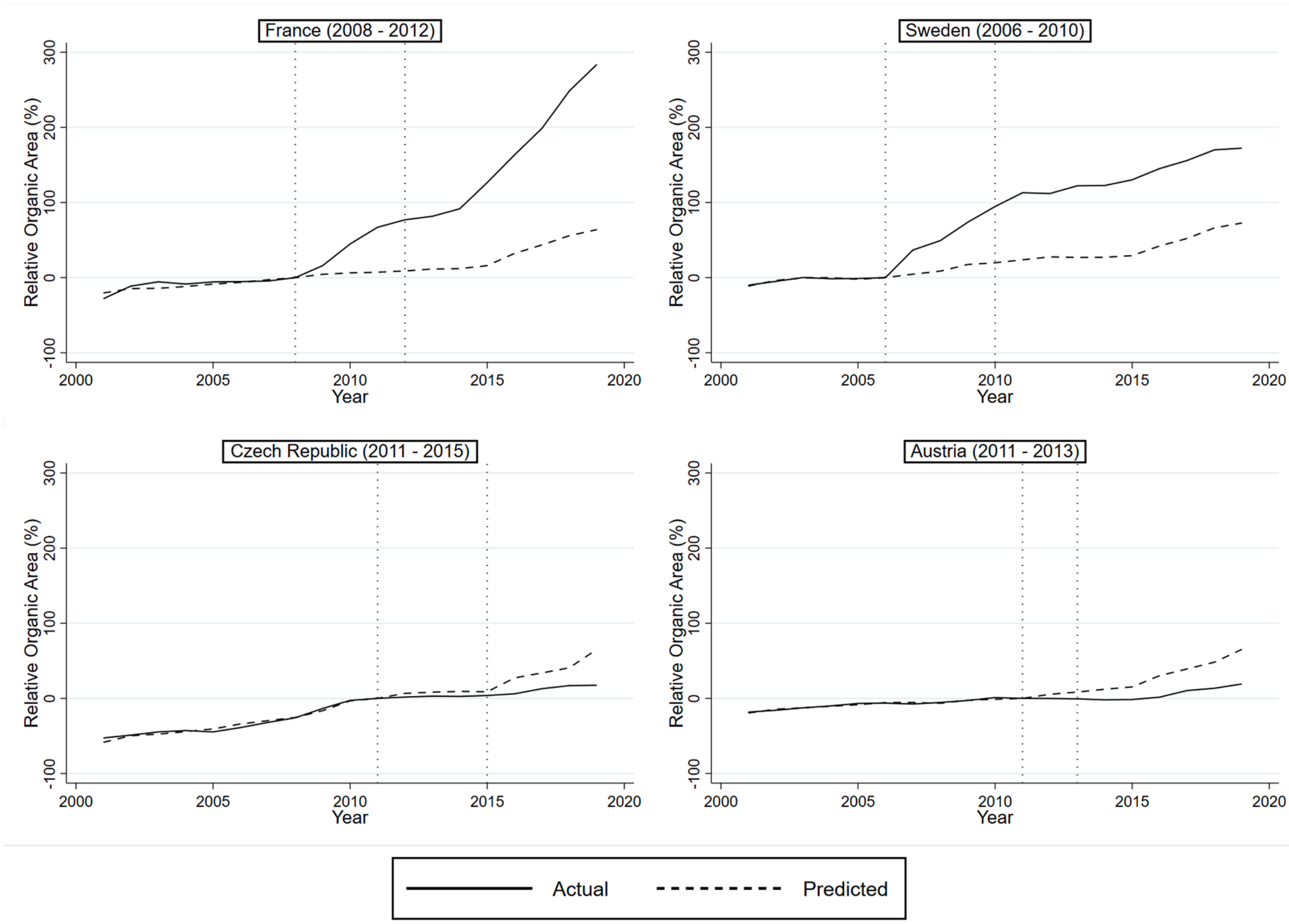

Fig. 2. Trends in organic area growth post-intervention versus the synthetic controls. See Table 3 for quantification of the relative changes presented above. Additionally, consult appendix Tables A1-A5 for a quantification of absolute area changes and the variable weights selected by the model. The donor unit weights for the construction of the synthetic control are presented in Table 4 below. Note: the gap between the two vertical dashed lines represents the running period of the organic action plans and thus the respective treatment periods considered in the analysis. The pre-treatment period refers to the graph areas left of the first vertical dashed line and the post-treatment period refers to the graph areas right of the first vertical dashed line.

6. Discussion

The results presented above provide robust estimations for both the presence of, and also the lack of, a statistically significant treatment effect resulting from the implementation of a select number of national organic action plans within the EU. These findings build on the existing qualitative literature and comprise the first rigorous econometric assessment on this topic. On that basis, one can argue with a large degree of confidence that the French and Swedish organic action plans caused an increase in the domestic organic area. This is also matched by the clear lack of robust, statistically significant evidence for any impact of the Czech and Austrian plans. Action plans have not been extensively studied quantitatively to date. Therefore, due to the research gap, it is also not possible to compare the results presented within this study to other empirical findings regarding the causal effect of organic or similar action plans on organic area growth or related outcomes. The focus of this discussion is thus on the critical assessment of the theory and methods employed, as well as the ability of this approach to identify a causal effect.

Through trials of different specifications and donor pools (see supplementary material), the treatment effects predicted across all model iterations for the French and Swedish action plans were very similar. This, at the very least, provides a reasonable confidence in the robustness of the results to changes in specification. The leave-one-out robustness checks also provide some degree of security over the reliability of the treatment effects presented and the placebo tests provide confirmation of the significance of these. The results varied more greatly across the different specification tests when the models were applied to the Czech and Austrian cases (see supplementary material), with the majority indicating a negative treatment effect. Through the placebo tests, the negative treatment effects were subsequently found to also not be significant.

In the Austrian case, a no-treatment effect, makes reasonable sense seeing as the 2011 action plan was preceded by several similar action plans (not the case in France or Sweden). This could logically result in a stagnation of growth. The findings for the Austrian case may also indicate some degree of diminishing marginal returns to the imposition of an organic action plan. In the Czech case, the apparent success of their first action plan starting in 2004 is likely highly correlated with their entry into the EU (also in 2004), and this effect had worn off by the second plan in 2011. Prior to the implementation of both the Czech and Austrian action plans, these countries already had relatively high shares of organic farmland compared to the EU average (also not the case in France and Sweden). The starting organic farmland area shares were

Table 3
Treatment effect predictions quantifying the difference between the observed and the predicted growth estimations for organic area following the implementation of the action plans by the separate synthetic control models of the four case studies. Values are relative changes.

Country	Evaluated Period	Actual Growth	Counterfactual Growth	Calculated Treatment Effect
France	2008 to 2012	177 %	109 %	68 %-points
Sweden	2006 to 2010	195 %	120 %	75 %-points
Czech Republic	2011 to 2015	104 %	109 %	−5 %-points
Austria	2011 to 2013	99 %	108 %	−9 %-points

Actual growth is the percentage difference between the organic area at the end of the evaluated period relative to the organic area at the start of the organic action plan, if the area remained the same over that period the value of this would be 100. The counterfactual growth is the trend growth that is predicted by the synthetic control for the particular case assuming no treatment. The calculated treatment effect is thus the percentage point difference between the actual growth and the counterfactual growth, i.e. the difference between the observed and predicted organic farmland areas. This percentage point difference therefore represents the share of the growth that is directly attributable to the organic action plan given our stated assumptions and in lieu of tests of significance. Please consult Table A1 in the appendix for detail on the values used to calculate the absolute area values provided in the text.

Table 4
Unit weights for the synthetic controls of the four treatment countries.

Country	Code	France	Sweden	Czech Republic	Austria
Austria	AUT	0	0	0	–
Belgium	BEL	0	0	0.202	0
Canada	CAN	0	0.081	0.016	0
Czech Republic	CZE	0	0	–	0
Denmark	DNK	0	0.214	0.105	0.151
Estonia	EST	0	0	0.144	0
Finland	FIN	0	0.249	0	0
France	FRA	–	0	0	0
Germany	DEU	0.664	0.080	0	0
Hungary	HUN	0	0	0.244	0.125
Ireland	IRL	0	0	0	0
Italy	ITA	0.131	0.058	0	0.127
Latvia	LVA	0	0	0	0
Lithuania	LTU	0	0	0.010	0
Netherlands	NLD	0.096	0	0	0
New Zealand	NZL	0	0	0	0
Norway	NOR	0	0.318	0	0
Poland	POL	0	0	0.218	0
Slovakia	SVK	0	0	0.061	0.095
Slovenia	SVN	0	0	0	0
South Korea	KOR	0	0	0	0
Spain	ESP	0	0	0	0
Sweden	SWE	0	–	0	0
Switzerland	CHE	0	0	0	0.478
Turkey	TUR	0	0	0	0.024
United Kingdom	GBR	0.109	0	0	0

13.8% and 19.7% for the Czech Republic and Austria respectively.[11] This is much lower than the shares for France and Sweden which were 2.0% and 7.2% respectively. Potentially, the lack of effect estimated by the models also indicates that the extent of organic area had already reached a critical point beyond which the imposition of an organic action plan could not conceivably result in increased farm-level adoption of organic agriculture in the Czech Republic and Austria. Whereas there was perhaps still latent capacity for organic area growth that could be initiated effectively by an action plan in France and Sweden. Additionally, the targets were much less ambitious in the Czech and Austrian plans relative to those of France and Sweden. The fact that the total Austrian organic area actually decreased by 3 thousand hectares between 2011 and 2013 (Table 3 and Table A1), could also potentially point to some other confounding situational effects that curtailed the plan. Additionally, this is likely an indication of decreasing marginal returns to action plans, whereby the repetition of plans, combined with higher organic farmland shares becomes increasingly less effective at delivering further organic farmland area growth.

A restricting factor affecting the quantitative analysis of organic action plans is that many EU members have enacted national and sub-national organic action plans, particularly throughout the time period studied. It is therefore difficult to disentangle exactly when and whether members of the donor pool have been affected by launching organic action plans at the same or similar times (refer back to Fig. 1). For instance, Ireland and Poland also initiated national action plans with area targets in 2008, at the same time as the French plan. Similar confounding treatments also occurred with the other organic action plans studied (e.g. Slovakia in 2006 and 2011). However, given the need to have a sizable donor pool to accommodate the four estimations, none of the countries with confounding treatments could be excluded from the analysis without resulting in a sub-optimal model fit for the pre-treatment period. The next best alternative was to exclude these countries from the calculation of the significance of the treatment effect during the placebo tests. Either way, assuming that the countries of non-zero-unit weights with concurrent action plans also experienced a positive or negligible effect on organic area, would imply that the estimation of the treatment effect in any given case would be negatively or unbiased by concurrent treatments. Therefore, overestimation of the treatment effects would be highly unlikely in this scenario.

A further limitation to this analysis is that organic action plans are typically not concrete policies or even concrete policy mixes, but rather softer agenda-setting tools. They are also implemented over a number of years and incorporate highly heterogenous targets and methods, please refer to the background section and selection criterion for the targets set at the start of each plan. Critically, they often build on or formalise previous policies that have been implemented prior to the action plan (Lampkin and Sanders, 2022). Their adoption effects can also be affected by wider agricultural policies which may act as push or pull factors towards organic agriculture, for example, the decoupling of subsidy payments from 2003 onwards (Jaime et al., 2016). Whilst this report provides evidence that there are some positive effects of organic action plans on the adoption of organic agriculture, it less straightforward to build insights into precisely what aspects of the plans were decisive in driving increases in organic area and why this was the case. For instance, it is highly likely that the growth seen in France from 2008 onwards was largely due to the introduction of national maintenance payments for organic farming under the action plan. These maintenance payments were implemented on top of pre-existing conversion payments as well as increases in the organic tax credit scheme (Chabé-Ferret et al., 2021; Madignier et al., 2013). This also built on the previously implemented agri-environmental scheme payments that had generated 90% of the organic area growth until that point, according to Chabé-Ferret and Subervie (2013). Yet, alterations to organic financial support are not exclusively made through action plans and the payment rates (Ha^{-1}) in France over the studied period were quite representative of, and increased in line with, those of other EU states (Lampkin and Sanders, 2022; Stolze and Lampkin, 2009).[12] This suggests that the effectiveness

[11] Calculated from FAO data, a country's own statistics may differ slightly. Shares for France and Sweden were 2.0% and 7.2% respectively.

[12] Until 2017 when France scrapped national organic maintenance payments (Lampkin and Sanders, 2022).

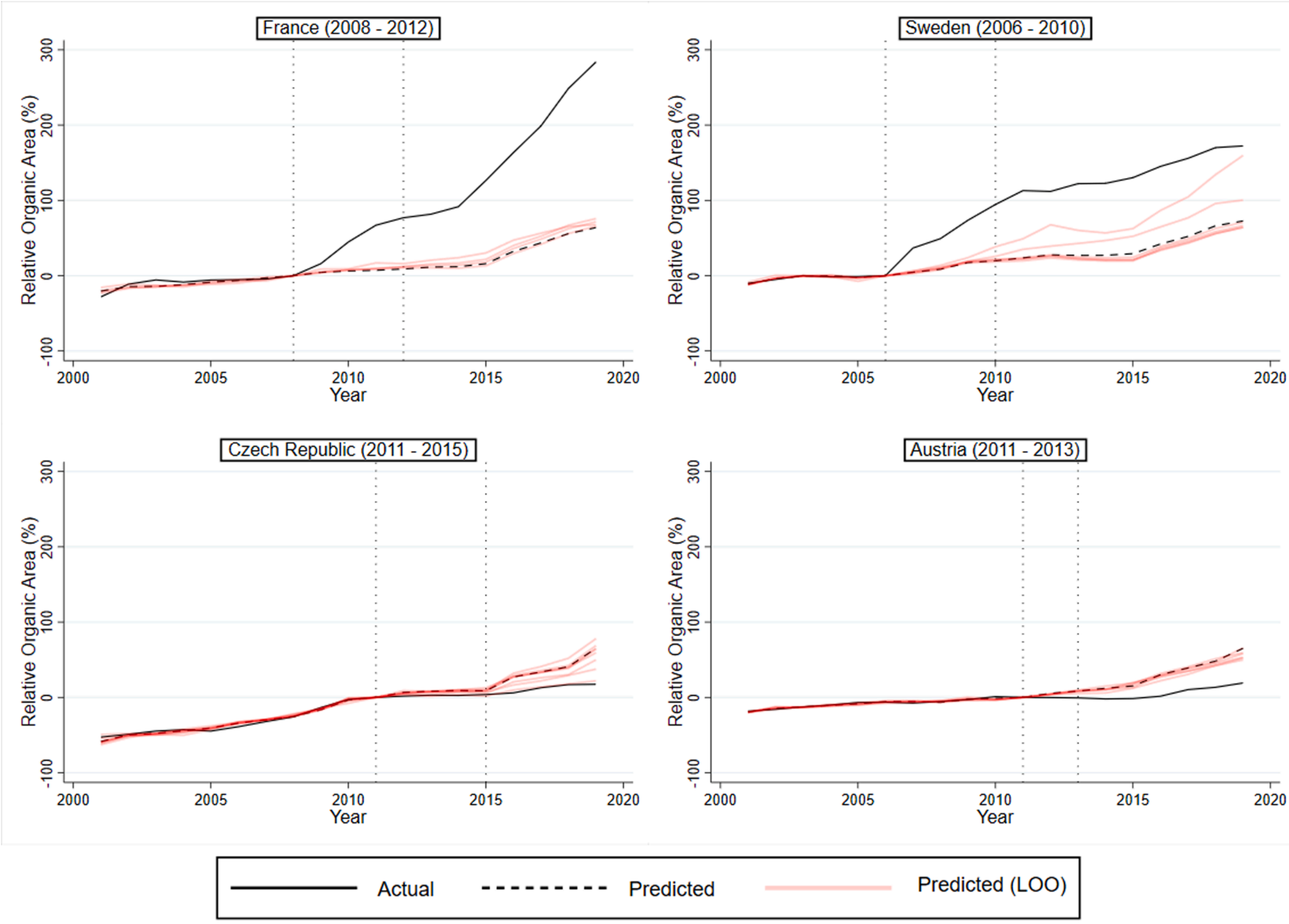

Fig. 3. Leave-one-out (LOO) robustness tests for the prediction of the non-intervention trend. See supplementary material for further detail. Note: the gap between the two vertical dashed lines represents the running period of the organic action plans and thus the respective treatment periods considered in the analysis. The pre-treatment period refers to the graph areas left of the first vertical dashed line and the post-treatment period refers to the graph areas right of the first vertical dashed line.

of support payment increases is highly context-specific and a deeper understanding of this, as well as the interactions with the demand-side elements such as public procurement, would need to be further developed through additional qualitative and mixed-method assessment of this topic in the future. Furthermore, targeted impact evaluation of the specific elements of an action plan would also contribute greatly to the current knowledge base of this topic.

7. Conclusion

This study quantifies the effect of organic policy interventions, in the form of organic action plans, on the development of the share of organic agriculture in four countries in the European Union. This is the first rigorous econometric analysis to quantitatively look at the effect of this policy mechanism in the setting of organic agriculture, which was achieved with the analysis of country case studies for France, Sweden, Czech Republic and Austria. The robustly tested results engender a high degree of confidence in the presence of a causal link between the implementation of an organic action plan and the observed increases in the organic farmland area of both France and Sweden, namely an additional 397 thousand and 169 thousand hectares (representing 68 and 75 percentage point increases) respectively. However, due to factors leading to both positive and negative bias inherent to econometric analyses relying on a quasi-experimental approach, one can quite rightly critique the magnitude of these predictions, and state that they arguably overplay the effectiveness of this policy instrument when considering it as just the sum of its parts. However, for our country-level analysis, we were constrained in our ability to decompose the plan further, in part due to the various data availability and information restrictions and given that this is a very formative quantitative analysis of organic action plans. This is a clear area for further research efforts to tackle.

This paper generates several key indications for policymakers. Firstly, the results support the argument that organic action plans can be effective at delivering growth, but can be confounded. This implies that the success of action plans can be inhibited through extenuating factors inherent in the planning, targeting and/or implementation phases of the plans. Nevertheless, it remains a realistic proposition that the initiation of a credible and financially backed organic action plan in a country where no such plan has yet been implemented is likely to positively affect the development of the organic industry in that country, particularly if organic uptake is low versus potential. Inter-governmental collaboration should be encouraged to this effect. Secondly, organic action plans may be subject to decreasing marginal returns and success could be dependent on the existing degree of organic coverage within the agricultural sector. This could signify that successive EU organic action plans based on similar sets of interventions may have a reduced leverage ability for the scaling of organic agriculture. Therefore, more wide-reaching measures and incentives for adoption by farmers, and for changes in consumer behaviour, may be required to meet the 25% target of farmland area to be farmed organically by 2030.

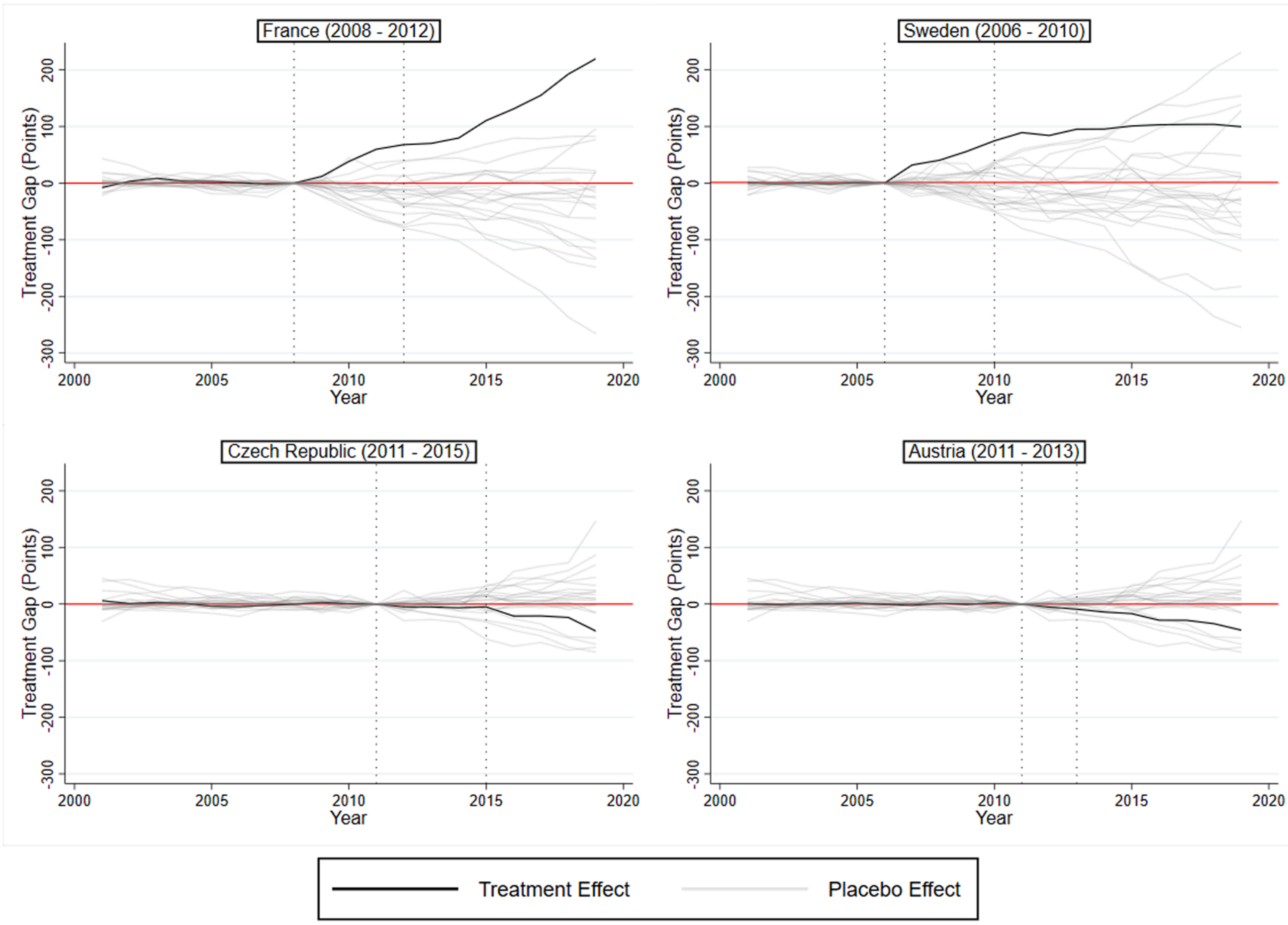

Fig. 4. Post-treatment gaps between actual and placebo treatment units. See supplementary material for details on calculated probabilities. Note: the red line represents zero-treatment effect. The gap between the two vertical dashed lines represents the running period of the organic action plans and thus the respective treatment periods considered in the analysis. The pre-treatment period refers to the graph areas left of the first vertical dashed line and the post-treatment period refers to the graph areas right of the first vertical dashed line.

Our analysis has implications for further research. It would be pertinent here to re-emphasise that the effectiveness of organic action plans is clearly very context-specific. The performance will be highly related to the contents, targets, financial means and political backing underpinning the plan. Thus, additional studies and systematic assessments of policies to foster organic agriculture are needed to improve our understanding of exactly which type of interventions are most promising. Moreover, future research shall strive to assess a wider range of success measures, i.e. go beyond the share of organic farming. Finally, future research shall address the heterogenous nature of action plans and their effects by using a combination of qualitative and quantitative methods.

CRediT authorship contribution statement

Charles Rees: Conceptualization, Methodology, Software, Validation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Christian Grovermann:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Robert Finger:** Conceptualization, Methodology, Supervision, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Table A1
Treatment effects for actual versus synthetic organic area estimations following the implementation of the action plans. Statistics in absolute terms.

Country	Actual Pre-Treatment Area (1000 ha)	Actual Post-Treatment Area (1000 ha)	Counterfactual Post-Treatment Area (1000 ha)	Δ Actual Pre and Actual Post Treatment Area (1000 ha)	Δ Actual and Counterfactual Post Treatment Area (1000 ha)
France	583.799	1032.941	635.821	449.142	397.119
Sweden	225.431	438.693	270.060	213.262	168.633
Czech Republic	460.498	478.033	500.931	17.535	−22.898
Austria	562.247	558.623	609.436	−3.624	−50.814

Note: the sum of all unit weights for any given synthetic control must add up to one. A weight of zero indicates that the given donor unit was not selected by the model to construct the synthetic control of the four respective treatment units. The treatment unit cannot, by default, be included in a synthetic control for itself. Please consult Tables A2-A5 for the variable weights that were calculated by the model in order to assign these unit weights. In these tables, it is also possible to see the degree of matching on the value of all variables in the model between the actual treatment unit and its respective synthetic control calculated by the unit weights in this table.

Table A2
Organic area growth predictors before the implementation of the French Organic Action Plan in 2008.

Covariate	Unit	Variable Weight	Value Treated	Value Synthetic	Control Bias
Agricultural Land Area	[ln(Ha)]	0.001	17.199	16.423	−4.510%
Cropland Proportion	[0–1]	0.026	0.661	0.653	−1.190%
Number of Farm Workers	[ln(#)]	0.000	13.765	13.488	−2.010%
Value Added (Agriculture)	[ln(USD)]	0.016	24.277	23.794	−1.990%
Net Investment (Agriculture)	[ln(USD)]	0.067	23.139	22.740	−1.730%
Net Capital Stocks (Agriculture)	[ln(USD)]	0.647	25.473	25.477	0.020%
Gross Domestic Product	[ln(USD)]	0.039	28.300	28.376	0.270%
Total Population	[ln(#)]	0.117	17.921	17.984	0.350%
Urban Population Proportion	[0–1]	0.087	0.772	0.758	−1.810%

Table A3
Organic area growth predictors before the implementation of the Swedish Organic Action Plan in 2006.

Covariate	Unit	Variable Weight	Value Treated	Value Synthetic	Control Bias
Agricultural Land Area	[ln(Ha)]	0.325	14.958	14.958	0.000%
Cropland Proportion	[0–1]	0.208	0.850	0.848	−0.190%
Number of Farm Workers	[ln(#)]	0.014	11.593	11.902	2.670%
Value Added (Agriculture)	[ln(USD)]	0.224	22.432	22.415	−0.080%
Net Investment (Agriculture)	[ln(USD)]	0.006	21.431	21.310	−0.560%
Net Capital Stocks (Agriculture)	[ln(USD)]	0.001	24.053	24.018	−0.150%
Gross Domestic Product	[ln(USD)]	0.222	26.486	26.469	−0.060%
Total Population	[ln(#)]	0.000	16.008	15.938	−0.440%
Urban Population Proportion	[0–1]	0.000	0.842	0.799	−5.130%

Table A4
Organic area growth predictors before the implementation of the Czech Organic Action Plan in 2011.

Covariate	Unit	Variable Weight	Value Treated	Value Synthetic	Control Bias
Agricultural Land Area	[ln(Ha)]	0.049	15.113	15.113	0.000%
Cropland Proportion	[0–1]	0.291	0.754	0.754	0.000%
Number of Farm Workers	[ln(#)]	0.091	12.139	12.139	0.000%
Value Added (Agriculture)	[ln(USD)]	0.218	21.846	21.848	0.010%
Net Investment (Agriculture)	[ln(USD)]	0.000	20.646	20.739	0.450%
Net Capital Stocks (Agriculture)	[ln(USD)]	0.000	23.020	23.201	0.790%
Gross Domestic Product	[ln(USD)]	0.122	25.662	25.664	0.010%
Total Population	[ln(#)]	0.000	16.151	16.043	−0.670%
Urban Population Proportion	[0–1]	0.229	0.736	0.736	0.030%

Table A5
Organic area growth predictors before the implementation of the Austrian Organic Action Plan in 2011.

Covariate	Unit	Variable Weight	Value Treated	Value Synthetic	Control Bias
Agricultural Land Area	[ln(Ha)]	0.183	14.862	14.888	0.180%
Cropland Proportion	[0–1]	0.000	0.507	0.540	6.370%
Number of Farm Workers	[ln(#)]	0.034	12.232	12.161	−0.580%
Value Added (Agriculture)	[ln(USD)]	0.130	22.193	22.225	0.150%
Net Investment (Agriculture)	[ln(USD)]	0.014	21.540	21.194	−1.610%
Net Capital Stocks (Agriculture)	[ln(USD)]	0.392	24.434	24.408	−0.110%
Gross Domestic Product	[ln(USD)]	0.247	26.472	26.521	0.190%
Total Population	[ln(#)]	0.000	15.927	16.098	1.070%
Urban Population Proportion	[0–1]	0.000	0.587	0.722	22.990%

Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodpol.2023.102531.

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