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Harmonizing economic and environmental costs in the CAP to improve efficiency and effectiveness of policies

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Abstract

The recent CAP aims at better targeting beneficiaries and being more selective in its objectives. This has drawn attention to how policies interact with resources used by farms in terms of both economic and environmental costs. Conditional Process Models under Structural Equation Modeling framework may offer statistical indications on these complex interactions. The proposed model, called SMIRNE, is applied to an Italian macro-area at severe risk of land pollution (Pianura Padana) caused by livestock sector. Results show a more substantial support from pillar I policies than those provided by pillar II in addressing a relevant response of policies to the economic and environmental costs of the livestock activities with reference to the use of land.
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Keywords: CAP evaluation; Environmental farms costs; Economic farms costs; Structural Equation Modeling; Conditional Process Models

1. Introduction

The Common Agricultural Policy (CAP) is considered one of the milestones of the European Union (EU) and certainly attracts the highest share of the EU balance. With the Agenda 2000

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reform in 1999, the CAP was organized into two pillars: the I pillar including market and income support, and the II pillar devoted to rural areas and farm competitiveness. Since then, the CAP has pretty much kept its features, progressively justifying its intervention through the concept of multifunctionality and the remuneration of positive externalities and public goods and reducing accordingly the envelope of financial resources devoted to price and market support (van Huylenbroeck & Durand (2003); Sorrentino et al. (2011); (Kiryluk-Dryjska & Baer-Nawrocka, 2019; Gohin & Zheng, 2020). With the most recent reform, the objectives of the CAP were focused on environmental sustainability (along with economic and social objectives) and Member States (MSs) were given more flexibility in designing and implementing policies, amplifying the principles of targeting, concentrating, and selecting instruments and resources (Henke et al., 2018; Guth et al., 2020; Cagliero et al., 2021; Cortignani & Coderoni, 2022). A timely research question for assessing whether agricultural production might be more environmentally sustainable in the future consists in the extent to which the CAP can have a persistent response on the environment without significantly reducing inputs or increasing costs of natural resources. This translates into the specific research question of this paper: how to quantify land tolerances and interpret natural resources loss rates to keep the uncertain balance between agricultural productivity and sustainability. In this respect, agricultural policies should play a crucial role to attenuate this potential uncertainty. This, in turn, leads to the choice of an ecological and economic-oriented statistical model that simultaneously tests for the efficacy of the agricultural policies as an outcome evaluation of the environmental impacts of the resources used, and their relative economic costs at the farm level. This sort of analysis is not new and the literature is rich of diverse approaches and results. Many of them essentially look at the II pillar of the CAP and specifically at the agro-environmental measures (AES) as the main vehicles of change in the environmental impact of agricultural policies (Ait-Sidhoum et al., 2023; Villamaor-Tomas et al., 2019). Other works refer also to the I pillar of the CAP, and particularly to the greening elements of direct payments (Cimino et al., 2015; Cortignani et al., 2017; Matthews, 2013). What is relatively new, in this work, is the assessment of the combined effect of the two pillars of the CAP in simultaneously reducing the environmental impact and the production costs of a specific agricultural activity. Other relevant work has been done on the matter, but with different methodology and with different objectives. Lovec et al. (2020), for example, explore whether the new CAP, with the new system of incentives and restraints, translates into a more effective policy. However, they conclude that there is not enough evidence of that in absence of proper policy impact evaluation. Mary (2013) looks at the total factor productivity of French crop farms investigating the impact of pillar I and pillar II, concluding how many measures have a negative impact. Quiroga et al. (2017) assess the impact of four different categories of CAP subsidy programs on efficiency of the system and on environmental sustainability. They conclude that both pillars generate a disincentive effect on productivity; however, the CAP overall promotes technical efficiency convergence within Europe.

To our view, the application of the Conditional Process Models (CPM) (Hayes & Rockwood, 2020; Hayes & Preacher, 2013) to ecological-economic problems, with simultaneously embodying mediations and especially moderators' effects for CAP processing under Structural Equation Modeling (SEM) framework (Bollen, 1989), is a novel and unseen statistical perspective. As a result, we developed the so-called SMIRNE model (Simultaneous Moderators Impact on environmental ResilieNce at Economies) with the use of the Italian Farm Accountancy Data Network (FADN). To verify the appropriateness of the model and the solidity of the theoretical background we worked on a specific intensive sector (livestock) where policies of both I and II pillars act quite intensively, in an Italian macro-region (the *Pianura Padana*, which include four administrative regions: Lombardia, Piemonte, Veneto and Emilia Romagna) with high level of pollution from livestock and other agricultural activities (Dell'Unto, Dono & Cortignani, 2023). Our model assumes direct and indirect relationships among input (land), output (livestock products) and policies (I and II pillars), in the years 2015–2021. Essentially, the proposed SMIRNE model aims to provide answers to two punctual research questions:

H1) do policies reduce the environmental impact of a specific agricultural activity?
H2) do policies reduce the costs of a specific agricultural activity?

The paper is structured as follows. The next section will present a brief background of the CAP efficiency and its evolution. Successively, the method and data will describe a short overview of CAP modeling with the CPM-based approach to SMIRNE model and the FADN data used. A fourth part will discuss the results of SMIRNE performance. The paper will end with conclusive remarks and policy implications for future research.

2. Policy targeting in the CAP reforms

In more than 50 years of CAP, objectives and tools of the policy have been deeply changed. From a common box tool based on the "one size fits all" principle, the CAP moved to a more tailored policy built to fit the specific needs of the National agricultures (Grochowska, 2023; Henke et al., 2018). The main characteristics of this long process were the progressive decoupling of support from production, together with the enhancement of the multifunctional roles of agriculture, and the progressive growth of a national-based path dependency that encourage MSs to seek and fulfil their own preferences in terms of policies goals. The decoupling paved the way to a more targeted support to farmers' income, in consideration of the poor terms of trade of agriculture with other sectors of the economy, switching the goal of support from the product to the producer (Sorrentino, Henke & Severini, 2011). Simultaneously, the CAP became the main payer of the public goods produced in agriculture (Burrell, 2009; Greer, 2013). Over time, CAP measures have been shifted away from their original targets, in a process of continuous adjustment and retargeting (Mathews, 2013: Swinnen, 2015). For this reason, while it is increasingly difficult to identify the main target of specific policies, they rather need to be evaluated in a holistic way, also considering the main interactions amongst them that are being built by time (Greer, 2023).[2] The model behind the new CAP is based on the policy cycle frame that includes the definition of sound objectives based on public needs, a direct and clear link between objectives and means and an evaluation of the measures implemented (Lovec et al., 2020). However, many scholars have criticized the lack of a real consistency among stated goals and actual measures, the former being announced in "new clothes" and the latter being the traditional measures of the CAP. Poor targeting and the resistance of an evident path

[2] For example, direct payments have been considered integrations to income, compensations for increasing costs, green compensations, incentives to increase farms' resilience, and so on. They are built as a direct support to farmers' income, but their effect on the increase of costs and the capitalization effect on the land value has been largely studied (Baldoni & Ciaian, 2023; Baldoni et al., 2021; Guastella et al., 2021).

dependency result in an opaque and inefficient distribution of support, not really modifying the old status quo (Lovec et al., 2020; Swinnen, 2015).

All in all, tools that can measure and verify the effectiveness of I and II pillar policies in addressing specific goals of the CAP are very useful for two concurrent set of reasons: to determine the ability of the CAP to give specific answers to well determined societal questions and if the current toolbox of the Cap is coherent with its renovated goals. For these reasons, our next step is to feed these questions into a structured model, with the specific goal of assessing the capability of I and II pillar policies in addressing environmental issues, according to the new CAP objectives and the more general goals of sustainability.

3. Method and data

3.1. Modeling the CAP with the CPM-based SEM approach

The past research on the ex-post modeling of the CAP impacts at the farm level appears vast and not only based on an econometric approach (Gohin & Zheng, 2020; Kiryluk-Dryjska & Baer-Nawrocka, 2019). Moreover, important mathematical developments through the Individual Farm Model for Common Agricultural Policies (IFM-CAP) (Kremmydas et al., 2021), the AGRITALIM (Cortignani & Buttinelli, & Dono, 2022), FSSIM, EFEM, FARMIS, and CAPRI models (Angenendt et al., 2018) were made at the EU level. However, structural statistical models with simultaneously embodying mediators and especially moderators' (or interaction) effects for the CAP processing under SEM framework seem a promising new direction for the CAP evaluations that goes beyond the classical econometric view. Moreover, SEM applications are becoming ever more popular in this field (Angelini et al., 2017; Li et al., 2018; Santibánez-Andrade et al., 2015).

CPMs belong to the broad family of the measured variable path analysis-based structural equation modeling (MVPA-based SEM) where mediators and moderators are both embodied into a path model (Hayes & Rockwood, 2020; Hayes & Preacher, 2013). In figure 1a parallel multiple mediation (Me1 and Me2) with multiple moderation (Mo1 and Mo2) example (but many others can be hypothesized) of a statistical conditional model is depicted. The multiple mediation process occurs when the direct relation between X and Y passes through the two variables Me1 and Me2 that mediate the effect of X

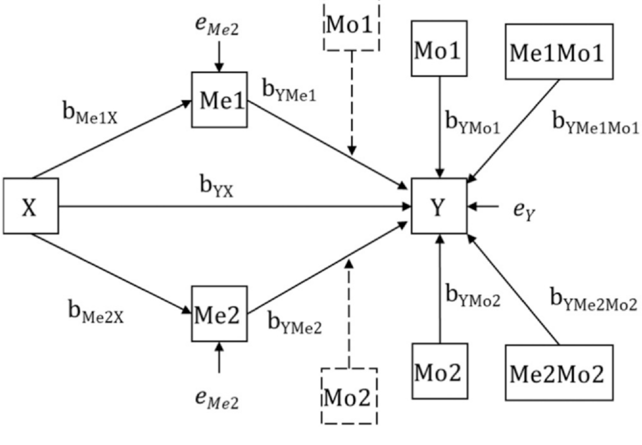

Figure 1. An example of multiple statistical conditional process model.

on Y. Differently, the multiple moderation process appears when the effects of Me1 and Me2 on Y depend on other two variables Mo1 and Mo2 (see the dashed lines in figure 1). These two moderator variables impact on Y both singularly (Mo1 and Mo2) and interactively (Me1Mo1 and Me2Mo2). (see the solid lines in figure 1).

The whole structural process depicted in figure 1 can be written in the following structural equations system with *b* and *e* are respectively the structural estimations and the error terms:

$$Me1 = b_{Me1X}X + e_{Me1} \tag{1}$$

$$Me2 = b_{Me2X}X + e_{Me2} \tag{2}$$

$$Y = b_{YX}X + b_{YMe1}Me1 + b_{YMe2}Me2 + e_{Y} \tag{3}$$

$$Y = b_{YMo1}Mo1 + b_{YMe1Mo1}Me1Mo1 + e_{Y} \tag{4}$$

$$Y = b_{YMo2}Mo2 + b_{YMe2Mo2}Me2Mo2 + e_{Y} \tag{5}$$

From the equations (1) to (3) it is possible to determine the mediation effects from X to Y by means of the indirect effects $b_{Me1X} * b_{YMe1}$ and $b_{Me2X} * b_{YMe2}$ whereas from the equations (3) to (5) the respective conditional effects ($b_{YMe1} + b_{YMe1Mo1}$) and ($b_{YMe2} + b_{YMe2Mo2}$). Notably that, on one hand, b_{YMo1} and b_{YMo2} represent the direct effect of the variables Mo1 and Mo2 on Y and they might not be of interest, but necessary for the correct estimation of the whole interaction process (Hayes & Preacher, 2013, p. 237–238); on the other hand, the $b_{YMe1Mo1}$ and $b_{YMe2Mo2}$ constitute the most relevant parameters for testing the interactions Me1Mo1 and Me2Mo2 and must be statistically different from zero to support these hypotheses.

3.2. SMIRNE model specifications

The SMIRNE mechanism is based on the links between quantities of farm resources Rs and a given output Y by passing through a cost-process that have a dual impact - one economic and

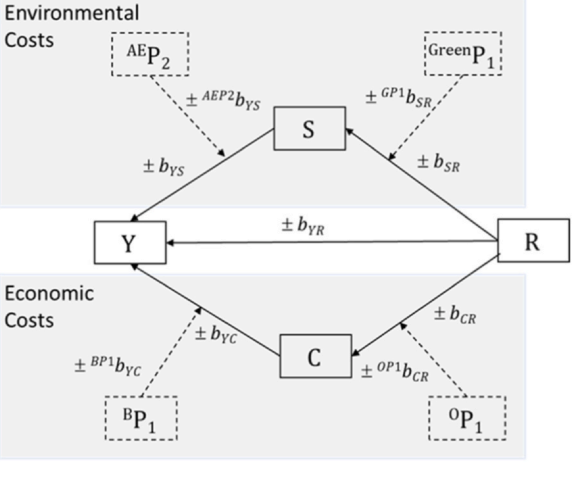

Figure 2. SMIRNE path model.

another environmental - on the farm economy and the environment resilience, respectively. Figure 2 represents the path diagram of SMIRNE, based on the CPM simplified path diagrams presented in figure 1, where Y is an output variable, for instance, the gross salable livestock production of each farm, that depends on the quantity of the resource R used and, from the bottom part of the model, on the economic costs while using that resource. Furthermore, these costs operate also like a mediator between Y and R. Likewise from the top part of the model, the Y depends on the environmental impacts S while using the resource R. S operates like another mediator between Y and R. As a result, SMIRNE hypothesizes the two types of impacts on the farm output Y, one is of economic nature, and the other is environmental by enclosing all this process in a multi-mediations rhomboidal system. Furthermore, the model introduces the influence of the agricultural policies, Ps, that operate like a moderator effect on the mediation paths.

Hence, the whole process of estimation that involves the non-fixed effects is presented: a) the structural parameters b_{SR} and b_{CR} respectively represent the impacts of using the resource R on the environmental and the economic costs; b) the structural parameters b_{YR}, $b_{YS,}$ b_{YC} respectively represent the impacts of the environmental and the economic costs on the output Y; c) the structural parameters ${}^{GP1}b_{SR}$ and ${}^{OP1}b_{CR,}$ respectively represent the agricultural policies impacts as moderator variable while using the resource R on the environmental and economic costs; d) the structural parameters ${}^{AEP2}b_{YS}$ and ${}^{BP1}b_{YC}$ respectively represent the agricultural policies impacts as moderator variables on the output Y while using the environmental and economic costs. The statistical significance and the signs of the structural parameters are essential to understand the SMIRNE process: a) whenever b_{SR} and b_{CR} are statistically different from zero and positive the more using of the resource R the more it costs; b) whenever b_{YS} and b_{YC} are statistically different from zero and positive the more using of that type of cost the more it impacts on the output Y; c) whenever b_{YR} is statistically different from zero and positive the more using of the resource R the more the farmer obtains an output Y, but without considering the costs. Now, focusing on the agricultural policies evaluation, every structural parameter of the interactions with policies needs to be statistically different from zero and negative to be potentially useful in terms of economic savings and environmental progresses (i.e., reducing the environmental impacts). As a matter of fact, by recalling the equations (3) to (5) the respective conditional effects in the SMIRNE path model are the following: (b_{SR} + ${}^{GP1}b_{SR}$), (b_{CR} + ${}^{OP1}b_{CR}$), (b_{YS} + ${}^{AEP2}b_{YS}$) and (b_{YC} + ${}^{BP1}b_{YC}$). The results of these algebras must be statistically different from zero and negative to get the desiderata effects of the agricultural policies.[3] Furthermore, by using the path analysis multiplicative parameters properties it is possible to calculate the indirect effects of each resource R on Y. For example, the farm output Y has the potential indirect effects ($b_{SR} * b_{YS}$) and ($b_{CR} * b_{YC}$) due to the mediation variables S and C. These indirect effects can respectively provide information about the impact of environmental and economic costs on Y while using a resource R that, in turn, affects the S and C costs. The indirect effects can be also set up with the agricultural policies coefficients when they occur and are of interest. For the greening pillar I polices a potential indirect effect on Y is the multiplicative term (${}^{GP1}b_{SR} * b_{YS}$) while for the other policies of pillar I is of (${}^{OP1}b_{CR} * b_{YC}$). These indirect paths provide information about how the policies interacting with the resource R

[3] Conversely, should these interactions terms be statistically different from zero and positive, or not statistically different from zero with any sign, they do not operate like economic savings and environmental progresses of the agricultural policies because their impacts are not those expected and thus the associated policies are not beneficial.

impacts on Y while passing through the S and C costs, respectively. All the path connections have been here considered as linear for a starting evaluation of the model in terms of simplicity of the interpretations, but they might be also modelled as non-linear in the future and in the case that more complex hypotheses were necessary.

3.3. Data source and variables description

The analyses were carried out using the Italian Farm Accountancy Data Network[4] (FADN) database, which is the only source at EU and farm level data on agricultural structures, productions, and economic results. In Italy, cattle farming is concentrated in the northern regions, particular in *Pianura Padana*, which houses over 29 % of livestock farms and 66 % of cattle (ISTAT, 2020). This area reaches levels of agricultural intensity similar to other major European producers, raising concerns about soil pollution from livestock farming. Recent EU policies, both specific and non-specific, aim to reduce this soil pollution. In this study and for the *Pianura Padana* alone, 3241 livestock farms were selected from the Italian FADN for the accounting years from 2015 (start of the 2014–2020 CAP) to 2021 (the latest available year).

To implement the SMIRNE model, FADN variables were grouped into functional macro-categories reported in table 1. Gross salable production from livestock activity was used as output, and the impact of agricultural policy interventions was estimated. All agricultural policies related livestock sector were included in the "outcome policies" category. In particular, CAP measures, distinguished in I and II pillars, have been grouped following an institutional criterion based on their explicit "main" goals as expressed in the regulations.[5]

I. pillar measures:

a) Basic payments (BP1) include all those measures which are an income support scheme for farmers meeting certain criteria, based on payment entitlements owned by farmers.
b) Greening (GreenP1) is the green payment, that is, the payments that the farmers receive for adopting environmental protection and climate change mitigation practices (maintaining permanent grassland, crop diversity and ecological focus areas).
c) Other (OP1) contains all measures of the I pillar not included into the two previous groups.

II. pillar measures:

d) Agri-environmental (AEP2) considers all rural development policy measures that contribute to climate action and sustainable management of natural resources.

Resources (environmental costs) gather all the physical resources that livestock farms are equipped with, which have a certain impact on the environment and are relevant to this case study.

Economic costs measure the economic value (expressed in euros) of factors that impact the environment, for example, expenses incurred for purchasing livestock feed, fertilizers, etc.

[4] The field of observation of the Italian FADN is composed of farms that achieved a threshold of economic size equal or greater to 8000 euros of Standard Output. More information is available at: https://rica.crea.gov.it

[5] For classification criteria of the EU agricultural policies see, for example, the recent OECD work (De Boe, 2020).

Table 1
List of model variables with means and standard deviations from 2015 to 2021.

Macro categories	Variable in short*	Description	Means (SD)
Output	Gspl_Y	Gross saleable livestock production	393859.750 (± 916372.019)
Outcome Policies	BP1	Basic Payment Pillar I	18132.733 (± 60894.043)
	GP1	Greening Pillar I	8479.420 (± 21172.322)
	OP1	Other Pillar I	9765.475 (± 34435.720)
	AEP2	Agri-environmental Pillar II	4218.557 (± 13452.161)
Resource (Environmental Costs)	Uaa_R	Utilized Agricultural Area (UAA)	58.641 (± 90.794)
	F_S	Forage crops (ha)	38.215 (± 58.902)
	Lsu_S	Total Livestock Units (LSU)	166.295 (± 371.223)
	Ll_S	Livestock load per hectare	4.283 (± 13.669)
	Kw_S	Power of machines (KW)	348.181 (± 334.652)
	Ma_S	Machine power per hectare	11.199 (± 12.353)
	Nt_S	Number of tractors per farm	10.027 (± 5.712)
	Fert_S	Fertilizers per hectare	124.797 (± 1402.265)
	Pest__S	Pesticides per hectare	127.434 (± 516.246)
Economic Costs	Li_C	Land Capital Intensity	15148.745 (± 20723.822)
	Oc_C	Operating capital	8050.293 (± 30464.704)
	Mec_C	Mechanization cost per UAA	258.782 (± 304.322)
	Feed_C	Feed cost per LU	407.690 (± 373.387)
	Fodd_C	Fodder cost per LU	76.928 (± 121.349)
	Fert_C	Fertilizers cost per hectare	3159.412 (± 7373.541)
	Pest_C	Pesticides cost per hectare	2101.554 (± 6906.188)
	TCR_C	Total cost of the land rent	20112.583 (± 135559.525)

Note: *extensions _R, _S, _C stands for Resource, Sustainability, Cost in the model, respectively.

Finally, the study also assessed the effects of agricultural policies on land values (a productive factor used in agricultural production) through opportunity cost. Using FADN data, an average provincial land rental cost per hectare was defined (at provincial level), which was multiplied by the farm's UAA to obtain the total cost of the land rent. This variable was considered to take into account the debated issue of the internalization of the capitalization rate in the land value (Graubner, 2018; Guastella et al., 2021; Baldoni & Ciaian, 2023) for controlling for a potential short-term period effect.

4. Results

For space reasons, we reported here only the main results concerning the structural models fit indices and the standardized estimations.[6] Since some involved variables[7] significantly deviate from multi-normality, we used the robust maximum likelihood (RML) (Satorra & Bentler, 1994) correction with an asymptotic covariance matrix, which is the most common method of

[6] Un-standardized estimations, standard errors, estimated correlations (these latter were found all under.85, especially the correlations among I and II pillar policies, to achieve a discriminant validity (Kline, 2011) can be requested to the first author. The analyses were conducted using LISREL v8.80 (Jöreskog & Sörbom, 2007).

[7] Some variances were found particularly extreme, and they were rescaled (i.e., multiplied by constants ranging from.01 to.0001 where they occur) before conducting the analyses to facilitate the model convergence (Muller & Hancock, 2019) but not affecting differences among the scores (Kline, 2011). The variables involved in the interactions were means centered to avoid convergence problems (Hayes & Preacher, 2013).

Table 2
Summary of SMIRNE model fit statistics.

n	SB χ^2	*df*	AIC	GFI	CFI	NNFI	RMSEA	90 % CI for RMSEA
3241	1592.18	444	2344.18	.62	.99	.99	.028	(.027;.030)
3241	*516.20*	*444*	*1268.20*	*.64*	*1.00*	*1.00*	*.007*	*(.004;.010)*

estimation in this situation (Finney & Di Stefano, 2013). Moreover, bootstrapping analyses on the asymptotic covariance matrix were performed[8] to test for the estimations' stability, considering the sampling variability, especially for testing mediation and moderator estimates (Hayes & Preacher, 2013; Lau & Cheung, 2012).

In tables 2 and 3 were respectively reported the model goodness of fits and the standardized coefficients of all the direct effects of the SMIRNE model with the using of the Total Cost of the Land Rent (i.e., TCR_C) as economic cost to consider the short-term effects of the policies. The overall model goodness of fits was all satisfactory according to the fit-indices cut off criteria stipulated by the main SEM literature (Fan et al., 2016; Hu & Bentler, 1999; Kline, 2011; Schermelleh-Engel et al., 2003). This was an initial important result that confirmed the rhomboidal specifications of SMIRNE path model were consistent with the data. Even the bootstrapping solutions (i.e., *italic line* in table 2) with 100 % of resampling were found satisfactory and thus the model seemed to be robust at sampling fluctuations.

As previously discussed, the significant interaction effects useful for reducing environmental and economic costs were those found with negative signs. Starting from the basic payment of pillar I (i.e., BP1) the only useful interaction effects were the ones with operating capital costs (BP1-Oc_C: −.21), land capital intensity (BP1-Li_C: −.05) and total cost of the land rent (BP1-LC_C: −.13) although the last one was found not statistically different from zero in the bootstrap solution and thus the interaction parameters of – .13 cannot be considered very trustful. In sum, it means that the basic payments of PI were found the most useful in reducing the operational costs while producing the gross saleable livestock (i.e., Gspl_Y). The direct coefficient of the operational costs on the gross saleable livestock was of.19 whereas the interaction term with the basic payment of PI was of – .21; consequently, the conditional effect of Oc_C on Gspl_Y was of – .03 (i.e.,.19 + (−.21)) that induces to a reduction of the operating capital costs themselves while using the basic payment of PI. Concerning the land capital intensity cost, the relative conditional effect was of – .05 (i.e., −.01 (not significant) + (−.05)).

Moving to pillar II, an effective support was found only for the livestock load per hectare (i.e., Ll_S) since both for fertilizers (i.e., Fert_S) and forage crops (i.e., F_S) the bootstrap solution did not confirm the statistical significance. The conditional effect of Ll_S on Gspl_Y was of – .20 (i.e., −.12 + (−.08)) with the polices that incremented an initial low impact of this environmental cost on the outcome.

Regarding the greening pillar I and the other pillar I to support the using of the utilized agricultural area (i.e., Uaa_R) they respectively effected on: a) the pesticides (i.e., Pest_S with the relative conditional effects of −.03 (i.e., .15 + (−.18))); b) the livestock load (i.e., Ll_S with the relative conditional effect of −.45); and on c) the costs of fodder (i.e., Fodd_C), mechanization (i.e., Mec_C), operating capital (i.e., Oc_C), feed (i.e., Feed_C) with the relative conditional effects respectively of – .05; – .37; – .33; – .14 (i.e., −.01 (not significant).

[8] The number of bootstrap samples was of 1000 (Hair et al., 2018) with 100 % resampling of the raw data.

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Table 3
Direct Effects of Standardized Coefficients for the SMIRNE model.

Model 1	Uaa_R	Pest_S	Fert_S	F_S	Lsu_S	Ll_S	Kw_S	Ma_S	Nt_S
Gspl_Y									
Direct effect	-.01 (−.00)	**-.01** (−.01)	**.01(.01)**	-.00 (−.02)	**.75 (.75)**	**-.12 (−.08)**	.01 (.00)	**-.01** (.00)	-.01 (−.01)
	Pest_C	Fert_C	Fodd_C	Li_C	Mec_C	Oc_C	Feed_C	TCR_C	
Gspl_Y Direct effect	**-.12 (−.08)**	**.05 (.03)**	**.03 (.04)**	-.01 (−.01)	**.03 (.04)**	**.19 (.09)**	**.10 (.11)**	**-.02** (−.01)	
	BP1	BP1-Pest_C	BP1-Fert_C	BP1 -Fodd_C	BP1-Li_C	BP1- Mec_C	BP1-Oc_C	BP1- Feed_C	BP1 – TCR_C
Gspl_Y Direct effect	**.31** (.33)	**.24 (.25)**	.00 (.05)	**.06** (.01)	**-.05** (−.04)	**.08** (.07)	**-.21 (−.14)**	**.36 (.52)**	**-.13** (−.14)
	AEP2	AEP2-Pest_S	AEP2- Fert_S	AEP2-F_S	AEP2-Lsu_S	AEP2-Ll_S	AEP2-Kw_S	AEP2-Ma_S	AEP2-Nt_S
Gspl_Y Direct effect	**-.06** (−.07)	.01 (.01)	**-.03** (−.05)	**-.04** (−.05)	-.03 (−.08)	**-.08 (−.10)**	.04 (.10)	.01 (.02)	.00 (−.01)
	Uaa_R	GP1	GP1_R						
S									
Direct effect									
Pest_S	**.15 (.16)**	**.25 (.24)**	**-.18 (−.18)**						
Fert_S	.23 (.19)	-.13 (−.09)	.18 (.15)						
F_S	**.73 (.77)**	.05 (.05)	.04 (−.00)						
Lsu_S	**.28 (.23)**	**.42 (.55)**	.09 (.04)						
Ll_S	**-.22 (−.21)**	**.45 (.45)**	**-.23 (−.23)**						
Kw_S	**.48 (.54)**	**.14** (.04)	-.06 (−.01)						
Ma_S	**-.40 (−.41)**	.11 (.06)	.09 **(.13)**						
Nt_S	**.11 (.12)**	**.15 (.07)**	**-.10** (−.06)						
	Uaa_R	OP1	OP1_R						
C									
Direct effect									
Pest_C	**.29 (.29)**	**.19 (.19)**	.09 (.05)						
Fert_C	**.37 (.39)**	**.20 (.22)**	.00 (−.07)						
Fodd_C	**.10 (.10)**	**.10 (.09)**	**-.15 (−.15)**						
Li_C	**-.17 (−.16)**	**.09** (.04)	.01 **(.03)**						
Mec_C	**-.19 (−.18)**	**.34 (.33)**	**-.18 (−.16)**						
Oc_C	**-.13 (−.11)**	**.34 (.34)**	**-.20 (−.21)**						
Feed_C	-.01 (.04)	**.17 (.09)**	**-.14 (−.11)**						
TCR_C	**.15 (.22)**	.01 (.03)	**-.02** (−.02)						

Notes: values in bold are significant at the 95 % confidence level. The bootstrap standardized estimations are between brackets.

By checking the indirect effects on Y by following the multiplicative paths between the policies moderator parameters and the relative mediation coefficients (refer to figure 3b and table 5) it was interesting to underline that:

a) the impact of GP1_R on Ll_S (i.e., −.23) passing through the path between Ll_S to Y (i.e, −.12) was of + .03 (i.e., −.23 * −.12) with providing and increasing of this cost on Y although attenuated by the influence of AEP2_Ll_S coefficient of − .08. Hence, the cost of using livestock load per hectare due to the UAA in producing gross sealable livestock production was attenuated both by the greening policies of pillar I at the step of using the resource UAA and by the agri-environmental policies of pillar II at the step of costs for the environment. On the other hand, for Pest_S the policy help was effective only at the using the resource UAA with the support of the greening policies of the pillar I (i.e., −.18) because the other two relative coefficients (i.e., Pest_S to Y and AEP2_Pest_S to Y) were respectively found unstable or not statistically different from zero.

b) the impacts of OP1_R on Fodd_C, Mec_C, Oc_C, Feed_C passing through the relative paths from C to Y provided all negative multiplicative terms on Y; and this was reinforced also by the respective moderator negative coefficients of BP1 for Oc_C, but not for Feed_C to which the BP1 did not properly help. In any case, this could mean that the basic payments of pillar I and the other payments worked well together in reducing those economic costs while producing Y with the only exception of the feed cost at the level of basic payments.

Overall, both H1 and H2 were satisfied by SMIRNE model with pillar I found to be more effective than pillar II. Such effect translates into an effective impact of pillar I on the general costs of the livestock activities, particularly in the case of the greening components of pillar I, which seem to be more selective and targeted compared to the environmental components of pillar II. This result is quite interesting in the overall evaluation of the CAP measures, because it is rather counterintuitive, and also because it does not follow a dominant stream of literature claiming pillar II as more targeted, selective and effective in supporting environmental issues and sustainability within the CAP toolbox.[9] The effect of the short-term period by using the total cost of the land rent variable did not provide trustful support: the bootstrap solution underlies a sampling fluctuation influence while estimating the interaction policies effects that yielded to an unstable statistical significance. However, this effect merits being investigated in the future.

5. Concluding remarks

The main CAP objective is to support the agriculture production without increasing costs both for farms and the environment. In this respect, the ambition of the proposed statistical model SMIRNE is to simultaneously quantify without any constraints the environmental progress, and the economic costs savings, due to the effective impact of the whole EU agricultural policies on the resources, and thus the relative costs, used by each farm in the agricultural production. So far, most analyses have been focusing only either on specific instruments or on single pillars, as if policies were totally isolated from one another. In this effort, the paper represents an advancement in the assessment research of policies impact because it takes into consideration both policies of the I and II pillars of the CAP simultaneously. In this work, only the UAA for each farm, together with examples of relative environment and economic costs,

[9] For a thorough discussion on pillar II efficacy, see, among the others, Defrancesco et al. (2008); Ribeiro et al. (2016) and, more recently, Canessa et al. (2024).

was tested as a resource, but other types of resources and relative costs can be tested. In essence, the proposed model performed well concerning the path specifications and opened rooms for theoretical (confirmative) and/or empirical (explorative) debate to understand the complexity of interaction of the CAP while influencing the economic system in agriculture and the consequent resilience of the surrounding environment. The extent to which the main CAP measures are targeted and selective represents a relevant research question towards the effectiveness of the generous public support to agriculture and rural areas. SMIRNE results stipulated that, with reference to the livestock sector in a highly polluted area such as *Pianura Padana*, pillar I performed better than II pillar. This latter was found effective for the livestock load per hectare environmental cost only. This result is, in our opinion, quite relevant since I pillar policies, and especially the direct payments on the operational and land capital intensity costs, the greening I pillar and the other I pillar respectively on pesticides, livestock load per hectare and operating capital, mechanization, feed, fodder costs, are considered not to be selective and targeted enough for addressing environmental issues. They have been indeed criticized for being basically decoupled with respect to any of the fundamental dimensions of sustainability, keeping the status quo and being less effective compared to II pillar policies. I pillar policies have always been most successful in terms of resources spent, beneficiaries addressed, and sectors covered, but not particularly seen as the right response to environmental and social policy goals, certainly less effective than II pillar voluntary policies, mostly based on a contractual approach incentivizing desirable behaviors. In the case presented here, livestock sector in intensive and polluted area such as *Pianura Padana* in Italy, shows that there is a mismatch between announced goals and tools used to meet more sustainable objectives. So, the system appears rather inefficient and there is room for improvement, trying to get the right answers from the proper instruments. With regards to the issue of the capitalization rate of the land, our results are essentially in line with other works (Ciaian, Kancs & Swinnen, 2014; Graubner, 2018; Guastella et al., 2021;) since even the SMIRNE approach confirms a tenuous short run effect. However, a long run effect should be further investigated in future research (Baldoni & Ciaian, 2023; Takáč et al., 2020; Whitaker, 2006). On the other hand, II pillar originated from the old accompanying measures with essentially keeping that function, despite the better reputation as pro-active policies opens rooms to further investigation about the continuous transformation of the CAP. In conclusion, our results are particularly relevant for policy makers and stakeholders at any level because the potential mutual effects, as well as crossed effects, of policies should be known and kept in mind when the whole policy is designed and agreed at the central level, but also when it is implemented and articulated at the local level. Given the possibility of the new CAP to be selective and targeted within EU territories, and the increasing involvement of stakeholders in all the preparatory steps of designing and implementing a sectoral and territorial policy, the knowledge, and the evaluation of all the effects of different measures, as in the case of I and II pillars of the CAP, is a key aspect to improve efficiency and effectiveness of policies.

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References

Ait-Sidhoum, A., Mennig, P., & Sauer, J. (2023). Do agri-environment measures help improve environmental and economic efficiency? Evidence from Bavarian dairy farmers. *European Review of Agricultural Economics, 50*(2), 918–953. https://doi.org/10.1093/erae/jbad007

Angelini, M. E., Heuvelink, G. B. M., & Kempen, B. (2017). Multivariate mapping of soil with structural equation modelling. *European Journal of Soil Science, 68*, 575–591. https://doi.org/10.1111/ejss.12446

Angenendt, E., Poganietz, W. R., Bos, U., Wagner, S., & Schippl, J. (2018). Modelling and tools supporting the transition to a bioeconomy. In I. Lewandowski (Ed.). *Bioeconomy*Cham: Springer. https://doi.org/10.1007/978-3-319-68152-8_9

Baldoni, E., & Ciaian, P. (2023). The capitalization of CAP subsidies into land process in the EU. *Land Use Policy, 134*. https://doi.org/10.1016/j.landusepol.2023.106900

Baldoni, E., d'Artis, K., Ciaian, P., & Dusan, D. (2021). The capitalization of agricultural subsidies into farmland prices, JRC Technical Report, JRC126423, Luxembourg.

Bollen, K. A. (1989). *Structural equations with latent variables.* NY: Wiley Press.

Burrell, A. (2009). The CAP: looking back, looking ahead. *Journal of European Integration, 31*, 271–289. https://doi.org/10.1080/07036330902782113

Cagliero, R., Licciardo, F., & Legnini, M. (2021). The Evaluation Framework in the New CAP 2023–2027: A Reflection in the Light of Lessons Learned from Rural Development. *Sustainability, 13*(10), 5528. https://doi.org/10.3390/su13105528

Canessa, C., Ait-Sidhoum, A., Wunder, S., & Sauer, J. (2024). What matters most in determining European farmers' participation in agri-environmental measures? A systematic review of the quantitative literature. *Land Use Policy, 140*, Article 107094. https://doi.org/10.1016/j.landusepol.2024.107094

Cimino, O., Henke, R., & Vanni, F. (2015). The effects of CAP greening on specialised arable farms in Italy. *New Medit, 14*(2), 22–31.

Cortignani, R., Buttinelli, R., & Dono, G. (2022). Farm to Fork strategy and restrictions on the use of chemical inputs: Impacts on the various types of farming and territories of Italy (Article) *Science of the Total Environment, 810*, Article 152259. https://doi.org/10.1016/j.scitotenv.2021.152259

Cortignani, R., & Coderoni, S. (2022). The impacts of environmental and climate targets on agriculture: Policy options in Italy. *Journal of Policy Modeling, 44*, 1095–1112. https://doi.org/10.1016/j.jpolmod.2022.11.003

Cortignani, R., Severini, S., & Dono, G. (2017). Complying with greening practices in the new CAP direct payments: An application on Italian specialized arable farms. *Land Use Policy, 61*, 265–275. https://doi.org/10.1016/j.landusepol.2016.11.02

De Boe, G. (2020). *Impacts of agricultural policies on productivity and sustainability performance in agriculture: A literature review.* Paris: OECD Food, Agriculture and Fisheries Papers No. 141,.

Defrancesco, E., Gatto, P., Runge, F., & Trestini, S. (2008). Factors affecting farmers' participation in agri-environmental measures: A Northern Italian perspective. *Journal of Agricultural Economics, 59*(1), 114–131. https://doi.org/10.1111/j.1477-9552.2007.00134.x

Dell'Unto, D., Dono, G., & Cortignani, R. (2023). Impacts of environmental targets on the livestock sector: An assessment tool applied to Italy. *Agriculture, 13*, 742. https://doi.org/10.3390/agriculture1304074

Fan, Y., Chen, J., Shirkey, G., John, R., Wu, S. R., Park, H., & Shao, C. (2016). Applications of structural equation modeling (SEM) in Ecological Studies: An updated review. *Ecological Process, 5*(19), https://doi.org/10.1186/s13717-016-0063-3

Finney, S. J., & Di Stefano, C. (2013). Nonnormal and categorical data in structural equation modeling. In G. R. Hancock, & R. O. Mueller (Eds.). *Structural equation modeling: A second course* (pp. 267–309). IAP Information Age Publishing.

Gohin, A., & Zheng, Yu (2020). Reforming the European Common Agricultural Policy: From price & income support to risk management. *Journal of Policy Modeling, 42*, 712–727. https://doi.org/10.1016/j.jpolmod.2020.02.008

Graubner, M. (2018). Lost in space? The effect of direct payments on land rental prices. *European Review of Agricultural Economics, 45*(2), 143–171. https://doi.org/10.1093/erae/jbx027

Greer, A. (2013). The common agricultural policy and the EU budget: Stasis or change? *European Journal of Government and Economics, 2*(2), 119–136. ⟨https://uwe-repository.worktribe.com/output/925395⟩.

Greer, A. (2023). Post-exceptional politics in agriculture: an examination of the 2013 CAP reform. *Journal of European Public Policy, 24*(11), 1585–1603. https://doi.org/10.1080/13501763.2017.1334080

Grochowska, R. (2023). From a centralised to a diversified common agricultural policy in the light of liberal intergovernmentalism theory. *Studies in European Affairs, 27*(2), 121–134. https://doi.org/10.33067/SE.2.2023.7

Guastella, G., Moro, D., Sckokai, P., & Veneziani, P. (2021). The capitalisation of decoupled payments in farmland rents among EU regions. *Bio-Based and Applied Economics, 10*(1), 7–17. https://doi.org/10.36253/bae-10034

Guth, M., Smędzik-Ambroż, K., Czyżewski, B., & Stępień, S. (2020). The economic sustainability of farms under common agricultural policy in the European Union Countries. *Sustainability, 10*(2), 34. https://doi.org/10.3390/agriculture10020034

Hair, J. F., Sarstedt, M., Ringle, C. M., & Gudergan, S. P. (2018). *Advanced Issues in Partial Least Squares Structural Equation Modeling*. Thousand Oaks, CA, USA: Sage.

Hayes, A. F., & Preacher, K. J. (2013). Conditional process modeling: Using structural equation modeling to examine contingent causal processes. In G. Hancock, R., R. Mueller, & O. (Eds.). *Structural equation modeling: A second course* (pp. 219–266). IAP Information Age Publishing.

Hayes, A. F., & Rockwood, N. J. (2020). Conditional process analysis: Concepts, computation, and advances in the modeling of the contingencies of mechanisms. *American Behavioral Scientist, 64*(1), 19–54. https://doi.org/10.1177/0002764219859633

Henke, R., Benos, T., De Filippis, F., Giua, M., Pierangeli, F., & Pupo D'Andrea, M. R. (2018). The new common agricultural policy: how do Member States respond to flexibility? *Journal of Common Market Studies, 56*(2), 403–419. https://doi.org/10.1111/jcms.12607

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling Multidisciplinary Journal, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Jöreskog, K., & Sörbom, D. (2007). *LISREL 8.80 for Windows*. Chicago, IL, USA: Scientific Software International Inc.

Kiryluk-Dryjska, E., & Baer-Nawrocka, A. (2019). Reforms of the Common Agricultural Policy of the EU: Expected results and their social acceptance. *Journal of Policy Modelling, 41*, 607–622. https://doi.org/10.1016/j.jpolmod.2019.01.003

Kline, B. R. (2011). *Principles and Practice of Structural Equation Modeling* (3rd ed..,). New York, NY, USA: The Guilford Press.

Kremmydas, D., Petsakos, A., Ciaian, P., Baldoni, E., & Tillie, P. (2021). *The EU-Wide Individual Farm Model for Common Agricultural Policy Analysis (IFM-CAP v.2): Manual of the model, EUR 30949 EN*. Luxembourg: Publications Office of the European Commission.

Lau, R. S., & Cheung, G. W. (2012). Estimating and comparing specific mediation effects in complex latent variable models. *Organizational Research Methods, 15*(1), 3–16. https://doi.org/10.1177/1094428110391673

Li, H., Liu, Y., & Peng, K. (2018). Characterizing the relationship between road infrastructure and local economy using structural equation modeling. *Transport Policy, 61*, 17–25. https://doi.org/10.1016/j.tranpol.2017.10.002

Lovec, M., Šumrada, T., & Erjavec, E. (2020). New CAP delivery model, old issues. *Intereconomics Review of European Economic Policy, 55*(2), 112–119. https://doi.org/10.1007/s10272-020-0880-6

Mary, S. (2013). Assessing the impacts of pillar 1 and 2 subsidies on TFP in French crop farms. *Journal of Agricultural Economics, 64*(1), 133–144. https://doi.org/10.1111/j.1477-9552.2012.00365.x

Matthews, A. (2013). Greening agricultural payments in the EU's Common Agricultural Policy. *Bio-Based and Applied Economics, 2*(1), 1–27. https://doi.org/10.13128/BAE-12179

Quiroga, S., Suarez, C., Fernandez-Haddad, Z., & Philippidis, G. (2017). Levelling the playing field for European Union agriculture: Does the Common Agricultural Policy impact homogeneously on farm productivity and efficiency? *Land Use Policy, 68*, 179–188. https://doi.org/10.1016/j.landusepol.2017.07.057

Ribeiro, P. F., Santos, J. L., Santana, J., Reino, L., Beja, P., & Moreira, F. (2016). An applied farming systems approach to infer conservation-relevant agricultural practices for agri-environment policy design. *Land Use Policy, 58*, 165–172. https://doi.org/10.1016/j.landusepol.2016.07.018

Santibánez-Andrade, G., Castillo-Argüeroa, S., Vega-Pena, E. V., Lindig-Cisneros, R., & Zavala-Hurtado, J. A. (2015). Structural equation modeling as a tool to develop conservation strategies using environmental indicators: The case of the forests of the Magdalena River basin in Mexico City. *Ecological Indicators, 54*, 124–136. https://doi.org/10.1016/j.ecolind.2015.02.022

Satorra, A., & Bentler, P. M. (1994). Corrections to test statistics and standard errors in covariance structure analysis. In A. von Eye, C. Clogg, & C. (Eds.). *Latent Variable Analysis: Applications for Developmental Research* (pp. 399–419). Thousand Oaks, CA, USA: Sage Publications.

Schermelleh-Engel, K., Moosbruger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive-of-fit measures. *Methods of Psychological Research, 8*(2), 23–74.

Sorrentino, A., Henke, R., & Severini, S. (Eds.). (2011). *The common agricultural policy after the Fischler Reform*. USA: ASHGATE.

Swinnen, J. F. M. (Ed.). (2015). *The Political Economy of the 2014-2020 Common Agricultural Policy: An Imperfect Storm*. Rowman and Littlefield International..

Takáč, I., Lazíková, J., Rumanovská, L., Bandlerová, A., & Lazíková, Z. (2020). The factors affecting farmland rental prices in Slovakia. *Land, 9*(3), https://doi.org/10.3390/land9030096

van Huylenbroeck, G., & Durand, G. (Eds.). (2003). *Multifunctional agriculture. A new paradigm for European agriculture and rural development*. Aldershot, UK and Burlington, (VT), USA: ASHGATE.

Villamaor-Tomas, S., Sagabiel, J., & Olschewski, R. (2019). Bringing the neighbors in: A choice experiment on the influence of coordination and social norms on farmers' willingness to accept agro-environmental schemes across Europe. *Land Use Policy, 84*, 200–215. https://doi.org/10.1016/j.landusepol.2019.03.006

Whitaker, J. B. (2006). *The Effect of Direct Payments on Agricultural Land Rents* (Working Paper)Logan, UT, USA: Utah State University.