What will be the budgetary cost for reaching Green Deal´s organic target? A farm level approach

Dimitrios Kremmydas[1], Pavel Ciaian[1], Edoardo Baldoni[1], Pascal Tillie[1], Giorgos N. Diakoulakis[2], Athanasios Kampas[2]

[1]European Commission, Joint Research Centre (JRC), Seville, Spain
[2]Department of Agricultural Economics and Rural Development, Agricultural University of Athens, Greece

Keywords
Organic farming; CAP; conversion incentive; farm model; IFM-CAP

Abstract

Under the Green Deal, the European Commission (EC) has set a target of 25% of the EU's agricultural land to be cultivated organically. The literature indicates that this target is challenging to reach in the current budgetary framework. We use the IFM-CAP model and a utility-based framework to estimate the required monetary incentive for a farm to convert into organic. Then we use simulations to estimate the budgetary cost to reach the organic target in the EU level. Our results show that in order to reach the 25% organic target, a substantial budget increase is required. This increase requires budgetary transfers from other CAP interventions, and thus more research is required on the cost effectiveness of the organic target regarding the environmental benefits in relation to other interventions.

Introduction

Under the Green Deal, the European Commission (EC) has set a target of 25% of the EU's agricultural land to be cultivated organically to transform the EU to a climate-neutral zone (Montanarella & Panagos, 2021). The rationale behind such a commitment lies in the premise that organic farming is considered environmentally friendly (Boone et al., 2019) and produces fewer greenhouse gases (Meemken & Qaim, 2018).

However, the literature indicates that this target is challenging to reach in the current budgetary framework. For example, the IFOAM report (IFOAM Europe, 2021) predicts that in 2030, only 15% of the utilized agricultural area will be organic. Similarly, Kowalska & Bieniek (2022) and Mowlds (2020) estimate, respectively, that 10.3% and 10.6% of UAA will be organic by 2030. Additionally, in an EC public consultation[1], 76% of the respondents answered that the current budget provides insufficient financial incentives for producers to convert to organic production.

Therefore, a crucial question refers to the different policy mix and the likely cost necessary to accomplish the 25% organic target. Presumably, the cost appraisal of achieving such a target is highly

[1] Public consultation of the European Commission regarding its Action Plan for the Development of the Organic Production, Accessible on https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021SC0065

relevant to policymakers. Accordingly, the main focus of this paper is to assess the (financial) transfers to farmers, necessary to induce the organic conversion.

Unfortunately, the literature on this subject is relatively thin and not directly relevant to the scope of our paper. The limited related research on the scholarly literature almost exclusively examines the effectiveness of subsidies as a means to organic conversion. Pietola & Lansink (2001) examined the relevance of land subsidies and found that such policy schemes are prone to adverse selection since they appeal to low-performance farms. Jaime et al. (2016) stress the beneficial role of decoupling on the uptake of organic farming. In another context, Kuminoff & Wossink (2010) found that the low rates of organic farming in US agriculture can be explained by the sizeable sunk costs required for conversion and combined with the uncertainty of future returns.

The only remotely related previous research to our paper is by Saint-Cyr (2022), who argues that farm heterogeneity determines the efficacy of conversion subsidies. In line with that, our paper exploits the farm heterogeneity present in the IFM-CAP farm-level model (Kremmydas et al., 2022) and examines the conversion issue using mathematical programming. In addition, our modelling approach explicitly addresses that farmers' decision-making includes economic and non-economic elements.

The remaining of this paper is organized as: In the next section, we describe the utility-based theoretical framework, the empirical application with the IFM-CAP model and the data we used. We then present the results of the estimations of the minimum conversion incentive and the required CAP budget for reaching the 25% target. We close the paper with a discussion on our methodology and the policy implications.

Materials and Methods

Our method uses a utility-based framework to estimate the required monetary incentive for a farm to convert into organic. Our approach distinguishes observed and an unobserved part in the decision process . The observed part equals the estimated change in profit from the IFM-CAP model, i.e. the profit of a conventional farm minus the profit if that farm converts to organic. This estimated change in profit, combined with the status of the farm (conventional or organic), provides us with the upper and lower limits of the unobserved part. Using those limits and a bootstrapping method, we get an estimate of the value of the unobserved part of individual conventional farms, which in turn allows us to estimate the monetary compensation required to induce conversion. The last step is to simulate a stepwise increase in organic payments across the EU. More and more farms will convert as the payment level exceeds their monetary compensation for conversion. At some point, the area of the converted farms will reach the 25% target. The sum of the monetary compensation of the converted farms provides us with the budget requirements.

Theoretical framework

This section describes the farmers' decision making process regarding the adoption of organic farming. Recent advancements from socio-psychological research indicate that individuals' prosocial behavior may deviate from the economic rationality prescription. For instance, theories such the Theory of

Planned Behavior (Ajzen, 1991), the Norm Activation Model (NAM, Schwartz, 1977) and the Value-Belief-Norm Theory (VBN, Stern et al., 1999) have successfully managed to explain such deviations in consumers' pro-environmental choices.

Similar research exists in the domain of producers' behavior, especially in the case of farmers. For instance, Howley (2015) suggests that the influence of non-economic benefits to farmers' behavior is significant and most importantly, that such type of benefits may make the less financial rewarding farming activities more attractive. Furthermore, Gholamrezai et al. (2021) test the influence of personal and social norms, and the perceived behavioral control on farmers' behavior. They conclude, inter alia, that social norms have the strongest impact and farmers' pro-environmental behavior. The latter can be associated with their dependence on the rural community and the tendency towards behaviors that are consistent with other farmers. Finally, Rezaei et al. (2019) integrate the TPB and NAM to examine the drivers of farmers' intentions. They found that the influence of constructs like subjective social norms is positive but indirect.

The implication from this strand of literature is that farmers may well be utility maximizing agents as opposed to profit-maximizing ones. Specifically, farmers may evaluate not only the economic outcome of their choices (i.e., profits), but also how this outcome is obtained (i.e., whether production uses environmentally friendly practices, etc.). Such a type of reasoning bears close resemblance with the concept of the procedural utility (Frey et al., 2004), which can generally be expressed with the following additive separable linear form:[2]

$$u_i(\cdot) = a\Pi_i + bV_i \tag{1}$$

where $u_i$is farmer's utility from agricultural production, $i = \{conv: conventional, org: organic\}$ refers to the available production technology, $\Pi_i \geq 0$ are farmer's economic outcome (i.e., profits) and $V_i \geq 0$ is a 'psychological utility' that reflects the cumulative non-economic benefit (e.g., satisfaction) associated with the adoption of the i production technology, defined as:

$$V_i = \sum_{k=1}^{K} v_{i,k} \tag{2}$$

where $v_{i,k} \geq 0$ refers to the valuation of a particular farming system's attribution. For instance, $K = \{environmental\ impact, level\ of\ effort, social\ approval, transaction\ costs, \dots\}$. Hence, a $v_{org,env} \geq 0$ may refer to the satisfaction the farmer receives by contributing to the environmental quality through the adoption of an organic farming system. Likewise, a $v_{con,effort} \geq 0$ may capture farmer's perceived behavioral control (Ajzen, 1991) associated with conventional farming. Specifically,

[2] Note that a more realistic assumption would have been of $u_i(\cdot) = \Pi_i^a V_i^b$. However, research indicates that linear forms is a satisfactory approximation of individuals' utility.

a high $v_{con,effort}$ indicates that conventional farming is a relatively "effortless" activity and so, the farmer receives a strong satisfaction of producing her goods conventionally due to the low effort exerted.

Esposti (2022) uses a similar approach of modeling farmers' utility. However, our formulation differs in two aspects. First, we explicitly define the value of V_i (see, (2)). Second, we introduce two parameters, $a > 0$, $b \geq 0$, that reflect farmer's preferences (i.e., the importance) of each utility component. Specifically, an $a > b$ means that a farmer ranks higher the economic outcome of her farming choices (i.e., profitability). On the contrary, $a < b$ means that a farmer cares more for the satisfaction derived from that the adoption of specific farming system. Thus, Esposti's analysis (Esposti, 2022) is a special case where $a = b = 1$, indicating that a farmer is indifferent between the economic and non-economic outcomes of her farming choices.

Now, let's assume that a social planner wants to facilitate the adoption of organic farming. To do so, the social planner offers a land subsidy, $S \geq 0$. Hence, farmer's profit from organic production can be defined as:

$$\Pi_{org} = \Pi_{org}(0) + S \tag{3}$$

where $\Pi_{org}(0)$ refers to the profits of organic farming prior to the introduction of the organic subsidy. In such a setup, (1) – (3) point that organic production strictly dominates conventional one if and only if:

$$a\Pi_{org}(0) + aS + bV_{org} > a\Pi_{con} + bV_{con} \tag{4a}$$

$$aS > a\Pi_{con} - a\Pi_{org}(0) + bV_{con} - bV_{org} \tag{4b}$$

$$S > \left[\Pi_{con} - \Pi_{org}(0)\right] + \left[(b/a)V_{con} - (b/a)V_{org}\right] \tag{4c}$$

and consequently, the social planner should offer a land subsidy:

$$S > \Delta\Pi + \rho\Delta V \tag{5}$$

Where, $\Delta\Pi = \Pi_{con} - \Pi_{org}(0)$, $\Delta V = \sum_{k=1}^{N}\left(v_{con,k} - v_{org,k}\right)$ and $\rho = (b/a)$.

In words, (5) states that the land subsidy been offered should cover farmer's opportunity cost, comprising by the profit differential (i.e., $\Delta\Pi$) plus a 'satisfaction differential' (i.e., ΔV) between conventional and organic farming. Importantly, one should note that the sign of both $\Delta\Pi$ and ΔV are unambiguous. Thus, by using (5) we can define the following thresholds that induce the adoption of organic farming for a given preference ratio, $\rho > 0$:

$$S^{++} = \min\{S | S > \Delta\Pi + \rho\Delta V, \text{given that } \Delta\Pi, \Delta V > 0\}$$

$$S^{\pm} = \min\{S | S > \Delta\Pi + \rho\Delta V, \text{given that } \Delta\Pi > 0 \text{ and } \Delta V < 0\}$$

$$S^{\mp} = \min\{S | S > \Delta\Pi + \rho\Delta V, \text{given that } \Delta\Pi < 0 \text{ and } \Delta V > 0\}$$

Hence, the following table illustrates the value of S that induces organic farming:

Scenario	$\Delta\Pi$	ΔV	S
(I)	$(+)$	$(+)$	$S \geq S^{++}$
(II)	$(+)$	$(-)$	$S^{\pm} \leq S < S^{++}$ or $S = 0$ if $\|\Delta V\| \gg 0$
(III)	$(-)$	$(+)$	$S^{\mp} \leq S < S^{++}$ or $S = 0$ if $\|\Delta\Pi\| \gg 0$
(IV)	$(-)$	$(-)$	$S = 0$

Scenarios (I) and (IV) are quite straightforward. Specifically, in scenario (I) both $\Delta\Pi < 0$ and $\Delta V < 0$ indicate that organic farming is beneficial both from an economic and non-economic point of view. Since the provision of land subsidy is costly to the social planner, she has an incentive to offer nothing. In scenario (IV), $\Delta\Pi > 0$ and $\Delta V > 0$, so if the social planner does not offer an incentive equal or greater than to $(\Delta\Pi + \Delta V) > 0$, no conversion will take place.

Scenarios (II) and (III) are more complex and they indicate that the social planner should offer at least something, but less than in the case (I). Few observations are worth mentioning. First, one can easily observe that $S^{\pm}, S^{\mp} < S^{++}$. The reason is that a $\Delta V < 0$ (resp. a $\Delta\Pi < 0$) implies that the satisfaction (resp. the profits) that the farmer receives from organic farming can reduce farmer's opportunity cost associated with the transition from conventional to organic farming and so the farmer will require a lower compensation. However, $S^{\pm} \gtreqless S^{\mp}$. Specifically, we can show (see Appendix for the proof) that if $\rho \geq \rho^{*}$, then $S^{\pm} \leq S^{\mp}$. In other words, if the preference ratio is above a threshold, we might observe an 'paradoxical' situation where the profitability of organic farming exceeds that of conventional one, but the farmer still requires a high land subsidy in order to switch from conventional to organic production.

Second, it is straightforward that $(\partial S^{\pm}/\partial\rho) < 0$. Thus, as the preference ratio increases, the value of $S^{\pm}$ approaches to zero, whereas if ρ decreases, then it approaches the value of S^{++}. The policy implication is that given that $\Delta\Pi > 0$ and $\Delta V < 0$, farmers who exhibit a more profit-oriented behavior (i.e., low ρ) will require a higher compensation than those who exhibit stronger non-profit preferences. Consequently, a horizontal subsidy scheme would lead to overcompensation. Hence, it might be of interest to a social planner to offer a menu of land subsidies that take into account both monetary and non-monetary preferences as well.

The empirical application with the IFM-CAP farm model

The IFM-CAP model is a static positive mathematical programming (PMP) model which solves a set of microeconomic models reproducing the behavior of individual farms. The model assumes that farmers maximize their expected utility of income subject to technical and policy constraints related to resource endowments, production relationships, and CAP policy. IFM-CAP models all Farm Accountancy Data Network (FADN) individual farms (81,107 farms for 2017) across 27 Member States (MS). Its calibration against the 2017 FADN data is performed with the PMP approach. The calibration can be concisely described as the recovery of some unknown parameters (an implicit quadratic cost function) for each individual farm so that: (i) the farm replicates its 2017 observed activity levels; and (ii) when all farms are pooled together, the resulting aggregate (regional) price supply elasticity approximates a set of supply elasticity priors. The IFM-CAP model has been used in various past studies for ex-ante CAP policy assessments at the EU level (European Commission., 2018; Louhichi et al., 2017, 2018; Petsakos et al., 2022).

The modeling of the conversion to organic agriculture, require a modified IFM-CAP to account for the differences in organic and conventional farms' performance and management practices. Organic and conventional farms have a different objective function coefficient vectors, representing the differences in output prices, yields, and unit costs. Also, the organic farms have additional technical constraints. These represent the farm practices specific to organic farming, like crop rotation, nitrogen management, stocking density, and livestock feeding practices. More details regarding the modification of the IFM-CAP model to account for organic farming is provided in Kremmydas et al. (2023).

).

Table 1. A summary of the adjustment of the IFM-CAP to model organic farming

	Parametrization	**Applied approach**
Farm performance parameters	Output price and yield differences between organic and conventional crops and livestock	Log-linear econometric estimation for main crops; taken from literature for minor crops
Farm performance parameters	Price differences between organic and conventional livestock feeds	Equal to the estimated organic crop prices
Farm performance parameters	Variable cost differences between organic and conventional crop production	Linear econometric estimation
Farm performance parameters	Feed efficiency difference between organic and conventional livestock system	Taken from literature
Technical constraints	Crop rotation	Flexibility constraint based on statistical estimations
Technical constraints	Nitrogen management	Flexibility constraint based on statistical estimations
Technical constraints	Maximum stocking density	As given in the EU regulation*
Technical constraints	Feed self-sufficiency	As given in the EU regulation*
Technical constraints	Minimum share of fodder in diet	As given in the EU regulation*

Note: * EU regulation 848/2018

The first step to estimate the required economic incentive of conversion is to utilize the IFM-CAP model to calculate the impact on farm profits[3]. The expected change in profit equals

$$\Delta\Pi_i'(\mathrm{S}') = \Pi_{i,org}'(0) - \Pi_{i,conv}' + \mathrm{S}' \tag{6}$$

where i is a conventional farm, $\Pi_{i,conv}'$ is its profit in its current conventional status, and $\Pi_{i,org}'(0)$ its profit when it is simulated with IFM-CAP as organic without considering organic subsidies. S' is the current level of organic subsidies.

In equation 6, $\Delta\Pi_i'(S')$ includes the profit c that we model in IFM-CAP. However, we do not model the additional labour requirements of organic crops and the required investments for conversion, for example, new machinery or certification costs. For this, in the monetary part of the utility function, we need to add a term related to the unknown to us component of profit change. Considering also those, the change in utility related to the conversion decision of farm i can be expressed as:

$$\Delta U = \Delta\Pi_i'(\mathrm{S}') + \Delta\Pi_{i,\mathrm{unknown}} + \rho_i \Delta V_i \tag{7}$$

where i is a conventional farm, $\Delta\Pi_{i,unknown}$ refers to the economic components of the conversion decision that are unobserved in IFM-CAP (e.g., investment costs, perceived effort to convert,), ΔV_i refers to the non-economic component (e.g., pro-environmental attitude, etc.) and ρ_i is the preference of the farm in relation to the monetary and non-monetary components.

Setting $\varepsilon_i = \Delta\Pi_{i,\mathrm{unknown}} + \rho_i \Delta V_i$, we get the expected change in utility for farm i

$$\Delta U = \Delta\Pi_i'(\mathrm{S}') + \varepsilon_i \tag{8}$$

where, $\Delta\Pi_i'(S')$ is the change in profit that the model can capture and ε_i (epsilon) is the utility part that is unobservable by the model.

The second step is to assume that farmers are rational with their conversion decision. That means that we assume that they strictly prefer organic production to conventional one if and only if the utility associated with organic production exceeds the utility associated with conventional production. We also assume that for the currently observed conventional farms, the current level of organic payment S' is not enough for them to convert. Thus, in line with equation (7), in order for a conventional farm to convert, a policy maker would need to offer a payment S'', greater than the current organic payment S' that should compensate for the observed and non-observed decline in utility. We represent this minimum value of the conversion incentive with S_i^*, and we name it as the minimum incentive of conversion. Since the incentive refers to a conventional farm, the change in utility will be negative, and for this, the minimum incentive should be the opposite of this change.

$$S'' > S' > S_i^* \equiv -(\Delta\Pi_i'(\mathrm{S}') + \varepsilon_i) \tag{9}$$

[3] Practically, for each conventional farm we run a 'what-if the farm was organic' scenario. We do so by applying the changes of Table 1, i.e., changes in farm's coefficients and adding the organic related technical constraints. This allows to get estimates for the changes on the income and the profitability of the farm in the case that it converts to organic.

The value of ε_i is unknown as it captures the non-modelled economic components and the non-economic ones, like potential transaction costs and farmers' behavioural characteristics. However, we need to estimate its value before S_i^* can be determined.

The main challenge for estimating ε_i is the need for information on an EU-wide scale on (i) which non-economic attributes farmers consider when they determine conversion to organic and (ii) how they value these attributes. Unfortunately, this type of information is not available in the EU scale.

On the other hand, the information on the status of the farm is both readily available and sufficient to provide us with bounds on the unobserved costs of conversion (ε_i) of the farm[4]. This leads us on the third step, of computing the upper and lower bounds of ε_i. More specifically:

- For a conventional farm f_1, we can get an estimate of the ε maximum value. Since the farm is currently conventional, the decision to convert to organic lead to a negative change in utility:

$$\Delta\Pi'_{f_1}(\mathrm{S}') + \varepsilon_{f_1} < 0$$

$$\varepsilon_{f_1} < -\Delta\Pi'_{f_1}(\mathrm{S}')$$

$$\varepsilon_{f_1} < \varepsilon_{f_1}^{max} \equiv -\Delta\Pi'_{f_1}(\mathrm{S}') \tag{10}$$

- For an organic farm f_2, we can get an estimate of the ε maximum value. Since the farm is organic, the conversion decision, lead to a positive change in utility:

$$\Delta\Pi'_{f_2}(\mathrm{S}') + \varepsilon_{f_2} > 0$$

$$\varepsilon_{f_2} > -\Delta\Pi'_{f_2}(\mathrm{S}')$$

$$\varepsilon_{f_2} > \varepsilon_{f_2}^{min} \equiv -\Delta\Pi'_{f_2}(\mathrm{S}') \tag{11}$$

We utilize the above information on the maximum ε of conventional farms and the minimum ε of the organic ones with the help of an extra assumption. We assume that the distribution of the unknown minimum ε of the conventional farms will follow that of the organic ones (already known).

$$P_{conv}\left(\varepsilon^{min}\right) \sim P_{org}\left(\varepsilon^{min}\right) \tag{12}$$

where $P(\cdot)$ are empirical distributions.

That assumption allows us to get an estimator of the minimum ε for a specific conventional farm f_1. The estimator is retrieved by bootstrapping a distribution of the minimum ε of organic farms that contains only ε^{min} that are lower than the maximum ε of the farm ($\varepsilon_{f_1}^{max}$):

$$\hat{\varepsilon}_{f_1}^{min} \sim P^*\left(\varepsilon_{org}^{min} \mid \varepsilon_{org}^{min} \leq \varepsilon_{f_1}^{max}\right) \tag{13}$$

For getting the ε_{org}^{min} distribution, we set up a simple accounting model that calculates the $\Delta\Pi'_{f_2}(S')$ of each of the 5200 current FADN organic farms. The accounting model uses the yield, price and cost

[4] For brevity and simplicity, we assume that farmers exhibit the same economic and non-economic preferences, i.e., $\rho = 1$. However, in the discussion section we deal with the implications of this assumption.

changes we used in the simulation for the conversion process. However, this time we use it to model the change from an organic farm to a conventional one. For example, suppose a reduction of 50% of fertilizer cost in the simulation for farms that convert from conventional to organic. Then, in the accounting model, when the organic farm converts back to conventional, there will be an increase of 50% in the fertilizer costs.

Thus, for a conventional farm f_1, we get an estimate of the minimum and maximum value of the non-observed utility related to the conversion decision

$$\varepsilon_{f_1}^{max} > \hat{\varepsilon}_{f1} > \hat{\varepsilon}_{f_1}^{min} \tag{14}$$

The next step on the estimation of the economic incentive is to utilize the bounds computed before, to get a point estimate for $\hat{\varepsilon}_{f1}$. In order to do so, we run a calibration procedure f, with $\varepsilon_{f_1}^{max}$, $\hat{\varepsilon}_{f_1}^{min}$ and a fitness function θ as inputs and $\hat{\varepsilon}_{f1}$ as output. We provide more details on the calibration procedure and the fitness function in the appendix.

$$\hat{\varepsilon}_{f1} = f\{\varepsilon_{f_1}^{max}, \hat{\varepsilon}_{f_1}^{min}, \theta\} \tag{15}$$

Finally, using the estimate $\hat{\varepsilon}_{f1}$ we can also get an estimate of the minimum incentive for conversion the farm f_1, S_i^*. From equation 8, and by replacing with the estimates:

$$S_i^* \equiv -\left(\Delta\Pi'_{f_1}(\mathrm{S}') + \hat{\varepsilon}_{f1}\right) \tag{16}$$

Any payment S'', that is greater than S_i^*, will make the farm to convert.

Data

Apart from the farms in the FADN database, the other data required is the current level of organic payment S' for each farm. However, the organic payments in the farm level are not readily available neither in the FADN data nor in any other database. This is because the level of payment[5] differs across Member States (MS), and even within MS, they vary by crop and sometimes by intensity level. Therefore, for the conventional farms, there is no direct information on the potential level of organic payment they will get if they convert.

Thus, to estimate the level of organic payment at the farm level, we use the following OLS regression on the FADN 2017 database.

$$\begin{aligned} P_i = b_{annual} \cdot X_{i,annual} \cdot MS_i + b_{hort} \cdot X_{i,hort} \cdot MS_i + \\ b_{perm} \cdot X_{i,perm} \cdot MS_i + b_{grass} \cdot X_{i,grass} \cdot MS_i + u_i \end{aligned} \tag{17}$$

[5] We can consider two types of organic payments: conversion and maintenance. The first one is paid for the first three to five years and compensates a farmer for the increased costs due to the adoption of organic practices and the inability to sell the products as organic since certification is lacking. The second payment is due after the conversion payments end and the farm is certified organic. Therefore, we use the maintenance payment as a fair proxy for the payments a farmer perceives he will receive after conversion.

where P_i is the level of organic payments at the farm level and $X_{i,annual}$, $X_{i,hort}$, $X_{i,perm}$, $X_{i,grass}$ is the area of annual crops, horticulture crops, permanent crops and grassland respectively at the farm level. MS_i is a dummy variable of the member state, and u_i is an error term that abides by the multiple OLS assumptions. Due to the interaction terms, the coefficients b_{annual}, b_{hort}, b_{perm}, b_{grass} provide the average payment level per hectare to each crop category (annual, horticulture, permanent and grassland) at the member state level. The regression provided an R^2 of over 95%, and most of the organic payment per hectare estimators were statistically significant (the OLS results are given in the supplementary material, part S2). For the cases where we have a non-statistically significant estimation, we use an average value from a recent IFOAM report (IFOAM Europe, 2021). Table 2 presents the payments used by crop group and member state.

Table 2. Organic payments from FADN estimations and from the IFOAM report

NUTS0	ANNUAL	PERMANENT	HORTICULTURE	GRASSLAND
AT	344	731	784	163
BE	52	0	0	94
BG	173	495	344	173*
CY	380*	825*	600*	450*
CZ	185	561	525*	74
DE	226	559	503	143
DK	125	529	150*	119
EE	130	239	405*	59
EL	286	514	550*	322*
ES	36	219	801*	40
FI	192	0	600*	92
FR	135	250	244	76
HR	186	554	481*	105
HU	117	780	514	116*
IE	100*	115*	110*	93
IT	154	479	894	49
LT	161	218	758	154
LU	192	518*	506*	152
LV	110	485*	399*	92
MT	555*	555*	555*	0
NL	0	0	0	0
PL	165	323	307*	77
PT	65	343	360*	46
RO	220	461*	391*	101*
SE	123	708*	472*	55
SI	326*	545*	600*	142

Notes:
- Asterisk (*) denotes that the value is from the recent IFOAM report (IFOAM Europe, 2021)
- NUTS0 codes: AT Austria, BE Belgium, BG Bulgaria, CY Cyprus, CZ Czech republic, DE Germany, DK Denmark, EE Estonia, EL Greece, ES Spain, FI Finland, FR France, HR Croatia, HU Hungary, IE Ireland, IT Italy, LT Lithuania, LU Luxemburg, LV Latvia, MT Malta, NL Netherlands, PL Poland, PT Portugal, RO Romania, SE Sweden, SI Slovenia
- In the FADN dataset we used, the represented organic payments amounts to 1.9 billion euros. That is relatively higher than the officially reported statistics. The rural development's EAFRD financial

reports[6] contain values from 0.9 to 1.3 billion for different years. These lower values can be due to the following reasons. First, a sampling bias in the FADN dataset as organic methods are not part of the sampling strata. Second, the organic payments are recorded in FADN, not in the production year but when the farmer receives them. Thus, there might be cases where farmers have received payments for two years and have recorded them in a single FADN year.

Results

Estimations of the unobserved part of the conversion decision (ε_i)

In Table 3 we provide the means of our estimations regarding the change in profits of conventional farms if they were to convert to organic (ΔΠ), the minimum and maximum unobserved utility change ε^{min} and ε^{max}, the point estimate of the unobserved utility change ε and the minimum conversion payment S_i^*, across farm types and geographical regions[7].

For interpreting the ΔΠ column, a positive number implies that organic performs better while a negative number that conventional performs better. Equally, a positive ε value means that that there are unobserved benefits for converting to organic while a negative that there are unobserved costs. For example, in the second column of the table (Profit change of South and Southeast), field crops have on average a potential monetary profit of 188 euro per hectare when converting to organic while dairy farms have a monetary loss of -781 euro per hectare. In the fourth column (ε), field crops have on average an unobserved cost of 379 (-379) for converting to organic while dairy farms an unobserved benefit of 524 (+524).

Regarding the minimum conversion payment S_i^* (sixth and last columns), the lower it is, the more probable is that farms will convert.

[6] https://agriculture.ec.europa.eu/common-agricultural-policy/financing-cap/cap-funds/eafrd-reports_en

[7] The regional disaggregation of the results is related to the bootstrapping procedure to retrieve the unknown ε^{min} (equations 12 and 13). In order to do so, we bootstrap from the population of farms of specific type of farming and of the two geographical regions (South and Southeast, and Central, West, East and North).

Table 3. Median values of the elements required to estimate the minimum conversion payment

Euro per ha	South and Southeast					Central, West, East and North				
	Profit change (ΔΠ)	ε^{min}	ε^{max}	ε	S_i^*	Profit change (ΔΠ)	ε^{min}	ε^{max}	ε	S_i^*
Field crops (1)	+188	-381	-178	-379	+200	+40	-211	-33	-210	+205
Horticulture (2)	+1,393	-6,299	-1,393	-3,223	+1,662	+7	-1,216	-7	-458	+1,383
Wine (3)	+691	-628	-439	-716	+115	+1,890	-738	-520	-107,525	+105,636
Other permanent crops (4)	+174	-642	-170	-379	+215	-785	-247	+787	+323	+463
Milk (5)	-781	+117	+781	+524	+257	-240	-257	+241	+48	+195
Other grazing livestock (6)	+36	-219	-36	-87	+90	-146	-193	+147	+60	+89
Granivores (7)	-3,088	+2,837	+9,855	+1,887	+7,960	-139	+624	+3,322	-11	+9,602
Mixed (8)	+163	-510	-163	-357	+198	+78	-287	-78	-195	+331

Notes: - 'South and Southeast' includes Bulgaria, Croatia, Romania, Greece, Italy, Spain, Portugal, Cyprus, Malta. 'Central, West, East and North' includes all other EU-27 countries
- 'Profit change' is defined as 'Organic profits' minus 'Conventional profits'
- All values are per hectare

Apart from the mean values, the distribution of the minimum incentive provides also useful information. In Table 4, we provide the quantiles of all farms in EU. For example, in the field crops farm type, 10% of the farms would convert with 105 euro per hectare or more (third column). For horticulture farms it requires 521 euro per hectare for the 10% of the farms to convert. The farm types with lower minimum conversion payment will contribute more farms for reaching the 25% area target. In addition, for some farm types the minimum conversion payment is too high for the majority of the farms (e.g. horticulture and granivores), meaning that the potential of conversion is limited.

Table 4. Distribution of minimum conversion payment (S_i^*) per type of farms

Quantile	*0%*	*10%*	*20%*	*30%*	*40%*	*50%*	*60%*	*70%*	*80%*	*90%*
Field crops (1)	0	105	158	181	193	200	218	248	300	404
Horticulture (2)	60	521	689	1,025	1,372	1,541	1,758	1,938	2,050	2,170
Wine (3)	0	64	79	100	105,636	105,636	105,636	105,636	105,636	105,636
Other permanent crops (4)	7	135	189	204	213	223	287	383	494	934
Milk (5)	18	110	174	182	186	197	276	407	673	1,494
Other grazing livestock (6)	19	42	47	68	79	90	117	174	262	465
Granivores (7)	1	123	455	1,278	2,853	9,302	62,797	89,727	89,727	89,727
Mixed (8)	107	125	146	181	210	282	444	1,116	3,272	4,654

It is important to note that the minimum conversion payment S_i^* refers to the extra payment on top of the current payment S', required for a farm to convert (see Equation 9). However, the current payment S' is not uniform across member states and crop groups. That means that for farms that belong to different member states or farm types, and thus have a different level of organic payments.

For example for two farms where $S_1' <> S_2'$, an equal additional payment $S_1^* = S_2^* = S^*$ does not necessarily result in an equal total organic payment $S_1^{total} = S_1^* + S_1' <> S_2^{total} = S_2 + S_2'$.

Estimation of the budgetary cost

In order to estimate the budgetary cost we need to take into account that although the target is set at EU level, the individual MS are responsible to set their own targets. That means that when the EU level target will be reached, some MS will be below and others above the 25% organic share. Thus, we need to use some projection for the share of the organic land per MS for the moment that the EU 25% target is reached. We use the IFOAM report (IFOAM Europe, 2021) that provide such projections based on the official targets in the national action or CAP strategic plans and/or expert opinion. In Table 5 we provide the current (2017) and the IFOAM projected shares of organic area for each MS. These MS projections are such that imply a 25% organic area share in the EU level.

Table 5. Current and projected shares of organic areas (source: FADN 2017 for current shares; IFOAM report for Projected shares)

	AT	BE	BG	CY	CZ	DE	DK	EE	EL
Current	29%	9%	1%	0%	24%	8%	16%	9%	2%
Projected	47%	24%	12%	12%	30%	24%	30%	35%	24%

	ES	FI	FR	HR	HU	IR	IT	LT	LU
Current	11%	12%	4%	8%	1%	3%	20%	8%	3%
Projected	30%	30%	30%	18%	18%	14%	41%	18%	30%

	LV	MT	NL	PL	PT	RO	SE	SI	SK
Current	23%	0%	7%	4%	6%	0%	19%	21%	10%
Projected	30%	2%	30%	12%	18%	12%	41%	18%	21%

Notes:
- The 'Current' share refers to the area reported in the FADN 2017 dataset under fully organic managements; areas reported from mixed farms are not reported.
- NUTS codes: AT Austria; BE Belgium; BG Bulgaria; CY Cyprus; CZ Czech Republic; DE Germany; DK Denmark; EE Estonia; EL Greece; ES Spain; FI Finland; FR France; HR Croatia; HU Hungary; IR Ireland; IT Italy; LT Lithuania; LU Luxembourg; LV Latvia; MT Malta; NL Netherlands; PL Poland; PT Portugal; RO Romania; SE Sweden; SI Slovenia; SK Slovakia

Given the above projections, in order to identify the budgetary cost in the EU level, we simulate a stepwise increase of the current payment level for each MS, until the MS's projected share has been reached. As the payment increases, more and more farms will convert because the payment level will exceed their minimum incentive for conversion. At some point, the area of the converted farms will reach the projected MS's share. The sum of the monetary compensation of the converted farms is the budget requirement.

More specifically, for a given MS, for reaching an organic area target T, a set of (conventional) farms $f: \{f_1, f_2, \dots, f_N\}$ need to convert. As already noted, we assume that farms requiring less additional payment are more likely to convert. Thus, we select f such that:

$$\sum_{f=1}^{N} w_f A_f = T \quad and\ S_1^* < S_2^* < \cdots < S_N^* \tag{18}$$

where w_f is the FADN weight of the farm, A_f is the utilized agricultural area of farm f, S_1^* is the additional payment required for conversion of the first selected farm, S_2^* that of the second selected farm, S_N^* that of the last selected farm. In other words, we select farms in ascending order of the additional conversion payment until the required area target T is reached. The budgetary cost will be equal to

$$B = \sum_{f=1}^{N} w_f \left(S_f^* + S_f'\right) \tag{19}$$

where S_f' is the current level of payment (see Table 2).

Using the above procedure for each MS and summing over all MS, we have estimated the budgetary cost for reaching the 25% organic area share in the EU level (Table 6). We estimate that the required conversion budget is around 7.3 billion. Given that the current organic farming budget, (as in 2017 FADN dataset) is around 1.6 billion euros, the required increase is about 4.5 times the current budget.

Table 6. Budgetary requirements for reaching the 25% organic target (million euros)

Current Budget (mil. EUR)	Required Budget	
	Value (mil. EUR)	% increase to current
1,610	7,335	455%

The profile of the converting farms

In Table 7, we compare the profile of the farms that convert to organic versus those that did not. We have performed a two-sample t-test for land size, livestock units, gross income per hectare and intermediate consumption per hectare between the farms that converted and those that did not. The differences show if the farms that converted have distinct characteristics from the farms that remained conventional.

Indeed, some interesting patterns appear. For example, for the “field-crop” farm type, more profitable and input-intensive farms with less land area convert. However, for the all the other farm types, less profitable and less input-intensive farms generally convert. In addition, the livestock-related farms that convert have fewer LSUs (-23 for milk and -53 for mixed farm types) than the ones that do not convert. An exception is the “other grazing livestock” farm type that the farms tha convert have more LSUs than the farms that do not convert.

Table 7. Differences between converting and non-converting farms in the MS scenario (converting minus non-converting)

	Land (ha)	Livestock units (LSU)	Gross Income (euro/ha)	Intermediate consumption (euro/ha)
Field crops (1)	-45	na	752	417
Horticulture (2)	-3	na	-20,841	-33,783
Wine (3)	ns	na	-3,062	-1,998
Other permanent crops (4)	ns	na	-3,125	-1,617
Milk (5)	ns	-23	-953	-2,221
Other grazing livestock (6)	15	8	-1,328	-1,405
Granivores (7)	28	ns	-31,752	-83,066
Mixed (8)	-51	-53	ns	-836

Notes: - A Welch's t-test was used (two-sample t-test). The null hypothesis was that the means of the converted and non-converted farms are equal.
- 'ns' means that a not statistically significant difference was detected.
- 'na' means non-meaningful number for a specific farm type.

Discussion and Conclusions

Methodological

Using a utility-based framework, the IFM-CAP model and the FADN dataset, we estimated the economic incentive that will make each FADN conventional farm convert to organic. This exercise required several assumptions to counterbalance the lack of accurate data (see Table 8 for a summary).

First, we assume that all current conventional farms do not find it attractive to convert. For the majority of the farms, this is likely true. However, some farms may have applied for conversion but received no payment and did not convert due to a national budget ceiling. A violation of this assumption leads to overestimating the budgetary cost because the farms that applied but did not enter the payment scheme are willing to convert with a lower payment than we estimate. More accurate data from national authorities on the number of farms excluded due to budget limitations could provide more accurate estimations.

The following two assumptions are due to unavailable data at the EU level. First, we only model fully organic farms (excluding mixed farms), and second, we do not model the current organic farms' conversion back to conventional agriculture. The first assumption can overestimate or underestimate the budget required because some farms may convert to mixed farms with a lower incentive than the one required to convert fully but will also contribute less land to the organic area[8]. The second

[8] We force a number of farms to convert so that we can achieve the target of 25% of UAA under organic agriculture. The fact that we force some conventional farms to become only fully organic and not mixed organic, means that the aggregate incentive is higher than in the case that we also would allow conversion to mixed farms. The underlying assumption is that on average a fully organic farm requires more incentive to convert than a mixed one because the latter retains some sectors to the conventional management. On the other hand, a mixed farm contributes less hectares to the overall 25% target. That means that we would need more mixed farms to get the same 25% target. So in the aggregate level the effect of not including mixed farms is undetermined.

assumption leads to an underestimation of the required budget because if some farms were reverting, a higher economic incentive would be required for them to avoid reverting.

Another assumption relates to the increase in payment schemes across crop groups and MS. Our model provides each FADN farm with a level of organic payment. If the payment exceeds the minimum conversion payment, the farm decides to convert to organic. However, the level of organic payment is external to our model and needs to be assumed. Therefore, the most plausible assumption is that the MS will increase their organic payment proportionally across the crop groups. As the organic payment offered to the farms increases, more and more farms will convert. A more realistic exercise would be to extract the information on the organic payment from the MS strategic plans, plug them into the model, and get an estimate of the conversion rates.

The last assumption relates to the lack of information regarding the relative preference of the FADN farms between the monetary and the non-monetary part of the utility function. For this, we assume an equal weight of one for both of these parts. However, for a farm with a non-monetary part having a higher weight than the monetary one, the actual minimum economic incentive would be higher than the one we estimate. The only possible remedy will be to incorporate information from EU-wide behavioural/discrete choice experiments regarding farmers' preferences if they are available.

Table 8. The assumptions of the empirical model, their implication for the estimation of the budgetary cost and possible remedies in future work

Assumption	Effect on estimation of budgetary cost	Possible remedy in future work
All current conventional farms do not find it attractive to convert with existing payments	Overestimation	More data from national authorities on the implementation details
Mixed farms are excluded	Unknown	More accurate data in future versions of FADN dataset
Organic farms do not revert to conventional	Underestimation	Incorporate data on the % of organic farms converting back to conventional
Current payment schemes are increased proportionally across crop groups and MS	Unknown	Extract and apply the organic payments in the MS strategic plans
Preferences for the monetary part of the utility function equals to the preferences for the non-monetary part	Unknown	Incorporate data from large scale behavioral/discrete choice experiments with farmers

A last point of discussion relates to the validity of the empirical implementation. To our knowledge, the only comparable study is that of IFOAM Europe (2021). The authors of the study estimate that to reach the 25% organic share in all MS, the CAP expenditure for organic should increase between 3.3 to 5.4 times. Our estimate of a 4.5-fold increase in the current budget lies within the same order of magnitude. Compared to the IFOAM study, our approach allows to also go beyond the budgetary requirements and get information on the effects of reaching the 25% target in relation to production and environmental performance. Although we do not deal with these two elements, we plan to do so in the future.

Policy implications

Our study concludes that a 4.5-fold increase in the organic budget is required to reach the 25% organic target. This increase is higher than the 3-fold increase from 9% of the current organic share to the 25% target. That means that increasing the current budget by 1% will result in less than 1% area converting to organic (decreasing return to scale).

The organic budget in 2014/20 CAP was around 6 billion euros of EU funding and another 3 billion of MS funding (IFOAM Europe, 2021). The EU part of the funding of the organic budget corresponded to around 6% of the Pillar 2 budget and 1.5% of the combined Pillar 1 & 2 budget. A 4.5-fold increase would mean that the EU funding for organic should go to around 30% of the Pillar II payment and 7% of the overall Pillar 1 & 2.

Given that both Pillar 1 and 2 have budget ceiling, increasing the organic budget implies that the share of other CAP interventions should decrease. From a policy maker's perspective, this is challenging given that together with the conversion to organic, other interventions also target environmental benefits, namely eco-schemes and the Pillar II agro-environmental measures.

Thus, a comparative analysis of the efficiency of the different environmental interventions is necessary to find an optimal path for achieving the policy targets. In principle, the efficiency of an intervention equals

$$EFFICIENCY = \frac{RESULTS}{BUDGETARY\ COST} \tag{20}$$

However, given the voluntary nature of the Pillar 1 and 2 environmental interventions, the results and the budget are not known a priori. The budget may be less than the administrative budget if an intervention is adopted to a smaller area than expected. Also, the profile of the adopting farms affects the results. For example, our results show that the lower input density farms participate in the organic scheme for most farm types. If the policymakers have a different profile of the adopting farms in their plans, the policy underperforms.

In the case of interventions that have broader effects on the food system, the estimation of efficiency becomes even more complicated. For example, in the case of organic farming, the expected decrease in crop production has implications for the consumers (decrease of aggregate production will lead to increase in consumer prices) and the trade balance of the EU (decrease in production will lead to decreased exports or/and increased exports) and could potentially lead to carbon leakage. These could be quantified with an analysis with a general equilibrium model.

Finally, a related issue is the horizontal payment scheme of the agro-environmental measures. As shown by our research through the distribution of the minimum conversion payment, not all farms have the same opportunity cost to convert to organic. The same holds for the opportunity cost to adopt another environmental measure. A flat payment per hectare based on "the additional costs incurred and income foregone" (Article 31, Regulation 2115/2021), equal for all farms, ignores this fact.

Overall, our study contributes to the policy discussion in two ways. First, it estimates that a 4.5-fold increase in the organic agriculture budget is required to reach the 25% target. Second, it can facilitate an efficiency assessment by providing an ex-ante quantitative estimation of the budget required and the profile of the farms that will participate. However, what is missing, and we are planning to do in the future, is the estimation of the environmental effects of reaching the 25% organic target. Additionally, the IFM-CAP model has already estimated the adoption rate of different eco-schemes (Petsakos et al., 2021); thus, a comparison of the efficiency of the different paths to reach the environmental targets of CAP is possible.

Disclaimer

The authors are solely responsible for the content of the paper. The views expressed are purelythose of the authors and may not in any circumstances be regarded as stating an official posi-tion of the European Commission

Acknowledgments

We would like to thank Maria Espinosa and Antti Simola for their critical comments that helped us improved the manuscript

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211.

Boone, L., Roldán-Ruiz, I., Van linden, V., Muylle, H., & Dewulf, J. (2019). Environmental sustainability of conventional and organic farming: Accounting for ecosystem services in life cycle assessment. *Science of the Total Environment*, *695*, 133841. https://doi.org/10.1016/j.scitotenv.2019.133841

Esposti, R. (2022). *Non-Monetary Motivations Of Agroenvironmental Policies Adoption. A Causal Forest Approach* (Issue 459). https://ideas.repec.org/p/anc/wpaper/459.html

European Commission. (2018). *Impact assessment accompanying the proposal for Regulations under COM(2018)392, COM(2018)393 and COM(2018)394*.

Frey, B. S., Benz, M., & Stutzer, A. (2004). Introducing procedural utility: Not only what, but also how matters. *Journal of Institutional and Theoretical Economics (JITE)/Zeitschrift Für Die Gesamte Staatswissenschaft*, 377–401.

Gholamrezai, S., Aliabadi, V., & Ataei, P. (2021). Understanding the pro-environmental behavior among green poultry farmers: Application of behavioral theories. *Environment, Development and Sustainability*, *23*(11), 16100–16118.

Howley, P. (2015). The happy farmer: the effect of nonpecuniary benefits on behavior. *American Journal of Agricultural Economics*, *97*(4), 1072–1086.

IFOAM Europe. (2021). *Organic in Europe: Prospects & Developments for Organic in National Strategic Plans*.

Jaime, M. M., Coria, J., & Liu, X. (2016). Interactions between CAP Agricultural and Agri-Environmental Subsidies and Their Effects on the Uptake of Organic Farming. *American Journal of Agricultural Economics*, *98*(4), 1114–1145. https://doi.org/10.1093/ajae/aaw015

Kowalska, A., & Bieniek, M. (2022). Meeting the European green deal objective of expanding organic farming. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, *17*(3), 607–633. https://doi.org/10.24136/eq.2022.021

Kremmydas, D., Ciaian, P., & Baldoni, E. (2023). Modeling conversion to organic agriculture with an EU-wide farm model. Bio-based and Applied Economics, 10.36253/bae-13925.

Kuminoff, N. V., & Wossink, A. (2010). Why isn't more us farmland organic? *Journal of Agricultural Economics*, *61*(2), 240–258. https://doi.org/10.1111/j.1477-9552.2009.00235.x

Louhichi, K., Ciaian, P., Espinosa, M., Colen, L., Perni, A., & Paloma, S. G. y. (2017). Does the crop diversification measure impact EU farmers' decisions? An assessment using an Individual Farm Model for CAP Analysis (IFM-CAP). *Land Use Policy*, *66*(September 2016), 250–264. https://doi.org/10.1016/j.landusepol.2017.04.010

Louhichi, K., Ciaian, P., Espinosa, M., Perni, A., & Gomez y Paloma, S. (2018). Economic impacts of CAP greening: application of an EU-wide individual farm model for CAP analysis (IFM-CAP). *European Review of Agricultural Economics*, *45*(2), 205–238. https://doi.org/10.1093/erae/jbx029

Meemken, E. M., & Qaim, M. (2018). Organic Agriculture, Food Security, and the Environment. *Annual Review of Resource Economics*, *10*, 39–63. https://doi.org/10.1146/annurev-resource-100517-023252

Montanarella, L., & Panagos, P. (2021). The relevance of sustainable soil management within the European Green Deal. *Land Use Policy*, *100*(July 2020), 104950. https://doi.org/10.1016/j.landusepol.2020.104950

Mowlds, S. (2020). The EU's farm to fork strategy: missing links for transformation. *Acta Innovations*, *36*, 17–32. https://doi.org/10.32933/ActaInnovations.36.2

Petsakos, A., Ciaian, P., Espinosa, M., Perni, A., & Kremmydas, D. (2022). Farm-level impacts of the CAP post-2020 reform : A scenario-based analysis. *Applied Economic Perspectives and Policy*, *February*, 1–21. https://doi.org/10.1002/aepp.13257

Pietola, K. S., & Lansink, A. O. (2001). Farmer response to policies promoting organic farming technologies in Finland. *European Review of Agricultural Economics*, *28*(1), 1–15. https://doi.org/10.1093/erae/28.1.1

Rezaei, R., Safa, L., Damalas, C. A., & Ganjkhanloo, M. M. (2019). Drivers of farmers' intention to use integrated pest management: integrating theory of planned behavior and norm activation model. *Journal of Environmental Management*, *236*, 328–339.

Saint-Cyr, L. D. F. (2022). Heterogeneous farm-size dynamics and impacts of subsidies from agricultural policy: Evidence from France. *Journal of Agricultural Economics*, *June 2020*, 893–923. https://doi.org/10.1111/1477-9552.12488

Appendix

Deriving the value of ρ^*

By using (5) let's assume that if $\Delta\Pi < 0$, then $\Delta\Pi = \Delta\Pi^-$, whereas if $\Delta\Pi > 0$, then $\Delta\Pi = \Delta\Pi^+$. Similarly, let's assume that if $\Delta V < 0$, then $\Delta V = \Delta V^-$, whereas if $\Delta V > 0$, then $\Delta V = \Delta V^+$. Hence, $S^{\pm} - S^{\mp} = \Delta\Pi^+ + \rho\Delta V^- - \Delta\Pi^- - \rho\Delta V^+ = \Delta\Pi^+ - \Delta\Pi^- + \rho(\Delta V^- - \Delta V^+)$. So, $S^{\pm} \geq S^{\mp} \Leftrightarrow \rho \leq \rho^* \equiv \frac{\Delta\Pi^+ - \Delta\Pi^-}{\Delta V^+ - \Delta V^-}$

Calibration procedure of $\widehat{\varepsilon_f}$

For a farm f, the unobserved part of the conversion decision can lie between ε_f^{max} and $\hat{\varepsilon}_f^{min}$. Since there is no information to get a farm-specific estimate, we set the mean value as a reasonable prior:

$$\widehat{\varepsilon_f} = \frac{\varepsilon_f^{max} + \hat{\varepsilon}_f^{min}}{2}$$

However, selecting the farms that will convert based on this prior, leads to questionable results regarding the share of farm types that convert. For example, in Table 9, while in the current data (2017 FADN dataset) 19.78% of organic farms are arable farms, using the priors results on a very much higher percentage of arable converting (50.80% of the farms that convert are arable). Also, while 27.20% of organic farms is currently permanent crop farms (column 2017 FADN dataset), only 0.77% of this farm type converts with the above prior.

This leads us to think that the prior of farms that belong to "Field crops" is underestimated and that of the farms that belong to "Other permanent crops" overestimated. Since $\widehat{\varepsilon_f}$ is used to estimate the minimum conversion payment (see equation 15), if too few farms of a farm type convert, it means that the minimum conversion payment is too high and thus ε_f is overestimated (considering that $\Delta\Pi'_{f_1}(S')$ does not have uncertainty).

Table 9. Share of farm types in all organic farms; using the uncalibrated prior

% of Organic farms	FADN 2017 dataset (9% of EU area organic)	Using the prior (25% of EU area organic)
Field crops (1)	19.78%	50.80%
Horticulture (2)	1.82%	1.91%
Wine (3)	7.09%	0.17%
Other permanent crops (4)	27.20%	0.77%
Milk (5)	10.87%	11.37%
Other grazing livestock (6)	20.98%	29.88%
Granivores (7)	1.20%	0.77%
Mixed (8)	11.06%	4.33%

Thus, we apply a calibration procedure that shifts the priors of all farms so that the % of farms of each farm type resemble the share of organic farms the FADN 2017 dataset (see Table 8). The calibration starts by setting the estimated non-observed part of conversion equal to the mean between the maximum and the minimum ε. Then, based on first estimated farm level $\widehat{\varepsilon_f}$, it selects the farms that will convert and compute the % of farms that convert in each farm type. Then, for each farm type it computes the % distance between the 2017 FADN share and the share derived from the current $\widehat{\varepsilon_f}$. Then, for all farms of a farm-type, it adjusts $\widehat{\varepsilon_f}$ to the distance computed. For example, if for a farm type, 30% of the farms converted to organic while in the 2017 FADN data only 20% were organic, it reduces $\widehat{\varepsilon_f}$ of all farms of this farm type by (0.3-0.2)/0.2. In pseudocode, the convergence algorithm is as follows:

Set $\widehat{\varepsilon_f} = \frac{\varepsilon_f^{max} + \hat{\varepsilon}_f^{min}}{2}$

Loop {

Select the farms that convert for $\widehat{\varepsilon_f}$ and the 25% area target

Estimate vector S_t (the % of farms that convert for farm type t)

If $dist(S_t, S_t^{2017}) \equiv c_t$ < 0.2, exit loop

Set $\widehat{\varepsilon_f}$=$\widehat{\varepsilon_f} \cdot c_t$

}

The application of the calibration procedure leads to a selection of farms where the share of the organic farms in farm types is closer to the observed ones (see Table 9).

Table 10. Share of farm types in all organic farms; using the calibrated prior

% of Organic farms	FADN 2017 dataset (9% of EU area organic)	Using the calibrated prior (25% of EU area organic)
Field crops (1)	19.78%	22.73%
Horticulture (2)	1.82%	1.80%
Wine (3)	7.09%	5.70%
Other permanent crops (4)	27.20%	21.65%
Milk (5)	10.87%	12.43%
Other grazing livestock (6)	20.98%	22.47%
Granivores (7)	1.20%	0.89%
Mixed (8)	11.06%	12.33%

SUPPLEMENTARY MATERIAL

S1. Organic maintenance payments for different member states for CAP 2014/20 (euros per hectare; source: IFOAM Europe (2021)

	Annual crops			Horticulture crops			Permanent crops			Grassland		
	min	max	average	min	max	average	min	max	average	min	max	average
Austria	70	230	150	450	1000	725			700	70	255	162
Belgium	240	400	320	400	900	650	240	900	570	120	200	160
Bulgaria			166	399	405	402	399	447	423	128	218	173
Croatia			290			481			723			258
Cyprus			380			600	750	900	825			450
Czech Republic	69	180	124	466	583	524	417	845	631			83
Denmark	116	183	149	116	183	149	652	719	685	116	183	149
Estonia			125	210	600	405			300	25	80	52
Finland			160			600			0	160	294	227
France			0			0			0			0
Germany	189	273	231	300	3800	900	665	2855	900	189	273	231
Greece	70	594	332			550	225	850	537	260	383	321
Hungary			172			516	568	802	685	84	147	115
Ireland	30	170	100	20	200	110	30	200	115	30	170	100
Italy	90	600	345	270	1200	735	102	900	501	12	450	231
Latvia			117			399			485			97
Lithuania	218	283	250	487	525	506			518			176
Luxembourg	218	283	250	487	525	506			518			176
Malta			555			555			555			0
Netherlands			0			0			0			0
Poland	153	217	185	305	308	306.5	154	349	251			124
Portugal	16	530	273	120	600	360	50	900	475	34	170	102
Romania			218	350	431	390	442	479	460	73	129	101
Slovakia			153	290	529	409	330	671	500			96
Slovenia			326			600	189	900	544			156
Spain	30	853	441	41	1561	801	60	900	480	41	450	245
Sweden			142			472			708	76	151	113

Notes: - In case there are no values in the min and max columns, it is implied that there is a single payment equal to the average column
- The 1305/2013 regulation imposes an upper limit of 900 euro per hectare for organic payments. Thus, all average values greater than 900 euro/ha has been reduced to 900 euro/ha.

S2. OLS regression results of the estimation of organic payments per Member State and crop group from FADN 2017

```
Call:
lm(formula = org_payment ~ 0 + ANNUAL:NUTS0 + HORTICULTURE:NUTS0 +
    PERMANENT:NUTS0 + GRASSLAND:NUTS0, data = tmp2)

Residuals:
    Min      1Q  Median      3Q     Max
-295206   -1098     310    2814  243025

Coefficients: (7 not defined because of singularities)
                       Estimate Std. Error t value             Pr(>|t|)
ANNUAL:NUTS0BG          173.357     41.867   4.141 0.000034947532488036 ***
ANNUAL:NUTS0CY               NA         NA      NA                   NA
ANNUAL:NUTS0CZ          184.843      6.223  29.703 < 0.0000000000000002 ***
ANNUAL:NUTS0DE          225.906      1.774 127.365 < 0.0000000000000002 ***
ANNUAL:NUTS0DK          124.832      2.350  53.111 < 0.0000000000000002 ***
ANNUAL:NUTS0EE          130.052      6.108  21.293 < 0.0000000000000002 ***
ANNUAL:NUTS0EL          285.519     25.226  11.319 < 0.0000000000000002 ***
ANNUAL:NUTS0ES           36.227      6.205   5.839 0.000000005444135048 ***
ANNUAL:NUTS0FI          192.044      7.026  27.332 < 0.0000000000000002 ***
ANNUAL:NUTS0FR          135.493      7.170  18.898 < 0.0000000000000002 ***
ANNUAL:NUTS0HR          186.223     19.468   9.566 < 0.0000000000000002 ***
ANNUAL:NUTS0HU          117.003     20.222   5.786 0.000000007454867315 ***
ANNUAL:NUTS0IE          138.520    129.275   1.072             0.283969
ANNUAL:NUTS0IT          154.237      6.009  25.669 < 0.0000000000000002 ***
ANNUAL:NUTS0LT          160.769      5.775  27.840 < 0.0000000000000002 ***
ANNUAL:NUTS0LU          192.358     68.101   2.825             0.004745 **
ANNUAL:NUTS0LV          109.650      3.561  30.795 < 0.0000000000000002 ***
ANNUAL:NUTS0PL          164.921     16.607   9.931 < 0.0000000000000002 ***
ANNUAL:NUTS0PT           65.287     10.647   6.132 0.000000000903393393 ***
ANNUAL:NUTS0RO          220.187     24.360   9.039 < 0.0000000000000002 ***
ANNUAL:NUTS0SE          122.575      3.482  35.207 < 0.0000000000000002 ***
ANNUAL:NUTS0SI          337.362    183.716   1.836             0.066342 .
ANNUAL:NUTS0SK          150.216      5.214  28.808 < 0.0000000000000002 ***
NUTS0BG:HORTICULTURE    344.007     98.484   3.493             0.000480 ***
NUTS0CY:HORTICULTURE         NA         NA      NA                   NA
NUTS0CZ:HORTICULTURE    191.157    726.415   0.263             0.792440
NUTS0DE:HORTICULTURE    502.509     55.368   9.076 < 0.0000000000000002 ***
NUTS0DK:HORTICULTURE    331.651    200.355   1.655             0.097895 .
NUTS0EE:HORTICULTURE   6095.508    909.233   6.704 0.000000000021502929 ***
NUTS0EL:HORTICULTURE   2092.469  14023.556   0.149             0.881390
NUTS0ES:HORTICULTURE   1641.539    973.540   1.686             0.091801 .
NUTS0FI:HORTICULTURE    176.470    608.768   0.290             0.771914
NUTS0FR:HORTICULTURE    244.135     70.549   3.461             0.000542 ***
NUTS0HR:HORTICULTURE  12337.255  28743.163   0.429             0.667771
NUTS0HU:HORTICULTURE    513.867     59.385   8.653 < 0.0000000000000002 ***
NUTS0IE:HORTICULTURE         NA         NA      NA                   NA
NUTS0IT:HORTICULTURE    893.695     48.329  18.492 < 0.0000000000000002 ***
NUTS0LT:HORTICULTURE    758.382    349.139   2.172             0.029871 *
NUTS0LU:HORTICULTURE   1345.397   1383.683   0.972             0.330913
NUTS0LV:HORTICULTURE    689.511   1208.153   0.571             0.568207
NUTS0PL:HORTICULTURE    193.880    140.466   1.380             0.167539
NUTS0PT:HORTICULTURE   3302.527   1631.691   2.024             0.043001 *
NUTS0RO:HORTICULTURE   -161.793 347093.317   0.000             0.999628
NUTS0SE:HORTICULTURE    397.092    337.808   1.175             0.239828
NUTS0SI:HORTICULTURE   -157.688   1918.364  -0.082             0.934490
NUTS0SK:HORTICULTURE    398.912     34.779  11.470 < 0.0000000000000002 ***
NUTS0BG:PERMANENT       494.752     53.689   9.215 < 0.0000000000000002 ***
NUTS0CY:PERMANENT       640.511   1791.467   0.358             0.720700
NUTS0CZ:PERMANENT       560.957     54.235  10.343 < 0.0000000000000002 ***
NUTS0DE:PERMANENT       559.394     55.488  10.081 < 0.0000000000000002 ***
NUTS0DK:PERMANENT       528.511    137.940   3.831             0.000128 ***
NUTS0EE:PERMANENT       239.001     32.835   7.279 0.000000000000364799 ***
```

```
NUTS0EL:PERMANENT       513.562    114.383   4.490 0.000007217137974084 ***
NUTS0ES:PERMANENT       219.469     14.044  15.627 < 0.0000000000000002 ***
NUTS0FI:PERMANENT       360.000    309.585   1.163             0.244923
NUTS0FR:PERMANENT       249.609     15.104  16.526 < 0.0000000000000002 ***
NUTS0HR:PERMANENT       553.955    146.806   3.773             0.000162 ***
NUTS0HU:PERMANENT       779.942    270.244   2.886             0.003910 **
NUTS0IE:PERMANENT            NA         NA      NA                   NA
NUTS0IT:PERMANENT       478.828     14.817  32.316 < 0.0000000000000002 ***
NUTS0LT:PERMANENT       217.947     34.849   6.254 0.000000000418502384 ***
NUTS0LU:PERMANENT       748.053   2129.397   0.351             0.725373
NUTS0LV:PERMANENT       521.239    316.934   1.645             0.100082
NUTS0PL:PERMANENT       322.524    132.439   2.435             0.014900 *
NUTS0PT:PERMANENT       342.955     92.871   3.693             0.000223 ***
NUTS0RO:PERMANENT       438.696    704.516   0.623             0.533504
NUTS0SE:PERMANENT            NA         NA      NA                   NA
NUTS0SI:PERMANENT       510.628    347.804   1.468             0.142100
NUTS0SK:PERMANENT     -1966.430    199.245  -9.869 < 0.0000000000000002 ***
NUTS0BG:GRASSLAND        55.390    177.789   0.312             0.755391
NUTS0CY:GRASSLAND            NA         NA      NA                   NA
NUTS0CZ:GRASSLAND        73.651      1.558  47.284 < 0.0000000000000002 ***
NUTS0DE:GRASSLAND       143.317      2.005  71.465 < 0.0000000000000002 ***
NUTS0DK:GRASSLAND       119.380      8.868  13.463 < 0.0000000000000002 ***
NUTS0EE:GRASSLAND        58.847      5.705  10.315 < 0.0000000000000002 ***
NUTS0EL:GRASSLAND        54.220    190.861   0.284             0.776355
NUTS0ES:GRASSLAND        40.465      5.244   7.716 0.000000000000013290 ***
NUTS0FI:GRASSLAND        91.689     36.229   2.531             0.011398 *
NUTS0FR:GRASSLAND        76.336      6.950  10.984 < 0.0000000000000002 ***
NUTS0HR:GRASSLAND       105.110      3.880  27.093 < 0.0000000000000002 ***
NUTS0HU:GRASSLAND        -5.044    153.997  -0.033             0.973870
NUTS0IE:GRASSLAND        93.177     30.489   3.056             0.002249 **
NUTS0IT:GRASSLAND        49.257      6.299   7.820 0.000000000000005902 ***
NUTS0LT:GRASSLAND       154.054     14.126  10.906 < 0.0000000000000002 ***
NUTS0LU:GRASSLAND       151.710     60.991   2.487             0.012886 *
NUTS0LV:GRASSLAND        92.371      5.089  18.153 < 0.0000000000000002 ***
NUTS0PL:GRASSLAND        77.355     35.244   2.195             0.028201 *
NUTS0PT:GRASSLAND        45.758      5.636   8.119 0.000000000000000534 ***
NUTS0RO:GRASSLAND            NA         NA      NA                   NA
NUTS0SE:GRASSLAND        55.110      8.365   6.588 0.000000000047134155 ***
NUTS0SI:GRASSLAND       142.356     23.126   6.156 0.000000000779746109 ***
NUTS0SK:GRASSLAND        82.421      2.444  33.722 < 0.0000000000000002 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 10410 on 8953 degrees of freedom
Multiple R-squared:  0.876,	Adjusted R-squared:  0.8748 
F-statistic:   744 on 85 and 8953 DF,  p-value: < 0.00000000000000022
```