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Analyzing Transition to Organic Farming in Italy Through a Dynamic Mathematical Programming Model: Impacts on Agricultural Area and Budget Allocations

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Abstract

The European Union aims to achieve the target of 25% of land under organic farming by 2030. Italy reached the share of 18.7% in 2022, although significant regional differences persist. This study analyzes farms' conversion response in the Lazio region (Italy) using a dynamic version of the AGRITALIM agro-economic supply model on a sample of 578 FADN farms. Addressing the limitations of static modeling frameworks that assume full conversion, this study aims to simulate individual farm conversion choices over time, by accounting for conversion and maintenance phases costs and price premiums. This framework tests the hypotheses that a dynamic modeling approach can highlight nuanced responses and that increases in Common Agricultural Policy (CAP) payments are able to increase organic conversion rates. Results show limited effects of increased economic support: the 2023–2027 CAP reform, characterized by higher support, leads to a 5.1% increase in the area under organic farming, while a 40% increase in financial support generates an expansion of 12%. Farm responses are highly heterogeneous: rural provinces, larger and arable farms are more responsive, while smaller farms and livestock are less likely to convert. These findings highlight the need for integrated policy strategies combining financial support, reduced costs, technical assistance, and improved market access. The methodological approach adopted in this study provides a useful tool for supporting the design of targeted and effective policy interventions.

Keywords: organic farming; mathematical programming; common agricultural policy; farm-level analysis; organic conversion incentives

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1. Introduction

In December 2019, the European Commission introduced the European Green Deal, aiming for climate neutrality by 2050 [1]. Within this framework, the Farm to Fork Strategy (F2F), specifically focused on the agricultural sector, highlights the benefits of organic farming and sets a target for 25% of EU agricultural land to be organic [2]. The 2014–2022 Common Agricultural Policy (CAP) had already supported organic farming expansion, allocating substantial financial resources to the sector. In Italy, a significant boost in this direction came from the Rural Development Programs (RDPs), which introduced Measure 11, specifically aimed at supporting organic farming [3]. As a result, by 2022, the organic area reached 18.7%, a 7.5% increase compared to 2021, bringing Italy closer to the F2F target set for 2027 [4]. However, despite Italy being a leader among EU in area under organic farming according to EUROSTAT, each region had the flexibility to define the role of organic farming within its RDP strategy. This has led to national-level disparities, reflecting not only regional agricultural characteristics but also the need for systemic change in policy mixes, farm management, processing and retail sectors, and diets [5,6]. Indeed, organic farming differs significantly from conventional farming, especially in management practices and productivity [7,8]. It faces sector-specific risks, i.e., the challenges of transition, soil conservation, and price volatility, with premium prices not always guaranteed [9–11]. While higher prices should compensate for lower yields [12], this is not always the case, especially for livestock products and vegetables [13]. The fragility of the production system can be exacerbated by specific territorial and climatic conditions, making economic returns uncertain [14]. Moreover, the difficulty of transitioning from conventional to organic farming remains a barrier, especially for small and medium-sized farms [15,16]. Despite being theoretically well-suited for organic production due to their higher labor intensity than larger farms [17], empirical evidence suggests that smaller farms often face higher structural and financial constraints. These include limited access to credit and premium markets and, consequently, a reduced capacity to absorb yield fluctuations during the conversion period. Moreover, even though organic farming is labor-intensive, recent studies indicate that farms tend to convert only when supported by larger land endowments [10]. Otherwise, they may struggle with financial sustainability and lower liquidity production compared to conventional farms [18]. However, being area and product-based, CAP payments may struggle to fully renumerate farmers for the multi-year nature of the conversion phase, including soil transition periods, learning processes, and adaptation of management practices occurring [17]. In this context, several studies have investigated and modelled the conversion to organic farming. Among them, most usually use individual farms [11] or representative farms, usually hypothesizing a full conversion [19,20]. Others use partial equilibrium models not considering all crops and countries across the EU [21] or considering the organic target of 25% jointly with other F2F measures [22,23]. Recently, Petsakos et al., Kremmydas et al., and Rey Vicario et al., [24–26] have used static farm-level models to analyze organic conversion patterns, the effects of alternative budget allocations, and different policy strategies aimed at achieving the F2F organic target. To address these limitations, this study adopts a dynamic agro-economic modelling framework that explicitly represents farms' conversion decisions over time i.e., the multi-year adjustment processes required to convert. This approach allows for capturing and representing the influence of transition costs and considering the distinct economic conditions characterizing the conversion and maintenance phases.

In this setting, the study has two main objectives: (i) to develop a dynamic farm-level model that explicitly distinguishes between the conversion and maintenance phases, enabling farm-specific adjustment decisions without imposing full conversion; and (ii) to assess how increases in CAP support affect the expansion of land under organic farming, taking into account farm-level and territorial heterogeneity. The underlying hypotheses are, respectively, that a dynamic modeling framework distinguishing conversion and maintenance phases provides more realistic predictions of farm-level organic adoption by capturing transition costs and benefits over time (H1) and increasing CAP payments significantly support the expansion of organic area, with a higher conversion rate for extensive areas and farms compared to small and intensive ones (H2).

To reach these goals, the Lazio region is considered a case study. The analysis simulates a set of scenarios characterized by progressively higher payment levels for organic farming, with the aim of assessing the effectiveness of increased budget allocations in promoting conversion and contributing to the F2F 25% target. Simulations are carried out through a dynamic version of the AGRITALIM model, a dynamic mathematical programming agro-supply model specifically calibrated to represent farm-level structure and production choices. While we acknowledge that farmer behavior is influenced by social values and risk perception, our profit-maximizing framework isolates the specific impact of CAP financial incentives, providing an assessment of the role of economic drivers in organic conversion and their efficacy. The model is applied to an Italian Farm Accountancy Data Network (FADN) sample of 578 farms for the year 2020. The sample is stratified to represent the main Types of Farming of the region and different economic size classes. Data include detailed farm and crop-level information on economic, structural, and resource characteristics, including incomes, yields, market prices, and CAP subsidies. The paper is organized as follows: Section 2 presents the materials and methods, i.e., the data used and the construction of the AGRITALIM model for organic farming conversion. Section 3 presents the results, Section 4 discusses them and highlights limitations and policy implications, and Section 5 concludes.

2. Materials and Methods

2.1. Data

Utilizing an agro-supply model rooted in microeconomic data and designed to consider farm-specific choices, i.e., AGRITALIM, the analysis provides detailed responses for each farm, leveraging data at the farm level from the Italian FADN. FADN is the only source of microeconomic data based on harmonized bookkeeping principles. Based on national surveys, it aggregates data on 68,000 farms, representing almost 5 million EU farms, 90% of the European UAA, and Standard Output. The Italian sample comprises 11,000 farms, whose data are stratified by region, size, and type of farming (TF). The data include Gross Output, land, crop-specific variable costs, work-related costs for families and employed workers, and irrigation water volumes. Specifically, for this analysis, AGRITALIM was applied to a FADN sample of 578 conventional farms in the Lazio region for the year 2020.

Table 1 presents the main descriptive statistics of the sample, whereas Figure 1 shows the distributions of key structural and economic variables for both Conventional and Organic groups. In terms of spatial distribution, organic farms are mainly located in Viterbo (52.9%), in Rieti (24.6%), followed by Rome (13.4%), Frosinone (7.0%), and Latina (2.1%). The distribution over farm size, instead, is homogeneous: farms between 5 and 15 hectares represent the 31.0%, farms between 15 and 40 hectares represent the 25.7%, and farms above 40 hectares represent the 35.8%. Instead, small farms under 5 hectares only represent 7.5%. Table 2 shows the distribution over Type of Farming (TF), showing that some sectors are more prone to conversion, such as Olive groves (62.5% of organic farms) and Vineyards (52%). Others, such as Cereals, are all classified as Conventional.

Table 1. Descriptive Statistics of the selected FADN sample, and for the Conventional and Organic groups of farms.

Variable	UM	Conventional		Organic		Total	
		Mean	SD	Mean	SD	Mean	SD
Land	ha	32.6	49.0	48.1	63.5	37.6	54.6
Operating Income	€/ha	3466.2	7043.9	1908.3	2764.5	2962.2	6044.2
Livestock Units (LSU)	Number of heads/ha	22.7	141.6	2.7	6.7	15.2	112.5
Hired Work	Working Units/ha	0.2	0.5	0.1	0.1	0.2	0.4
Family Work	Working Units/ha	0.1	0.4	0.1	0.1	0.1	0.3
Gross Margin	€/ha	4367.2	7930.3	2604.4	3176.8	3796.9	6814.9
Total Gross Output	€/ha	7196.8	9264.4	4143.3	5398.5	6208.9	8333.8
Crop Gross Output	€/ha	4434.4	7892.9	2944.7	4813.1	3952.4	7075.5
Livestock Gross Output	€/ha	2359.4	5670.6	867.9	2755.1	1876.8	4966.8

UM = Unit of measures, SD = Standard Deviation.

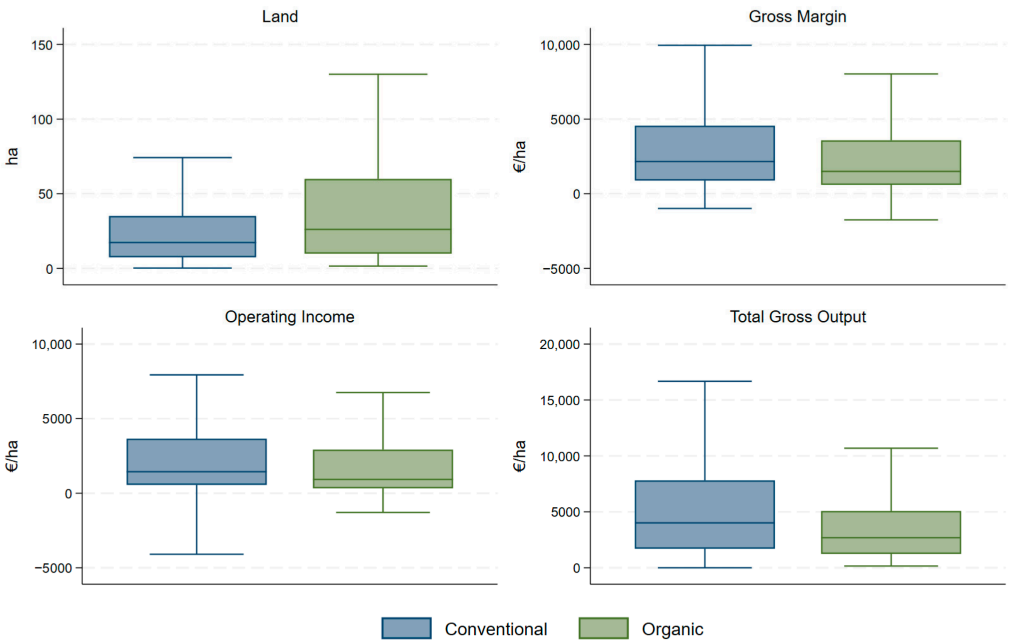

Figure 1. Distribution of key structural and economic variables for conventional and organic farms. Values refer to Land, Gross margin, Total Gross Output, and Gross Margin. Outliers have been excluded from the visualization to improve readability.

Table 2. Distribution of Conventional and Organic farms over Type of Farming.

Type of Farming	Conventional	Organic	Total	% Organic Farming on Total
Dairy Cattle	49	9	58	15.5
Cereals	12	0	12	0.0
Livestock	81	48	129	37.2
Tree Crops	51	44	95	46.3
Granivores	12	12	24	50.0
Mixed Crops and Livestock	30	22	52	42.3
Olive Groves	6	10	16	62.5
Horticulture	60	20	80	25.0
Arable farms	78	9	87	10.3
Vineyards	12	13	25	52.0
Total	391	187	578	32.4

2.2. The AGRITALIM Model

Operating within the category of agro-economic supply models, AGRITALIM is based on non-linear Mathematical Programming, combining Leontief technology for variable costs with a quadratic cost function. It is calibrated through the Positive Mathematical Programming (PMP) approach [27–32]. One of the key aspects of this methodology is the recovery and/or estimation of the parameters of the quadratic cost function (or other functional forms, much less commonly used in the literature), which allows for perfect calibration of the model to the observed situation (or baseline). Different combinations of the cost function parameters allow for perfect calibration.

Over the years, various approaches have been developed to overcome the problem of arbitrary recovery/estimation of cost function parameters: in the standard (3-phase) approach, by introducing a priori exogenous information (e.g., land rental values, land allocation elasticities with respect to own gross margins, etc.); or alternatively, with the econometric approach, by estimating parameters using first-order conditions, and also adding a priori exogenous information [32]. In our case, the approach used is the standard one with a priori exogenous information on land rental values, obtained from the FADN for the different agricultural regions of Italy (distinguishing for land production attitude, presence or absence of irrigation facilities, etc.). Furthermore, the model also considers other constraints (labor, water, feeds), and therefore, the related dual values generated in the calibration phase allow us to take into account other information regarding the market of these production factors.

The main components of the objective function and constraints concern land, labor (both manual and mechanical), water, and feed availability (Equation (1)). AGRITALIM maximizes the farm operative income, considering market elements (prices of outputs and inputs), production functions (linking crop yields and inputs), agricultural policy support, and depreciation costs (The general specification of the AGRITALIM model, including the objective function and general constraints, is detailed in Cortignani et al. (2022) [33]. Equations (1) and (2) build on this general structure but represent a methodological advancement specifically developed to model organic farming and capture the dynamic nature of conversion). Specifically, in this study, the model maximizes farm income over two phases, i.e., conversion and maintenance, incorporating the allocation of resources and investment decisions. Future revenues are discounted using an interest rate (r). Equations (1) and (2) describe the objective function:

$$\boldsymbol{max\ Z} = \sum\nolimits_t \frac{1}{(1+\boldsymbol{r})^{\boldsymbol{t}}} \boldsymbol{Income_t} \quad (1)$$

$$\boldsymbol{Income_t} = [(\boldsymbol{pc} + \Delta \boldsymbol{pc_t}\, \boldsymbol{BIN_t})\cdot(\boldsymbol{y} + \Delta \boldsymbol{y_t}\, \boldsymbol{BIN_t}) + \boldsymbol{Pbio_t BIN_t} - (\boldsymbol{c} + \Delta \boldsymbol{c_t BIN_t})]\boldsymbol{X_t} \quad \forall \boldsymbol{t} \quad (2)$$

The model maximizes the discounted operating income $\boldsymbol{Z}$ for each farm (Equation (1)), where $\boldsymbol{t}$ denotes the two phases of organic adoption: conversion and maintenance. The discount factor $1/(1+\boldsymbol{r})^{\boldsymbol{t}}$ accounts for the intertemporal valuation of income streams. Period-specific income, $\boldsymbol{Income_t}$, is defined in Equation (2). The variables $\boldsymbol{pc}$ and $\boldsymbol{y}$ denote output prices and yields, respectively, while $\boldsymbol{X}$ represents the levels of each activity, expressed in hectares for crops and number of heads for livestock. The parameter $\boldsymbol{c}$ represents production costs associated with each activity.

The transition to organic farming is modeled through a binary variable, $\boldsymbol{BIN_t}$, which activates the organic farming payment $\boldsymbol{Pbio_t}$ when a farm chooses to convert ($\boldsymbol{BIN_t} = 1$) (This specification implies that farms either fully convert their UAA or do not convert at all, as partial conversion is not considered in this modeling framework). The same variable also activates the differential terms $\boldsymbol{\Delta pc_t}$, $\boldsymbol{\Delta y_t}$, and the cost differential component $\boldsymbol{\Delta c_t}$, capturing deviations in prices, yields, and marginal costs under organic management relative to conventional farming for each product. The differential parameters were obtained using FADN data from the previous three years for organic crops and livestock within the same geographical area, province, and altitude class. For non-converting farms ($\boldsymbol{BIN_t} = 0$), all differential terms are null, and conventional production conditions apply.

Table 3 shows the information on the number of observations per each group and stratum, in order to provide data on the distribution of information used to compute $\boldsymbol{\Delta pc_t}$, $\boldsymbol{\Delta y_t}$ and $\boldsymbol{\Delta c_t}$. In cases where no organic observations are available within a given stratum, transitions to organic farming are not allowed in the simulation. This reflects a conservative assumption, where the absence of observed transitions over the reference period analyzed may be associated with structural constraints, such as climatic and soil conditions, limited technical knowledge, or supply chain and market limitations. Table A1 in the Appendix A presents an illustrative example for a single province and altitude, showing aggregated values by crop category for each farming system and the corresponding differential pa-

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rameters. While Δpc_t, Δy_t, and Δc_t are calculated at the individual product level, the table reports the average values for crop groups to simplify presentation and improve readability.

Table 3. Number of observations and share of organic farms on total by production system, province, and altitude class used for the computation of differential parameters (Δpc, Δy, Δc).

	Conventional	Organic	Total	% Organic
Hills	3496	1552	5048	30.7
Frosinone	277	55	332	16.6
Latina	218	17	235	7.2
Rieti	215	189	404	46.8
Roma	770	242	1012	23.9
Viterbo	2016	1049	3065	34.2
Mountain	431	351	782	44.9
Frosinone	70	67	137	48.9
Rieti	300	281	581	48.4
Roma	61	3	64	4.7
Plain	1096	196	1292	15.2
Latina	306	34	340	10.0
Roma	407	130	537	24.2
Viterbo	383	32	415	7.7
Total	5023	2099	7122	29.5

Considering that Italy is already at 18.7% of organic land [34], and aiming to reach 25%, assuming the target is set at the Member State level, a contribution from each region will be necessary. This is especially relevant since, under the CAP 2014–2020, rural development measures (including support for organic farming) were implemented through regional Rural Development Programmes (RDPs). Under the CAP 2023–2027 Strategic Plans (CSPs), support for organic farming and other rural development measures continues to be implemented at national and regional levels as part of each Member State's plan, with allocations often tailored to regional needs. The Italian CSP allocates record financial resources to organic farming. In particular, the intervention dedicated to the adoption and maintenance of organic farming practices receives the largest budget among all rural development interventions, with a total allocation exceeding 2.2 billion euros. This corresponds to approximately 48% of all agri-environment interventions and about 14% of total public expenditure planned under the second pillar over the programming period [34].

Based on this, an analysis was conducted on the share of organic land across all Italian regions. Some, particularly in the North, show organic areas around 5–6%, such as Lombardy and Piedmont. This is largely due to the characteristics of farming in those regions, where intensive and profitable livestock farming likely limits the expansion of organic practices. This suggests that other regions, where the trend in organic farming has been more positive in recent years, can help achieve the overall target of 25%. Thus, the simulations are based on a set of assumptions involving a progressively higher commitment from regions with greater shares of organic land, such as Lazio, where 22.6% of the regional area was organic in 2020. Simulations are designed to assess farms' sensitivity to changes in policy support for organic farming. Specifically, the analysis evaluates whether alternative payment levels can foster further conversion and to what extent they contribute to increasing the regional organic area.

As a first scenario, the model considers the CAP 2023–2027 payment levels for organic farming as defined in the CAP Strategic Plan. Compared to the previous programming period, payments in Lazio decreased from 483 to 376 €/ha during the conversion phase and from 406 to 318 €/ha during the maintenance phase. This scenario represents the baseline policy framework. Importantly, while unit payments are lower, the overall budget allocated to organic farming is substantially higher. This reflects a policy choice aimed at broadening participation by spreading available resources over a larger number of farms and hectares. The simulations, therefore, assess whether this strategy is sufficient to sustain further conversion, or whether higher per-hectare payments would be more effective in achieving more ambitious regional organic targets. Figure 2 provides a schematic overview of the analytical framework adopted in this study, detailing the scenarios, sample, and data inputs used by the AGRITALIM model to produce the outputs.

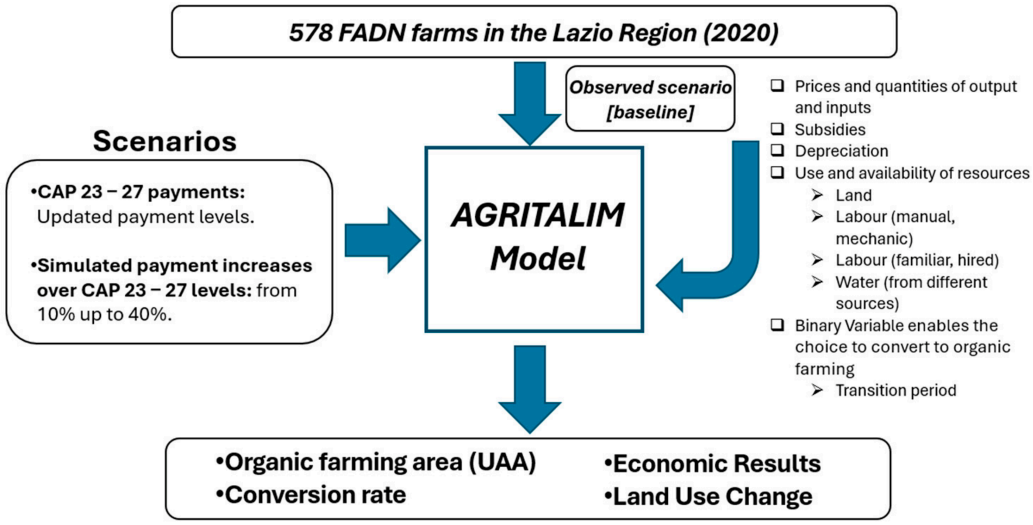

Figure 2. The AGRITALIM model, inputs, outputs, and simulated scenarios.

3. Results

3.1. Overall Impacts

The model provides results in terms of the variation of land under organic farming at the farm level. Specifically, it allows us to determine the rate of conversion and, consequently, the variation in unitary payments necessary to stimulate conversion and to assess the cost-effectiveness of this mechanism. Table 4 shows the main results in terms of variation in the number of organic farms and UAA under organic farming in the simulated scenarios. The CAP 2023–2027 reform represents a step forward in the conversion of farms, leading to an increase of 5.1% in UAA under organic farming. However, this result is achieved at the cost of a 15.4% increase in the budget. This pattern becomes even more evident in the other scenarios, i.e., farms respond in a relatively rigid way to increases in unitary payments. In fact, with a 15% increase in the unitary payment, the number of converted farms rises to 17, increasing to 20 farms in the intermediate scenario (+25%) and reaching 24 farms in the scenario with a 40% increase in payments. These changes correspond to increases of 7.8%, 8.5%, and 11.9% in UAA under organic farming, respectively, supported by overall budget increases of 25.8%, 29.9% and 47.5%. In other words, a substantial increase in regional expenditure, amounting to approximately €554,864, leads to the conversion of only 24 farms (around 12%), making this strategy relatively non-cost-effective for policymakers, as shown by Figure 3.

Table 4. Simulated Scenarios and their effects on conversion to organic farming and overall budget for organic payments. Results are expressed as variations from the baseline scenario.

Δ Payment	Δ Organic Farms (n)	Δ UAA Under Organic Farming (ha)	Δ of UAA Under Organic Farming on Total (%)	Δ Organic Budget Payments (1000 €)	Δ of Organic Budget Payments (%)
CAP 23–27	12	1074	5.1	180.1	15.4
10%	14	1189	5.7	226.2	19.4
15%	17	1637	7.8	302.0	25.8
20%	19	1710	8.2	335.0	28.7
25%	20	1780	8.5	349.9	29.9
30%	21	1860	8.9	388.8	33.3
35%	22	1933	9.2	420.8	36.0
40%	24	2495	11.9	554.9	47.5

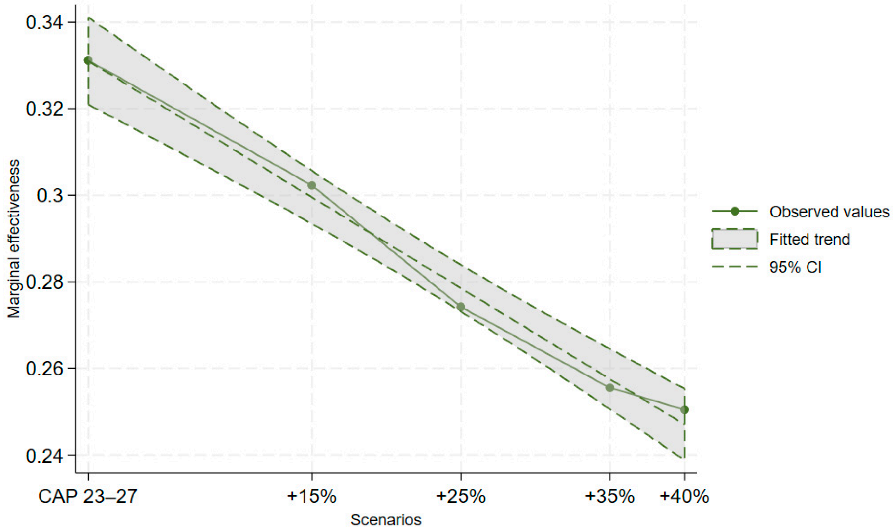

Figure 3. Marginal economic effectiveness of CAP payments on organic conversion. The indicator represents the ratio between the additional organic area (hectares) and the additional budget spent for each incremental scenario.

3.2. Territorial Patterns

In terms of the spatial distribution of conversion, the situation is highly heterogeneous. Looking at Figure 4, for example, the provinces that show an increase in the share of UAA under organic farming are mainly Rome and Viterbo, while Rieti, Frosinone, and Latina show very limited increases (between 0 and +2.9% in all scenarios considered). Rome, instead, shows a high sensitivity, with already large increases under the CAP 2023–2027 baseline (+20.2% from the baseline of the same province) and further increases of +40.4%, +43.2%, and +49.2% in the +15%, +25% and +35% scenarios, respectively. A similar pattern is observed for Viterbo, which shows increases ranging from 18.9% up to 29.8% in the scenario with a +35% increase in unitary payments.

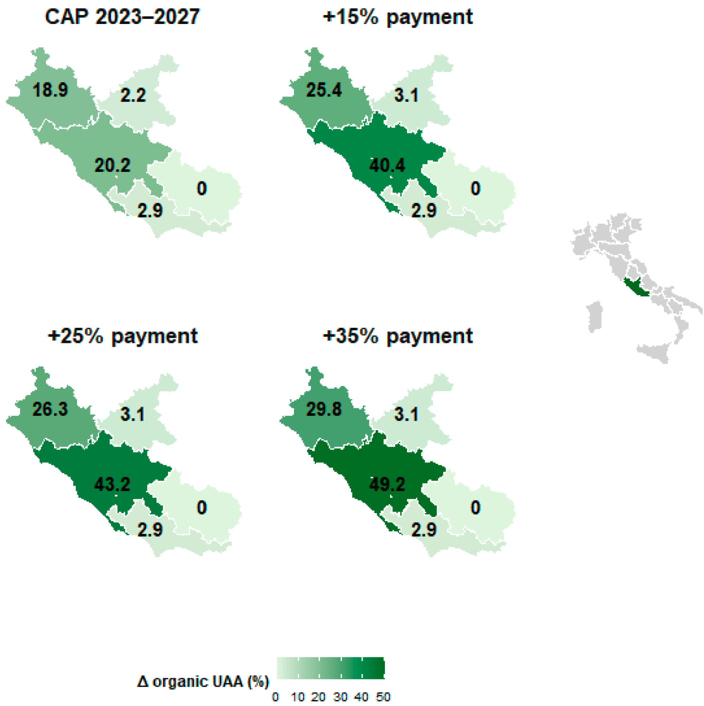

Figure 4. Increase in Organic Farming over the baseline by Province in selected scenarios. Variations indicate the percentage difference from the baseline of each province.

These results partially confirm the baseline situation, in which Viterbo and Rieti already showed a higher incidence of organic farming, while Rome, Frosinone, and Latina showed a lower incidence. According to the results, Viterbo and Rome show a strong potential for expansion, while Rieti remains substantially stable, and Frosinone and Latina confirm a rigid response. This can be explained by the characteristics of these provinces, with Viterbo and Rieti being much more rural and likely characterized by extensive agricultural systems, while Latina and Frosinone are characterized by more intensive production, such as horticulture, greenhouses, and livestock production.

3.3. Heterogeneity Across Types of Farming

Further information emerges from the distribution of converting farms by type of farming (Table 5). Conversion mainly occurs among Arable Crops farms, which already show high sensitivity under the CAP 2023–2027 baseline (+71%) and increase organic area up to 122.6% under this type of farming. Mixed Crops and Livestock farms follow, with more limited increases ranging from 4.4% in the CAP 2023–2027 scenario to 15.8% in the +35% scenario. Finally, Mixed Crops farms respond only starting from a +25% increase in payments, and their variation remains stable even in higher scenarios (+40.2%). Herbivores and Granivores farms, instead, do not respond to increases in unitary payments. Similarly to the distribution of conversion rate across provinces, the results show that the types of farming more prone to increasing organic area are the most extensive, i.e., mixed and arable systems. Other types of farming, such as for livestock farms, conversion is more difficult and less economically convenient in the short run. Moreover, sectors with an already high incidence in the baseline, such as olive groves and tree crops, do not show any relevant variation, suggesting that these clusters of farms have already reached the maximum expansion of organic farming, considering their current structure and characteristics.

Table 5. Variation in Organic Farming (%) in selected scenarios by Type of Farming. Results are expressed as variations from the baseline scenario.

Type of Farming (TF)	Baseline (ha)	CAP 2023–2027	15%	25%	35%
Mixed Crops	103	-	-	40.2	40.2
Mixed Crops and Livestock	692	4.4	6.8	6.8	15.8
Arable Crops	1434	71.0	109.1	111.3	122.6
Tree Crops	1308	1.9	1.9	1.9	1.9
Herbivores	4310	-	-	-	-
Granivores	216	-	-	-	-
Total	8063	13.3	20.3	21.2	24.0

Source: AGRITALIM model simulations based on FADN data.

3.4. Heterogeneity Across Farm Size Classes

At the farm size level, large farms are more willing to convert. These farms already represented the largest share of UAA under organic farming in the baseline (Table 6). Under all of the simulated scenarios, these farms increase both in terms of representativeness and in terms of converted area, from 16.1% in the CAP 2023–2027 scenario up to 28.5% in the +35% scenario. The increase for medium-sized farms (15–40 ha) is more limited, with converted UAA rising from 2.1% to 8.4% over the same scenarios. Small and medium farms (5–15 ha) show a stable increase of 4.9% in UAA under organic farming, i.e., they are not sensitive to increases in unitary payments. Finally, very small farms (<5 ha) do not show any sensitivity to higher payments. Overall, these results show that different farm size classes react differently: although the baseline distribution of organic land was relatively homogeneous, conversion dynamics under increasing payments favor larger farms, while smaller farms remain unresponsive even in the presence of significant increases in policy support.

Table 6. Variation in Organic Farming (%) in selected scenarios by Farm Size. Results are expressed as variations from the baseline scenario.

Farm Size (ha)	Baseline (ha)	CAP 2023–2027	15%	25%	35%
<5	49.8	-	-	-	-
5–15	511	4.9	4.9	4.9	4.9
15–40	1160	2.1	5.7	8.4	8.4
>40	6343	16.1	24.4	25.0	28.5
Total	8063	13.3	20.3	21.2	24.0

Source: AGRITALIM model simulations based on FADN data.

4. Discussion

This study introduces a methodological advancement for analyzing the conversion to organic farming by combining detailed farm-level data from the Italian FADN with the AGRITALIM agro-economic model. The strength of this approach lies in its dynamic structure, which allows the modeling of farms' decision-making over time, explicitly taking into account the costs and potential productivity losses experienced during the conversion phase. These costs and losses are differentiated by crop and livestock product and are based on observed historical data. Unlike many studies that focus solely on full conversion or employ static models, our approach enables the explicit modeling of the conversion decision for each individual farm, capturing the real trade-offs that farmers face during the transition process. By relying on observed farm-level data, the model provides a more accurate representation of farmers' responses to policy incentives and market conditions, making it a valuable tool for simulating the impacts of agricultural policies and for supporting the design of targeted and sustainable interventions.

4.1. Economic Effectiveness and Budget Implications

The results indicate that increasing unitary payments for organic farming leads to relatively limited gains in terms of converted area and the number of farms involved. Kremmydas et al. [25] estimate that achieving the 25% organic target at the EU level would require an increase in the Pillar 1 budget ranging between 4% and 21%, depending on the allocation strategy, while Kremmydas et al. [35], in addition, shows that such increases may come at the expense of other CAP measures. In line with these findings, our results suggest that, at the regional level, the response to higher payments is relatively rigid, pointing to the presence of structural and technical barriers that go beyond financial incentives. This discrepancy suggests that, as the most suitable farms have already transitioned, attracting the remaining conventional farms requires higher payments to compensate for their greater structural rigidities.

Indeed, several studies state that organic farmers, in addition to the typical risks of agriculture, also face sector-specific risks such as those of transition, soil conservation, crop protection, as well as increased price volatility and lower yields [9]. Our simulations confirm that for many farm clusters, the return on conversion remains negative even with significant payment premiums. In these cases, the threshold required to convert highly exceeds the current policy support. Home et al. [36] further show that profit maximization alone is often insufficient to induce conversion, as regulatory, informational, and institutional factors also play a relevant role. However, several studies show a strong positive correlation between CAP organic support and the area under organic farming, highlighting that where payments are low or unstable, organic remains marginal in area converted [37].

Evidence has been found in Poland [38] and in Sweden, where certified organic farming is found to be exclusively driven by agro-environmental subsidies [39]. In Finland, regional differences in organic shares are partly explained by reliance on subsidies [40]. This suggests that scenarios without CAP payments will lead to a reduction in area converted, as suggested by the response in the CAP 2023–2027 scenario, where area increased following higher budgets. Moreover, other research highlights that CAP payments support rapid and broad adoption [41], while other interventions, such as consulting and training, can lower required payment levels and improve persistence, but cannot fully replace financial support [42,43], suggesting that these interventions can support CAP subsidies in their efficacy and cost-effectiveness.

4.2. Territorial Drivers

This pattern becomes even more pronounced under higher payment scenarios, suggesting a relatively rigid response from farms in the Lazio region to financial incentives. Under the most ambitious scenario (+40%), the additional conversion results in an increase in organic UAA of approximately 12%, supported by nearly a 50% rise in the organic budget. These findings point to a declining cost-effectiveness of payment-based strategies, where increases in public spending generate relatively modest additional environmental benefits. Similar patterns of heterogeneous responses to policy incentives across regions and farm types have been highlighted at the EU level [26], suggesting that structural and sector-specific constraints influence the effectiveness of organic conversion policies

The analysis also reveals marked heterogeneity in conversion responses across provinces, farm types, and farm sizes. Spatially, conversion is mainly concentrated in the provinces of Rome and Viterbo, while other provinces, such as Rieti, Frosinone, and Latina, show very limited responsiveness across all scenarios. This spatial heterogeneity suggests that the effectiveness of policy support is strongly conditioned by the structural characteristics of the local productive territory. These differences partly reflect pre-existing structural characteristics and baseline levels of organic farming, with more rural and extensive provinces exhibiting greater potential for expansion compared to areas characterized by intensive agriculture. In more rural and extensive provinces such as Viterbo, the technical gap between conventional and organic management is likely to be lower, making economic incentives more attractive. At the same time, provinces in mountainous areas such as Rieti seem to have reached the maximum expansion of organic systems. Conversely, in areas characterized by intensive agriculture, such as Latina, higher fixed costs in conventional production due to capital investments, i.e., greenhouse systems, participation in producer organizations, or specific supply chains integration create higher barriers. In these contexts, higher payments fail to compensate for the potential loss of market channels or intensive production and higher productivity [44,45]. In addition, physical and climatic conditions may further amplify production fragility, reducing the effectiveness of economic incentives in certain contexts [13,46].

4.3. Sectoral Barriers

At the sectoral level, arable crop farms are the most responsive to increased payments, mixed farms display moderate responses, and livestock farms show little to no reaction. This is consistent with the results of [47], who highlight higher production and market risks in organic livestock systems, where sales often take place in niche markets characterized by price volatility and lower yields. In our framework, the lack of responsiveness in the livestock sector reflects the complexity of balancing animal management and feed production requirements. Transitioning to an organic livestock system often requires significant investments in land for grazing and high-quality fodder, which may not be feasible for smaller and constrained farms in land endowments or those already dependent on the external market for feed supply. Similarly, refs. [8,48] state that farms in intensive sectors tend not to convert because of technical and organizational rigidities. As mentioned before, for these farms, this transition is not a change in input use, but a complete reorganization of farm management, often requiring knowledge and human capital not easily available. For these farms, perceived risks or the risk of not meeting organic quality standards are likely have a stronger influence than the financial incentive. These results confirm that structural and technical constraints, particularly in livestock, may limit the feasibility of organic conversion even in the presence of higher financial support.

4.4. The Role of Scale

Farm size further reinforces this trend, with medium-to-large farms accounting for most of the converted area, while smaller farms appear largely insensitive to changes in unitary payments. This finding is consistent with previous studies showing that farms requiring a more intensive production process tend to convert only when sufficient land endowments and scale economies are available [48,49]. Indeed, smaller farms often face disproportionately higher costs related to organic certification. These fixed costs make area-based payments less effective for these farms. Moreover, access to profitable markets for organic products is often limited to larger farms, also because the benefits of selling organic products go largely to intermediaries and traders, while exporting to richer markets is only accessible to larger farms [50–52]. As a result, conversion barriers remain strong for small and medium-sized farms, which represent the majority of Italian agriculture [15,16,53].

However, Buttinelli et al. [10] state that organic farms are generally less financially constrained, but they are also more dependent on public payments [54]. Sgroi et al. and Mohamad et al. [12,55,56] conclude that, on equal terms, the financial situation of organic farms could get much worse without the liquidity contribution of public payments, underlining the relevance of policy support for the expansion of organic land. Therefore, the combination of market, productive, and policy conditions is key in the decision to convert. Many authors stress the relevance of the combination of these three factors, where the higher prices obtained by organic products in the market should compensate for the lower yields [12,55–57], even though this is not always the case, especially for livestock products and some vegetables, as well as under specific soil conditions [13,47,58].

4.5. Limitations

These results should be interpreted in light of the behavioral assumptions embedded in the model, which assume rational, profit-maximizing farmers who respond to policy incentives based on expected revenues and costs. While this framework allows a clear assessment of economic trade-offs, it does not fully capture the non-economic drivers of conversion decisions, such as risk preferences, personal values, information constraints, or generational factors [42,43]. Moreover, AGRITALIM is designed to model the choice to transition toward organic systems but does not currently account for reversion, i.e., the decision to switch back to conventional farming, nor does it model partial conversion at the farm level. The partial responsiveness observed even under favorable payment scenarios may therefore reflect not only economic constraints but also the presence of structural and informational barriers that are not explicitly modelled. Among them, the lack of specialized technical assistance or consulting is not explicitly parameterized in the current version of the model [17,45]. In the real world, environmental values, social networks, and individual risk aversion could either mitigate or amplify these trends. Furthermore, the model operates under the assumption of stable market conditions, not accounting for potential input price spikes or higher volatility driven by geopolitical, commercial, or climate-related events. While this approach allows for isolating the role of CAP payments in organic farming conversion, market volatility could alter the conditions of profitability of organic versus conventional farming. Finally, we do not account for changes in crop quality, even if partially addressed by the coefficients differentiating organic and conventional products, as lower quality may limit access to high-value supply chains or markets. A further limitation concerns the assumption that transitions to organic farming are only allowed in strata where organic production is observed in the reference period. While this ensures a conservative and empirically grounded modelling framework, it may also reflect limitations in the sample coverage of organic farms in the FADN data. However, the flexibility of the model allows for the inclusion of differential parameters from various sources or can be estimated econometrically.

4.6. Policy Suggestions

Instead, from a policy perspective, these findings suggest that strategies relying solely on higher organic payments are unlikely to achieve widespread adoption. More comprehensive policy strategies are needed, combining financial incentives with measures aimed at reducing fixed conversion costs, providing targeted technical assistance, and facilitating market access, particularly for structurally disadvantaged farm types [36,45]. Market access, price premiums, structural conditions, and technical constraints therefore emerge as key determinants of farmers' willingness to convert to organic farming. Furthermore, the dynamic nature of the model emphasizes the importance of continuous monitoring and evaluation of policy outcomes over time. Farm-level simulation tools, such as the one proposed in this study, can support evidence-based policy design and help identify more targeted and cost-effective pathways to achieve the objectives of the F2F Strategy. Future research could further integrate non-economic factors influencing farmers' decisions, such as risk preferences, sociodemographic factors, and information access in the modelling framework, in order to improve the accuracy of predictions and policy relevance. Additionally, exploring the role of consulting, training, and market support could shed light on their comparative cost-effectiveness and complementarities with CAP payments.

4.7. Future Research Directions

Future research could further extend the proposed framework in several directions. First, applying the model to other regional contexts would allow for comparative analyses and improve the generalization of the results. Second, incorporating behavioral heterogeneity among farms, i.e., factors influencing farmers' decisions, such as risk aversion, sociodemographic factors, and information constraints, could provide a more comprehensive understanding of farmers' decision-making processes. Additionally, future studies could explore the interaction between CAP payments and other policy instruments, such as training programs, market access, and advisory services. This would allow assessing the effectiveness of integrated policy mixes across territories as sustainability-oriented practices, innovation, and integrated policy frameworks are found to support firm performance and sustainable transitions in the EU context [59,60]. Finally, including market dynamics, such as price volatility and consumer demand evolution, could further improve the policy relevance of the proposed framework.

5. Conclusions

This study highlights the complexity of promoting organic farming in the Lazio region, Italy. Two main hypotheses were tested. The results support the H1, as the dynamic modeling framework distinguishing conversion and maintenance phases captures more realistic and gradual adoption patterns at the farm level. They also support H2, showing that increasing CAP payments contributes to the expansion of organic area, with stronger responses among extensive, larger, and arable farms compared to small, intensive, and livestock farms. The analysis indicates that increasing unitary payments for organic farming leads to additional conversion, but with a declining cost-effectiveness of purely payment-based strategies. Conversion patterns are not homogeneous across areas and types of farming: arable and large farms are more responsive, while livestock and small farms show more limited reactions even under ambitious payment scenarios.

Overall, increases in payment-based incentives generate an expansion of the area converted, but financial support alone appears insufficient to foster homogeneous adoption across areas, farm sizes, and types of farming. These findings suggest the relevance of structural, technical, and informational constraints in influencing farmers' decisions. Policy mixes combining CAP payments with training, consulting, and improved information and market access may enhance policy support and promote a widespread adoption of organic practices across territories and sectors.

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Appendix A

Table A1. Number of observations by production system (conventional and organic) for selected group of crops in a single province and altitude class (Viterbo-Hills), used to compute differential parameters (Δpc, Δy, Δc).

Crop	Conventional	Organic	% Organic	Δpc (€/100 kg)	Δc (€/ha)	Δy (100 kg/ha)
Tree crops	506	321	38.8	8.9	−280.1	−3.5
Cereals	404	134	24.9	1.5	−86.1	−6.9
Vegetables	93	30	24.4	27.3	1780.4	−20.9
Legumes	193	101	34.4	44.2	17.9	−8.6

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