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SUBMITTED ARTICLE

Farm-level impacts of the CAP post-2020 reform: A scenario-based analysis

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Abstract

We analyze the farm-level economic and environmental impacts of the post-2020 reform of the Common Agricultural Policy (CAP) of the European Union, examining six scenarios constructed around the budget allocated to eco-schemes and the stringency of enhanced conditionality. Results suggest that the CAP post-2020 can improve environmental performance but at a cost for farms. Enhanced conditionality appears to play a greater role than eco-schemes in delivering environmental improvements. The new CAP provides the Member States ample options to choose among different measures. The optimal policy mix will depend on the balancing of income support versus environmental performance that reflects policy priorities.

KEYWORDS

Common Agricultural Policy, eco-schemes, enhanced conditionality, farm model, IFM-CAP

JEL CLASSIFICATION

C61, Q12, Q18

The gradual transformation of price support mechanisms to farm income support (i.e., direct payments [DP]), conditional on respecting specific environmental standards, has been among the most important changes of the European Union's (EU) Common Agricultural Policy (CAP) over the last decades. Continuing along the same path, the CAP post-2020 reform (which will be implemented starting from 2023) aims at increased environmental and climate performance, at a more equitable distribution of DP across farms, and at a better alignment with the United Nations' Sustainable Development Goals (SDGs). When implemented, the new CAP is expected to play a major role in promoting the transition to a fairer, healthier, and more environmentally friendly European food system, as envisaged by the European Commission in the European Green Deal and reflected in the "Farm to Fork" strategy (EC, 2020a).

Although the previous CAP reform of 2013 attracted a lot of interest in the literature and the modeling community (Espinosa et al., 2020; Gocht et al., 2017; Louhichi et al., 2017; Louhichi, Ciaian, et al., 2018), there is still not sufficient quantitative information, particularly at farm level, that can feed into the policy discussion about the CAP post-2020. The reason is the emphasis of the new CAP on a more decentralized design, which abandons the "one-size-fits-all" approach to policy implementation of previous reforms and allows Member States (MS) to prepare their own strategic plans according to national and local specificities. Since the strategic plans, and even the related funding details, are still being designed with their approval pending at the time of writing this paper, the future European agricultural policy mosaic remains unclear, which impedes conducting quantitative policy impact analyses by considering the actual future implementation of the CAP.

The discussion about the CAP post-2020, until now, has mostly revolved around the design, the overall reform agenda, and the capacity of the CAP to meet its objectives. For example, some authors have questioned the relevance of proposed measures to address specific challenges (Lovec et al., 2020; Navarro & López-Bao, 2019), while others have indicated misalignments of the CAP objectives with the SDGs (Pe'er et al., 2019; Scown et al., 2020). Various authors have also argued that the CAP lacks the appropriate multi-level governance, advocating for an inclusive policy-making process that is required for the transition towards a sustainable European food system (Galli et al., 2020; Kugelberg et al., 2021; Recanati et al., 2019). In contrast, only a handful of studies have attempted any type of quantitative assessment of the economic and/or environmental impacts of the new CAP, having relied on scenario analyses because of little information about the CAP implementation details (Barreiro-Hurle et al., 2021; Beckman et al., 2020; Bremmer et al., 2021). Despite the differences among these studies with respect to their modeling approach and scenario assumptions, there appears to be a consensus that the new CAP can reduce the environmental footprint of EU agriculture at the expense of lower production and higher food prices. While these findings constitute important inputs to the policy debate, farm-level impacts have generally been overlooked.

With this paper, we attempt to contribute to the policy discussion about the CAP post-2020 by taking a preliminary look at the potential farm-level economic and environmental impacts of some of the measures introduced with the reform. Since national strategic plans are yet to be finalized, the MS implementation of the CAP post-2020 is not known and thus it is not considered in this paper. To circumvent this lack of information, and like in the studies mentioned above, our analysis is based on a set of plausible policy scenarios that draw on the Commission's legislative proposal for the CAP post-2020 (EC, 2018a) and on the political agreement reached between the EU institutions in June 2021.[1] The scenarios incorporate assumptions about the stringency of environmental constraints and about different budgetary allocations, thus encompassing a broad range of CAP implementation options that may potentially resemble those adopted by MS. Our analysis is not exhaustive, it does not capture all elements of the policy debate and it should not be seen as an impact assessment for the new CAP. However, the scenarios analyzed do offer insights on the general direction of change brought about by specific measures of the CAP post-2020 reform through some key economic and environmental indicators at the farm level, and they can also reveal the trade-offs and possible implementation issues that arise thereof.

THE CAP POST-2020 REFORM

The main change introduced by the CAP post-2020 (EC, 2018a) is the "new delivery model" for payments that links financing with the achievement of environmental and climate objectives rather than just compliance with EU legislation. The CAP post-2020 is built around nine key EU-level objectives, out of which three relate to environment and climate.[2] The CAP post-2020 is implemented through national strategic plans by which each MS sets its own policy targets, defines measures, and allocates payments needed to meet the targets. National strategic plans should address the specific needs of EU countries (including environment and climate) and are expected to deliver results to the EU-level objectives.[3]

Under the CAP post-2020, all greening measures introduced with the 2013 reform are replaced by the enhanced conditionality requirements, as it is now called the new—and more ambitious—minimum set of requirements for receiving DP. Enhanced conditionality is thus envisaged to become the baseline of compulsory environmental and climate obligations upon which MS can design even more ambitious, albeit voluntary, measures referred to as eco-schemes, funded through Pillar 1, or Agri- Environment-Climate Measures (AECM) that receive payments from Pillar 2.[4] Farm self-selection into eco-schemes is incentivized by granting per hectare payment to adopting farmers. According to the June 2021 agreement, a minimum of 25% of the national DP budget must be allocated to eco-scheme payments in each MS.

The value of DP (coupled and decoupled) granted under Pillar 1 and their distribution across farms changes in the CAP post-2020. The main change comes from the reduction of the overall CAP budget compared to the 2014–2020 pre-reform period [Regulation (EU) No. 1307/2013; EC, 2018a]. Decoupled payments are allocated through the "Basic Income Support for Sustainability" (BISS), which replaces the "Basic Payment Scheme" (BPS) that was introduced by the 2013 CAP reform.[5] Coupled payments, in the form of payments per hectare of a particular crop, or per head of particular animal activity, are maintained under the CAP post-2020 reform. MS can grant coupled payments to maintain the current production in regions, or sectors that face difficulties, but they are perceived important for economic, social, or environmental reasons.

The CAP post-2020 retains the main mechanism of payment redistribution introduced by past reforms, which aims at the adjustment of individual DP per eligible hectare towards a more uniform value, both among MS (external convergence), and within a given MS or region (internal convergence).[6] A second redistributive mechanism, which is currently voluntary for MS, is the redistributive payments scheme. It involves using a part of the national DP envelope as an additional aid for small and medium-sized farms by granting a higher payment for the first hectares than for the remaining farm area (usually for the first 2–30 hectares of land). For the CAP post-2020, a redistributive payment that amounts to at least 10% of the DP envelope becomes mandatory for all MS, and it is further supported by funds collected by reducing direct payments granted to large farms (large subsidy recipients). This payment reduction, called capping, was initially introduced by the 2013 CAP reform as a voluntary measure for MS. It entailed a decrease of BPS to large farms, while the funds saved were allocated to rural development plans funded by Pillar 2. Under the CAP post-2020, capping remains voluntary and aims to generate a more equal distribution of DP among farms by reducing direct payments received by a farm above 60,000 EUR, and by setting a maximum payment threshold at 100,000 EUR per farm after considering (subtracting) salaries and labor costs.[7,8]

METHODOLOGY

The model

The IFM-CAP model (Individual Farm Model for Common Agricultural Policy Analysis) (Louhichi, Espinosa, et al., 2018; Louhichi, Ciaian, et al., 2018) used in this study is an EU-wide static optimization model which attempts to simulate the behavior of individual farms. It assumes that farmers maximize their expected utility of income for the given yields, variable costs, and prices (Leontief technology representation), under a set of constraints related to the land endowment, animal feed requirements, and policy obligations. The policy constraints determine eligibility with different types of direct payments (coupled and decoupled) and control compliance with environmental obligations. Adoption of voluntary farm measures is modeled endogenously using binary variables that add any related payment and costs (e.g., for eco-schemes) in the objective function when the farm activity mix at the optimal solution satisfies the corresponding constraints.

A post-solution module allows the model to estimate the impacts of different policy scenarios on environmental sustainability. To the extent of our knowledge, this constitutes the first attempt to include a set of environmental indicators in an EU-wide farm-level model.[9] Among the three CAP environmental objectives, IFM-CAP can assess progress towards "fostering sustainable development and efficient management of natural resources" with an erosion index, and towards the objective of "preserving landscapes and biodiversity" with a set of crop diversity indicators (Shannon's index and Simpson's reciprocal index). These indicators are complemented with an agricultural intensification indicator (pesticide and fertilizer expenditures per hectare), which can also partially assess progress towards the third CAP environmental objective of "tackling climate change."

The parameterization of IFM-CAP is based on individual farm-level information (83,292 farms for 2012; the model's baseyear) across 26 MS from the Farm Accountancy Data Network (FADN) database.[10] The FADN is a European system of annual farm surveys that collects structural and accountancy information on EU farms, such as output, land use, input costs, subsidies, and income. It is unique in the sense that it is the only source of EU-wide harmonized and representative farm-level microeconomic data. Its survey, however, covers only "commercial farms," that is, farms that exceed a minimum economic size threshold established at MS level. Nevertheless, the FADN represents a population of around five million farms, covering approximately 90% of the total utilized agricultural area in the EU. To meet the intensive data needs of the model, FADN data is complemented by other external EU-wide data sources such as the European Farm Structure Survey, the CAPRI model database[11], and Eurostat.

The calibration of IFM-CAP against the 2012 baseyear FADN data is performed with a Positive Mathematical Programming (PMP) approach. It can be succinctly described as the recovery of some unknown parameters (an implicit quadratic cost function) for each individual farm so that: (i) the farm replicates its baseyear activity levels; and (ii) when all farms are pooled together, the resulting aggregate (regional) price supply elasticity approximates a set of supply elasticity priors provided by the CAPRI model. More information on the calibration of IFM-CAP can be found in Louhichi, Espinosa, et al. (2018).

IFM-CAP lends itself as an appropriate tool for ex-ante impact analyses of CAP reforms because of its micro-foundation, and its capacity to capture the heterogeneity of farms' response to policy changes. These traits allow for a flexible assessment of a wide range of CAP policies at the EU level, and across different types of farm aggregations (e.g., per economic size, land size, production specialization, among others). For this reason, the model has been used extensively in the past for ex-ante policy assessments at the EU level, including the analysis of the economic impacts of CAP greening (Louhichi, Ciaian, et al., 2018) and of the crop diversification measures (Louhichi et al., 2017). The model was also used for the impact assessment of the Commission's legislative proposal for the CAP post-2020 (EC, 2018b).

An important advantage of IFM-CAP, compared to other models used for CAP ex-ante impact analysis, is its EU-wide coverage. In contrast, individual farm models used in the literature usually cover only selected MS/regions or specific agricultural sectors (Cortignani & Dono, 2020; Vosough-Ahmadi et al., 2015). On the other hand, most studies that provided EU-wide impacts of previous CAP reforms—except for those based on IFM-CAP (Espinosa et al., 2020; Louhichi et al., 2017; Louhichi, Ciaian, et al., 2018)—relied on the representative (average) farm, or regional models. However, such aggregated approaches are not fully able to model policies targeted at farm-level without imposing strong assumptions on farmers' behavior (Gocht et al., 2017; Van Zeijts et al., 2011). For the analysis of the CAP post-2020 reform performed in this paper, the eligibility and uptake of the new measures (i.e., enhanced conditionality and eco-schemes) depend largely on farm-specific characteristics (farm size, specialization, etc.). Therefore, modeling the self-selection of farms into eco-schemes and analyzing the potential economic and environmental impacts with more aggregated approaches (e.g., at the representative farm, regional, or MS level) is subject to significant aggregation bias.

Specification of scenarios for the CAP post-2020

The scenarios analyzed in this study were constructed around two dimensions, specifically (i) the budget allocated to voluntary farm environmental measures (eco-schemes), and (ii) the stringency of the mandatory farm measures (enhanced conditionality). We distinguished between high, medium, and low budget allocations to eco-schemes (prefixes HE, ME, and LE in the scenario names), corresponding to 40%, 25%, and 10% of the national DP envelopes, respectively. This allocation could be interpreted as the "environmental ambition" of policymakers since it represents the level of economic incentives provided to farmers for adopting more environmentally friendly practices. We note that 25% (the ME case) is the minimum allocation, which has been decided during the latest CAP agreement. The LE and HE allocations were used in this study to examine how adoption rates vary with different eco-scheme payment levels; the HE allocation can account for situations where MS allocate higher budget shares to eco-schemes than the minimum 25%, while the LE allocation is used to examine the sensitivity of the results to very low eco-scheme payments.

The environmental ambition modalities were combined with two types of enhanced conditionality measures (high or low stringency, corresponding to suffixes HC and LC in the scenario names, respectively). This dimension does not have any budgetary implications but instead, it refers to the parameterization of the environmental constraints. It examines the effectiveness of different combinations of mandatory and voluntary measures in improving farm environmental performance under varying levels of eco-scheme payment.

Scenario results were compared against a reference, or "baseline" scenario, which represents a mid-term projection of the European farming sector under the current policy setting, that is, it includes existing CAP provisions introduced with the 2013 reform (greening measures, capping, specific payments). The baseline was created by applying price and yield trends for 2030, taken from the CAPRI model, to the 2012 FADN baseyear data. These trends are based on a set of plausible assumptions regarding macroeconomic conditions and other variables of interest, and they are consistent with the European Commission's annual baseline projections of agricultural commodity markets (EC, 2020b). All scenarios for the CAP post-2020 were created by appropriately modifying the baseline with respect to the policies simulated (i.e., DP envelopes, types of payments, and farm environmental constraints). Therefore, the baseline serves as a counterfactual for a "what-if" type of analysis since it represents a continuation of the existing policy.

The IFM-CAP baseline uses DP envelopes for each MS as agreed for the previous 2013 CAP reform [Annex II of Regulation (EU) No. 1307/2013]. National DP envelopes used for the scenarios are those proposed for the CAP post-2020 reform, as defined in Annex IV of the CAP reform legislative proposal (EC, 2018a).[12]

The unitary payment for eco-schemes (EUR/hectare) for adopting farms was exogenously calculated by dividing the eco-scheme envelope in each scenario with 75% of total entitlements (eligible hectares) at MS level. Thus, for the purpose of calculating the eco-scheme payment in each scenario, we initially assumed an aggregate adoption rate of 75% which corresponds to an approximation of the equilibrium between the adoption of eco-schemes and the resulting unitary payment, under the premise that the national envelopes for eco-schemes are fully distributed among adopting farmers. The reason that motivated the "75% assumption" is that IFM-CAP, being a static farm model, cannot simulate such equilibrium endogenously under a fixed payment envelope; this would require that the unitary eco-scheme payment (equal for all farms in an MS) be treated as an endogenous variable and not as a parameter, which is beyond the scope of farm modeling. When the final aggregate area adoption from the model solution is lower than the initially assumed 75%, the envelope is not exhausted, and adopting farms receive an increased payment for eco-schemes after the model is solved. When area adoption exceeds 75%, adopters receive less than what was initially calculated. This adjustment of unitary eco-scheme payments for adopting farms, which is performed ex-post based on the adoption levels solved by the model, ensures that 100% of the budget for eco-schemes is spent.

Because of the uncertainty regarding the final policy design in each MS, the envelope shares for coupled support to different crop or animal activities were assumed identical to the baseline.[13] For all scenarios, it was further assumed that 10% of the national DP envelopes is allocated to the redistributive payment scheme, as per the minimum share decided in the June 2021 political agreement. The unitary redistributive payment (EUR/hectare) was calculated based on the first 2–30 hectares for each farm. Finally, the BISS envelope in every MS was calculated as a residual to their DP envelope after deducting the shares for eco-schemes, redistributive payments, and coupled support. As a result, the BISS envelope decreases with higher levels of environmental ambition (expressed through the level of eco-scheme payment). The corresponding farm unitary BISS payments (EUR/hectare) were calculated based on total hectare entitlements in each MS, but they were capped at 100,000 EUR per farm, after adjusting for wages paid. This implies full internal convergence with respect to the BISS (prior to its capping). The funds made available from capping were added to the redistributive payment received by farms. Pillar 2 payments reported in the baseyear FADN data, or other national payments, were assumed to stay constant both in the baseline and in the scenarios. Finally, the scenarios did not consider any other type of DP allocations (i.e., young farmers and small farmer schemes), which were deducted from the national DP envelopes used in the analysis.

It is important to note that, since IFM-CAP is based on farms from the FADN sample, the model's baseline does not exactly capture the official DP envelopes for the different MS. Besides those decoupled payments that the model does not capture by design (like payments to young farmers mentioned above), an important reason for this discrepancy is that certain farms—particularly non-commercial ones—may be under-represented in the FADN sample. An additional reason is the nature of some coupled payments that target processing industries instead of farms and are therefore not considered in IFM-CAP. Despite these shortcomings, overall, the model's baseline is still able to capture about 97% of the officially reported total EU DP envelope. We have assumed that the same level of payment representation also carries over to the scenarios and we have adjusted all MS envelopes of the CAP post-2020 accordingly.

Farm environmental measures

The specific environmental measures included in the baseline and those considered in the scenarios are presented in Table 1. The baseline includes the greening measures introduced by the 2013 CAP reform: crop diversification, maintenance of permanent grasslands, and ecological focus areas (EFA). The CAP post-2020 reform replaces greening with new mandatory environmental obligations (enhanced conditionality) and additional voluntary measures (eco-schemes). The enhanced conditionality obligations in our policy scenarios are as follows: (i) restrictions in the change of grassland area at the regional level; (ii) winter soil cover; (iii) fallow land, which is assumed to satisfy the requirement for allocating area to landscape features; (iv) cover crops between tree rows; and (v) crop rotation. These measures represent a subset of the mandatory environmental standards included in the Commission's legislative proposal (EC, 2018a). Since the same measures are also included in the list of indicative eco-scheme practices published by the European Commission,[14] eco-schemes in our study were defined as stricter variants of some of the selected conditionality obligations.

The specification of the various measures (e.g., the required share of land under cover or fallow, or years of rotation) draws on the modeling exercise by Barreiro-Hurle et al. (2021) and extends the scenario specifications considered in the Commission's impact assessment for the CAP post-2020 proposal (EC, 2018b). Specifically, farm measures were defined such that high conditionality implies less demanding eco-schemes and vice versa. For example, and as per the latest CAP agreement, under LC scenarios it is mandatory for the farm to allocate 3% of its arable land to fallow land and can opt for an additional 4% through the adoption of the related eco-scheme. The corresponding shares for HC scenarios are 5% and 2% respectively. All measures were introduced horizontally for all modeled EU farms, except for organic ones, which were exempted both in the scenarios and in the baseline. For a farm to be considered "adopter," and to receive the related eco-scheme payment, it needs to comply with every individual eco-scheme measure listed in Table 1.

Winter soil cover is modeled by assuming that farms cover a percentage of their arable land with the following: (i) winter cover crops; (ii) catch or cover crops grown between spring successive crops; and/or (iii) mulching. IFM-CAP does not model the specific crops that are used for soil cover, or as catch crops. Instead, it solves for the covered area allocated to existing cropping activities (e.g., we model the share of maize area that is under cover and not the type of crop that is used to cover the maize area). Introducing cover crops between tree rows is modeled in a similar way. Farms are assumed to apply some cover in the baseyear, and they continue the same practice under the baseline or under any other policy scenario. Baseyear covers for individual farms are national averages, estimated from observed land-use practices across MS, as reported by Eurostat.[15] The costs related to these default cover practices are assumed to be

TABLE 1 Farm environmental measures modeled in the baseline and in the scenarios

Baseline—Greening (2013 CAP reform—Regulation (EU) no. 1307/2013)				
Crop diversification	*Farms with 10–30 hectares of arable land*: the main crop cannot cover more than 75% of the available arable land (at least two crops must be grown). *Farms with more than 30 hectares of arable land*: as above, plus the two main crops together cannot cover more than 95% of arable land (at least three crops must be grown).			
Change of grassland area at regional or MS level	Maximum allowed decrease of 5%			
Ecological Focus Areas (EFA)	5% of agricultural land with fallow, N-fixing crops or be under cover with catch crops.			
Scenarios (CAP post-2020 reform)				
	High (stringency) conditionality		**Low (stringency) conditionality**	
	Enhanced conditionality	**Eco-schemes**	**Enhanced conditionality**	**Eco-schemes**
Change of grassland area at regional level	0% (no change allowed)	—	0% (no change allowed)	—
Winter soil cover—winter crops, catch crops, mulching	90% of arable crop area	+10% additional cover area (100% total)	50% of arable crop area	+50% additional cover area (100% total)
Fallow land (landscape elements)	5% of arable crop area	+2% additional on arable crop area (7% total)	3% of arable crop area	+4% additional on arable crop area (7% total)
Cover crops between tree rows	90% of permanent crop area	—	50% of permanent crop area	—
Crop rotation	3 years	4 years	3 years	4 years

captured by the PMP terms of the objective function. If the baseyear cover is not enough to ensure compliance with a specific measure, the farm introduces additional cover, which is accompanied by further costs that enter the objective function, thus reducing farm income.[16]

Crop rotation is interpreted as a sequence of crops in which a given crop can appear only once in two consecutive years. In modeling terms, it means that an arable crop cannot be grown on more than 66% of the farm arable area for a 3-year rotation, and on 50% of the arable area for a 4-year rotation. This interpretation is similar to the "continuous cropping—2 years" and "biennial" rotations examined by Cortignani and Dono (2020).

RESULTS

Adoption of eco-schemes

As shown in Figure 1, the HE scenarios, with 40% of the DP envelope allocated to eco-schemes, lead to the highest adoption rates, both in terms of adopting farms and areas under eco-schemes.

Farm adoption at the EU level in all scenarios is lower than area adoption, suggesting that medium-sized or larger farms—in terms of total land use—are more likely to adopt eco-schemes. The low conditionality scenarios (LC) result in lower adoption compared to HC scenarios because the eco-scheme obligations for LC scenarios are stricter and thus more costly for farmers to adopt. However, the relative importance of conditionality stringency seems to increase with smaller eco-scheme payments, as can be seen particularly in the case of the LE scenarios (i.e., there is a relatively large difference in eco-scheme adoption between LE/HC and LE/LC scenarios). Of interest is also the comparison between the HE/LC and ME/HC scenarios as they lead to comparable adoption rates, despite the different eco-scheme payments.

Farms specializing in horticulture, which are often large in terms of economic size but small in terms of agricultural area, have the lowest adoption rates in all scenarios (Table 2), followed by farms specializing in fruits and other field crops (e.g., tobacco, cotton). The reason is the high value of their outputs, which makes any further land reallocation, beyond what is required by enhanced conditionality obligations, a non-optimal choice. In other words, the foregone income from applying additional farm measures outweighs the eco-scheme payment. Similar results are reported by Schmidt et al. (2019) who examine the impact of stringer cross-compliance standards in Switzerland and point out that farms with higher-than-average income, or whose income depends less on DP (e.g., pig farms or farms growing perennial and vegetable crops), are less likely to comply with stricter environmental standards.

Income and production

As depicted in Figure 2 (the blue dot), aggregate farm income decreases in the EU between 3.46% and 2.15% across the different scenarios.[17] This decrease is greater for HC scenarios and for higher eco-scheme payments. The aggregate changes in income are the combined result of

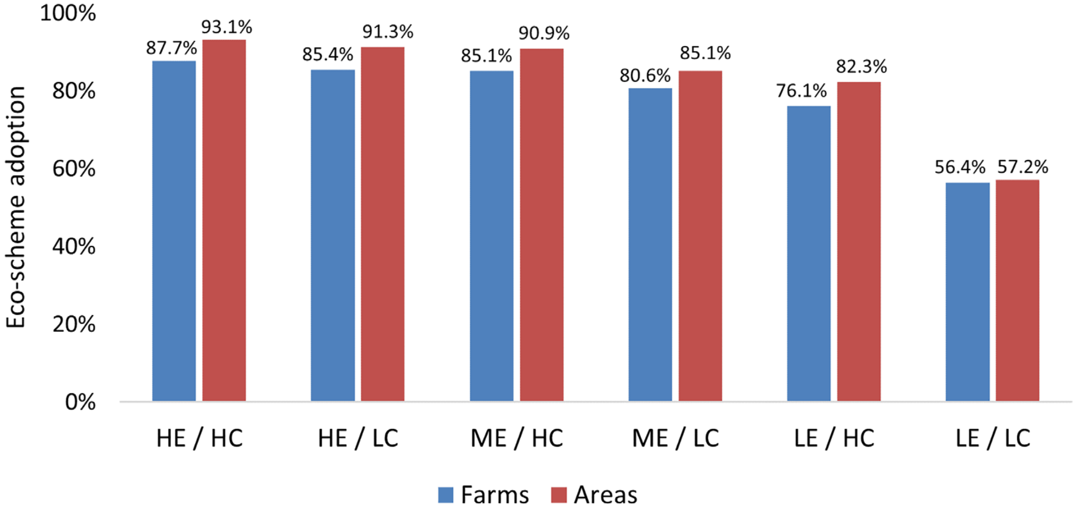

FIGURE 1 Adoption rates of eco-schemes at European Union-level for different scenarios. HC, high (stringency) conditionality; HE, high budget allocations to eco-schemes; LC, low (stringency) conditionality; LE, low budget allocations to eco-schemes; ME, medium budget allocations to eco-schemes

TABLE 2 Farm eco-scheme adoption rates per scenario by farm specialization and economic size

	HE/HC	HE/LC	ME/HC	ME/LC	LE/HC	LE/LC
Farm specialization						
Mixed crops	84.7%	82.4%	79.9%	76.9%	70.2%	52.9%
Mixed crops and livestock	91.0%	88.8%	89.5%	85.4%	81.8%	58.7%
Mixed livestock	91.4%	90.1%	89.2%	87.1%	84.4%	56.0%
Permanent crops combined	92.3%	91.4%	91.0%	88.5%	81.8%	65.4%
Specialist cattle	93.4%	91.5%	91.0%	86.4%	83.0%	67.6%
Specialist COP	96.5%	95.8%	94.6%	90.9%	85.6%	54.3%
Specialist granivores	90.9%	88.3%	89.0%	81.5%	79.2%	46.9%
Specialist horticulture	34.1%	29.1%	30.3%	25.2%	23.0%	15.1%
Specialist milk	93.8%	90.4%	90.3%	84.2%	78.9%	56.6%
Specialist olives	93.0%	92.8%	92.6%	92.5%	89.6%	86.6%
Specialist orchards—fruits	80.0%	75.4%	76.4%	68.2%	62.1%	54.1%
Specialist other field crops	80.0%	77.1%	75.4%	69.3%	64.1%	39.5%
Specialist sheep and goats	92.3%	89.6%	88.9%	84.8%	80.4%	64.6%
Specialist wine	80.0%	78.3%	78.5%	75.1%	67.8%	58.7%
Farm economic size (EUR)						
2000–<8000	87.7%	85.1%	84.9%	81.3%	76.3%	54.5%
8000–<25,000	89.6%	88.1%	87.7%	84.5%	80.1%	64.5%
25,000–<100,000	88.2%	86.2%	85.5%	80.3%	75.8%	56.4%
100,000–<500,000	83.3%	79.3%	79.1%	71.0%	66.9%	43.2%
≥500,000	72.8%	68.5%	68.8%	57.0%	57.0%	28.6%

Abbreviations: COP, cereals, oilseeds, and protein crops; HC, high (stringency) conditionality; HE, high budget allocations to eco-schemes; LC, low (stringency) conditionality; LE, low budget allocation to eco-schemes; ME, medium budget allocations to eco-schemes.

three individual effects: (i) the removal of the previous greening measures and the change in the DP distribution according to the CAP post-2020 (relative to baseline); (ii) the enhanced conditionality obligations which affect income by setting constraints to farming production plans and by increasing compliance costs (for soil cover); and (iii) the adoption of eco-schemes which introduce additional farm measures. We attempt to analyze the relative importance of these individual effects by running two additional sub-scenarios for each of the six "parent" scenarios. Both sub-scenarios retain the same CAP post-2020 budget and the same payment distribution among farms as the parent scenarios,[18] they assume that all baseline greening measures are abolished but differ with respect to the imposed CAP post-2020 farm measures: The first sub-scenario (SS1) only considers enhanced conditionality and it does not impose the constraints related to the eco-schemes, while the second sub-scenario (SS2) completely removes all environmental constraints. The three individual effects were calculated as follows: (i) the removal of greening and the change of DP was calculated as the difference between SS2 and the baseline; (ii) the effect of the enhanced conditionality obligations as the difference between SS1 and SS2; and (iii) the effect of eco-schemes as the difference between the parent scenario and SS1. The results of this decomposition exercise are presented in Figure 2, which reveals that enhanced

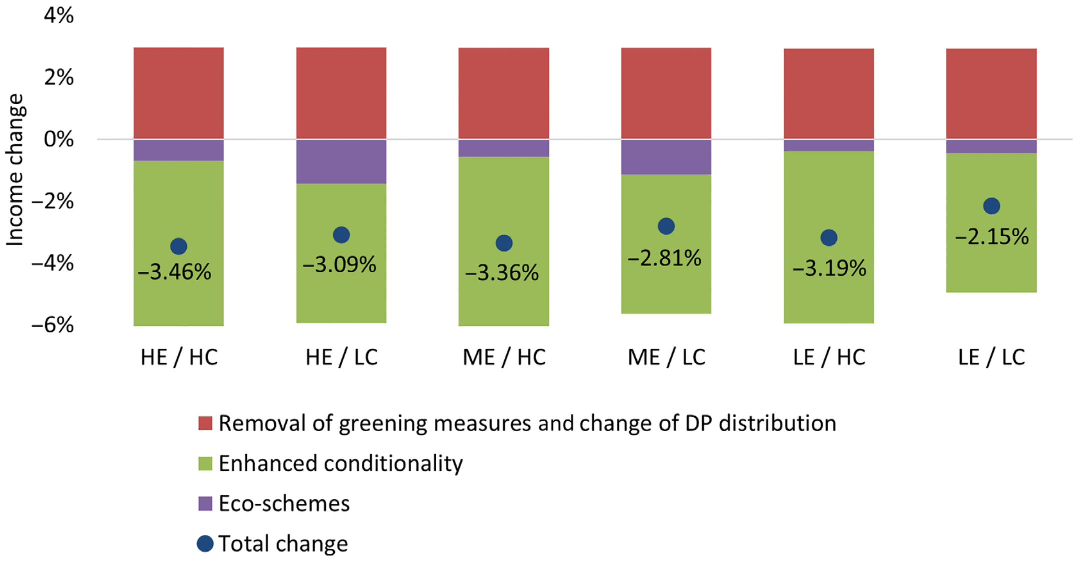

FIGURE 2 Income changes compared to the baseline and the decomposition of the individual income effects, per scenario at the European Union level. DP, direct payments. HC, high (stringency) conditionality; HE, high budget allocations to eco-schemes; LC, low (stringency) conditionality; LE, low budget allocations to eco-schemes; ME, medium budget allocations to eco-schemes

conditionality is the main driver for income change in all scenarios. On the contrary, the income reduction attributed to eco-schemes is small because of farm self-selection (not all farms are affected) and because the additional farm obligations are relatively weaker compared to those under enhanced conditionality, particularly in HC scenarios.

All scenarios lead to a significant increase in fallow land compared to the baseline (Table 3), which is the consequence of the mandatory fallow under enhanced conditionality, and of the additional fallow land obligation from eco-scheme adoption. More importantly, the share of fallow land in all scenarios is more than 7%, which is the minimum threshold for individual farms adopting eco-schemes. This suggests that it is optimal for many farms to exceed the fallow land requirements, which, in aggregate, leads to over-provision of this policy measure. As modeled in IFM-CAP, crop rotation plays an important role in determining the land-use changes across all scenarios because it is more restrictive than the baseline diversification obligation (current CAP—greening). Crop rotation also affects more farms, as farms with less than 10 hectares of arable land are exempted from diversification, whereas we have assumed no exemptions for the scenarios.

Since the modeled measures are assumed to only target crops, the increase in animal activities reported in Table 3 is the indirect result of changes in crop production plans, which in turn affect the feed supply and demand balances at farm level. Some of the measures may have even positive production implications (e.g., maintaining current grassland areas may stimulate on-farm feed production). Production changes mainly affect the income of farms specialized in olives, COP (cereals, oilseeds, and protein crops), and other field crops (Table 4). The measures modeled have a relatively smaller impact on the income of livestock farms because crops comprise only a small part of their portfolio. This impact can even be offset by the increase in livestock production reported previously, thus leading to a positive income change, as can be seen

TABLE 3 Changes in aggregate activity levels (hectares or heads) at the EU level per scenario (percentage changes compared to baseline, area shares in parenthesis)

	HE/HC	HE/LC	ME/HC	ME/LC	LE/HC	LE/LC
Animal activities						
All cattle	+1.34%	+1.39%	+1.35%	+1.40%	+1.35%	+1.39%
Other animals	+4.46%	+4.31%	+4.43%	+4.35%	+4.36%	+4.37%
Crop activities						
Cereals	+4.24% (26.93%)	+4.32% (26.95%)	+4.20% (26.92%)	+4.17% (26.91%)	+3.74% (26.80%)	+3.46% (26.73%)
Fodder activities	−6.49% (37.57%)	−6.37% (37.62%)	−6.34% (37.63%)	−5.78% (37.86%)	−5.57% (37.94%)	−3.88% (38.62%)
Oilseeds	1.71% (9.88%)	1.84% (9.89%)	+1.50% (9.86%)	+1.62% (9.87%)	+1.67% (9.88%)	+2.84% (9.99%)
Other arable field crops	−7.32% (7.06%)	−6.76% (7.10%)	−7.09% (7.08%)	−6.33% (7.13%)	−6.92% (7.09%)	−4.15% (7.30%)
Vegetables and permanent crops	−2.85% (8.00%)	−2.43% (8.03%)	−2.71% (8.01%)	−2.28% (8.04%)	−2.52% (8.02%)	−2.00% (8.07%)
Set aside and fallow land	+25.36% (10.56%)	+23.50% (10.41%)	+24.79% (10.51%)	+20.87% (10.19%)	+21.88% (10.27%)	+10.32% (9.30%)

Abbreviations: HC, high (stringency) conditionality; HE, high budget allocations to eco-schemes; LC, low (stringency) conditionality; LE, low budget allocations to eco-schemes; ME, medium budget allocations to eco-schemes.

TABLE 4 Changes of aggregate farm income per scenario compared to the baseline by farm specialization and economic size

	HE/HC	HE/LC	ME/HC	ME/LC	LE/HC	LE/LC
Farm specialization						
Mixed crops	−6.11%	−5.71%	−5.86%	−5.35%	−5.51%	−4.92%
Mixed crops and livestock	−3.02%	−2.71%	−2.90%	−2.42%	−2.67%	−1.59%
Mixed livestock	−1.31%	−1.12%	−1.20%	−0.91%	−1.10%	−0.25%
Permanent crops combined	−4.72%	−4.51%	−4.60%	−3.86%	−4.29%	−3.61%
Specialist cattle	−0.99%	−0.68%	−0.97%	−0.26%	−0.82%	+0.68%
Specialist COP	−7.55%	−7.19%	−7.58%	−6.56%	−7.47%	−4.80%
Specialist granivores	−1.96%	−1.84%	−1.91%	−1.53%	−1.83%	−1.23%
Specialist horticulture	−5.75%	−4.71%	−5.61%	−4.61%	−5.46%	−4.51%
Specialist milk	−1.16%	−1.09%	−1.14%	−0.94%	−1.08%	−0.53%
Specialist olives	−10.98%	−10.54%	−10.93%	−10.48%	−10.90%	−10.23%
Specialist orchards—fruits	−3.42%	−2.76%	−3.32%	−2.51%	−3.08%	−2.02%
Specialist other field crops	−8.27%	−7.71%	−7.92%	−7.21%	−7.42%	−6.11%
Specialist sheep and goats	+5.63%	+5.77%	+5.62%	+5.85%	+5.65%	+6.50%
Specialist wine	−1.73%	−1.21%	−1.68%	−1.10%	−1.59%	−0.84%
Farm economic size (EUR)						
2000–<8000 EUR	−3.32%	−2.91%	−3.09%	−2.54%	−2.67%	−1.43%
8000–<25,000 EUR	−3.37%	−3.03%	−3.25%	−2.70%	−3.10%	−1.54%
25,000—<100,000 EUR	−3.38%	−3.03%	−3.28%	−2.75%	−3.10%	−2.02%
100,000–<500,000 EUR	−3.60%	−3.26%	−3.50%	−2.99%	−3.33%	−2.47%
≥500,000 EUR	−3.33%	−2.90%	−3.27%	−2.61%	−3.16%	−2.17%

Abbreviations: COP, cereals, oilseeds, and protein crops; HC, high (stringency) conditionality; HE, high budget allocations to eco-schemes; LC, low (stringency) conditionality; LE, low budget allocations to eco-schemes; ME, medium budget allocations to eco-schemes.

for farms specialized in sheep and goat production. Overall, however, most farms experience an income loss in all scenarios.

The reduction in income across farms of different economic sizes becomes increasingly uniform with higher eco-scheme payments (Table 4). On the contrary, large farms tend to experience greater income loss compared to smaller farms as the level of environmental ambition decreases, particularly in the LE scenarios. One of the reasons is the higher BISS payment in the LE scenarios, which is more likely to be capped for large subsidy recipients, while smaller farms with BISS below 100,000 EUR (adjusted for wages) are not affected. This result also reflects the relatively greater importance of the eco-scheme payment for smaller farms, which leads to higher eco-scheme adoption rates and can partially compensate for the reduced output brought about by the mandatory and voluntary measures. For larger farms, the lower adoption rates (e.g., as seen for horticulture farms) lead to the loss of the eco-scheme payment that was received in the baseline in other forms, such as greening payments. Moreover, as previously explained, the unspent part of the eco-scheme envelope is re-allocated as a top-up payment to adopting farms, which are generally smaller in economic size.

TABLE 5 Environmental indicators by scenario at the European Union level per scenario (average value of the indicator across all farms, SD in parenthesis)

	Baseline	HE/HC	HE/LC	ME/HC	ME/LC	LE/HC	LE/LC
Shannon's index	0.919 (0.417)	1.050 (0.426)	1.047 (0.429)	1.047 (0.426)	1.040 (0.429)	1.035 (0.424)	1.007 (0.421)
Shannon's index per hectare	0.158 (0.331)	0.225 (0.574)	0.218 (0.539)	0.224 (0.573)	0.216 (0.536)	0.221 (0.570)	0.210 (0.531)
Simpson's reciprocal index	2.181 (1.034)	2.518 (1.098)	2.512 (1.099)	2.510 (1.097)	2.493 (1.096)	2.475 (1.088)	2.400 (1.062)
Simpson's reciprocal index per hectare	0.527 (2.022)	0.776 (3.280)	0.806 (3.744)	0.774 (3.282)	0.803 (3.745)	0.768 (3.284)	0.787 (3.748)
Erosion index	0.216 (0.079)	0.185 (0.060)	0.199 (0.064)	0.185 (0.061)	0.200 (0.065)	0.185 (0.061)	0.202 (0.067)
Pesticide expenditure (EUR/hectare)	228.0 (1684.7)	217.0 (1406.1)	219.0 (1420.1)	217.4 (1406.4)	219.4 (1420.3)	217.8 (1406.7)	220.2 (1420.5)
Fertilizer expenditure (EUR/hectare)	319.8 (2374.2)	303.1 (2026.4)	305.9 (2049.7)	303.4 (2026.6)	306.2 (2049.1)	304.0 (2027.0)	307.4 (2049.4)

Abbreviations: HC, high (stringency) conditionality; HE, high budget allocations to eco-schemes; LC, low (stringency) conditionality; LE, low budget allocations to eco-schemes; ME, medium budget allocations to eco-schemes.

Environmental impacts

The average values of different environmental indicators per scenario across all farms in the EU are given in Table 5. Shannon's index (SH) and Simpson's reciprocal index (SI) are used to assess crop diversity. SH focuses more on crop richness, that is, the number of functional crop groups cultivated in a farm,[19] while SI puts more emphasis on how evenly crop richness is distributed in each farm. Higher values for both SH and SI in all scenarios, compared to the baseline, suggest that the CAP post-2020 can increase crop diversity (on average) at individual farm level in the EU. Specifically, the increase in the value of SH indicates that farms cultivate a larger number of different crops, while the improvement of SI suggests that the dominance of some crops tends to be reduced at farm level. Both indicators improve as the eco-scheme payment increases. The changes are mainly driven by the crop rotation measure, which has a bigger impact on crop diversity than the crop diversification measure in the baseline. While the indicator values generally increase more under HC scenarios compared to LC scenarios, a notable exception is the comparison of the HE/LC and ME/HC scenarios that offer almost identical improvements to the value of both diversity indicators. These scenarios, as shown in Figure 1, also exhibit comparable eco-scheme adoption rates.

Crop diversity indicators are correlated with farm size since farms with more land have more opportunities to rotate. Thus, the indicators SH/hectare and SI/hectare are calculated to control for farm size effects. The increased value of the indicators compared to the baseline confirms that crop diversity improves at farm level in all scenarios. When comparing the value of the two indicators among scenarios with different stringency conditionality assumptions (by keeping environmental ambition fixed), SH/hectare improves more in HC than LC scenarios, whereas the opposite is observed for SI/hectare.

The erosion index (ERO) informs about how changes in cropping plans and farm practices contribute to the risk of erosion. ERO does not specify the magnitude of the erosion in terms of tons of soil lost. Instead, it is a dimensionless indicator with lower values indicating better environmental performance and, as modeled in IFM-CAP, it is negatively correlated with grassland and soil cover. Table 5 shows that the value of the indicator decreases in all scenarios compared to the baseline. The differences in the value of ERO between scenarios with similar conditionality assumptions but different environmental ambition (i.e., different eco-scheme adoption rates) appear to be very small, or almost zero in the case of HC scenarios. This shows that eco-schemes, as defined herein, have a limited effect on erosion risk when mandatory obligations are sufficiently stringent because the additional soil cover from eco-schemes adoption is too small to improve the average value of the indicator.

Finally, input use at farm level is reduced in all scenarios compared to the baseline, as implied by the lower pesticide and fertilizer expenditures per hectare. Since the Leontief technology assumption in the model corresponds to fixed variable input costs per hectare and crop, the decrease in input expenditure is the result of changes in cropping patterns and of the higher shares of fallow land required by both enhanced conditionality and the eco-schemes.

Overall, three general observations can be derived from the results reported in Table 5. First, LE scenarios generate relatively sizable environmental improvements over the baseline, which are even comparable to the improvements reported for HE (ME) scenarios: that is, LE represents between 66% and 100% (70% and 100%) of the improvement induced by the HE (ME) scenarios across the considered indicators. Second, the improvement in the value of the environmental indicators for low stringency conditionality (LC) scenarios across different levels of environmental ambition is between 45% and 112% of the improvement from the corresponding HC scenarios. Third, HC scenarios lead to greater environmental improvements compared to LC scenarios, and the differences between the two scenario types become more pronounced with smaller eco-scheme payments, except for the case of the SI/hectare indicator. This last result appears to mirror the eco-scheme adoption rates depicted in Figure 1.

DISCUSSION AND CONCLUSIONS

In this paper we assess the economic and environmental impacts of some of the farm-specific measures introduced by the CAP post-2020 reform, using a set of scenarios that are constructed around assumptions about the distribution of DP across farms and the stringency of mandatory and voluntary farm obligations. Our results clearly show that the new farm environmental obligations, which are more demanding compared to the old CAP, can deliver environmental improvements at rather moderate costs in terms of farm income loss. On the contrary, our analysis does not contribute directly to answering the question of whether the decentralized design of the new CAP is more effective than the current CAP in achieving its objectives since we do not consider in our scenarios the MS-specific implementation of the policy. However, our simulations do reveal the heterogeneity of the income and environmental effects of different policy scenarios across different indicators and farm groups, which needs to be considered by national strategic plans.

While our results suggest that there is scope for the new CAP for contributing to the improvement of the environment, a more complicated issue, with direct budgetary implications, is the optimal pathway towards such improvements. Overall, and with few exceptions, we have shown that our environmental indicators improve with greater environmental ambition (higher eco-scheme payments). However, although the minimum share decided in the 2021 political agreement for eco-schemes amounts to 25% of the DP envelope (as considered in the ME scenario), the alternative LE scenarios (10% allocation) also appear to offer considerable improvements and at smaller income losses. An associated policy choice question is the optimal stringency of enhanced conditionality, in other words, whether it is more effective to achieve environmental targets through greater emphasis on enhanced conditionality or on eco-schemes. While even LC scenarios improve the values of the considered environmental indicators substantially compared to the baseline, the improvements brought about by HC scenarios are generally greater and the performance differential between the two scenario types tends to increase as the eco-scheme payment becomes smaller. This discussion suggests that enhanced conditionality, at least as it is modeled herein, is the key determinant of environmental performance across all scenarios.

In this paper, we do not attempt to investigate the effects of policy choices made by MS, since the CAP implementation is still unknown and thus not considered. Nevertheless, our analysis reveals the rather ample options at the disposal of MS to balance the trade-offs between environmental improvements and income effects for different farm groups. This can be seen through the comparison of the HE/LC and ME/HC scenarios that exhibit rather similar eco-scheme adoption rates, and almost identical improvements to the SH and SI indicators, but at slightly different costs in terms of farm income loss. The example demonstrates how different policy options (in our case, environmental ambition, and conditionality stringency) can be combined in different ways for achieving a specific target. Ultimately, the optimal combination of the examined policy options depends on the chosen national priorities; if environmental targets are set relatively high, a greater budget for eco-schemes, combined with stringer conditionality are needed to reach these targets. An additional argument in favor of increased environmental ambition appears to be the progress towards the objective of equity in payment distribution, achieved with the redistribution of capped payments and of the unspent eco-scheme payments, which are re-allocated to adopting farms. On the contrary, if income support were a policy priority, a lower environmental ambition and a less stringent conditionality would be preferred given that they also deliver sizable environmental improvements. The comparison between HE/HC and LE/LC is an example of scenarios reflecting different policy priorities, as they represent two opposite extreme cases in terms of economic and environmental outcomes.

The complexity of the simulated CAP impacts presented in this paper illustrates the relevance of quantitative ex-ante analysis to support evidence-based policymaking for the CAP post-2020 reform. Given the flexibility available to MS in choosing among different CAP measures to achieve their policy targets, model-based ex-ante analysis is required to guide these choices at an early stage of the policymaking process to reduce the risk of not meeting the set targets and to identify possible trade-offs generated by the said choices. In this context, the current paper also demonstrates the relevance of farm-level models to analyze the heterogeneous impacts of the CAP post-2020, which stems from their ability to assess the different policy options available for MS at the appropriate level of granularity. This refers particularly to the MS choice of environmental measures (whose implementation is usually farm-specific) and to farmers' endogenous adoption of eco-schemes.

An important issue, which is tightly linked to modeling the CAP reform, and which has come under heavy scrutiny in the literature, is the existence of appropriate indicators and the quantification of targets to assess environmental performance (Guyomard et al., 2020; Lovec et al., 2020). Our analysis highlights the importance of impact indicators for ex-ante modeling to support policy planning, particularly considering the wide range of policy options at the disposal of MS. Unfortunately, the information included in existing databases, like FADN, has not yet allowed the development of a coherent and inclusive set of impact indicators. It is widely accepted that the lack of impact indicators (and therefore of quantifiable targets) undermines the capacity of current models to assess the full spectrum of environmental impacts of the new CAP (Guyomard et al., 2020). For IFM-CAP, the lack of EU-wide biophysical information for individual farms limits our analysis to the erosion, crop diversity, and intensification indicators, and it has not yet allowed the calculation of indicators capturing other environmental impacts (e.g., water pollution, greenhouse gases emissions). Nevertheless, the selected indicators still offer a general picture of the potential environmental improvements of the new CAP.

The above shortcomings of EU databases relate directly to their current structure, which limits their capacity to provide the necessary data for robust evidence-based support to the widening objectives of the CAP reform, including its contribution to promoting a transition to a sustainable food system envisaged within the Farm to Fork strategy. While various data sources exist in the EU,[20] they are not interlinked and they are topic-specific,[21] with the collected information not covering all those aspects of agricultural production that are needed for integrated policy assessments, particularly at micro/farm-level (e.g., information about adopted environmental practices; environmental indicators; biophysical characteristics, the spatial dimension of the information). This calls for improvements of the existing EU data infrastructure, at least in two directions: (i) interlinkage of existing datasets and (ii) collection of additional information that is required for analyzing the new CAP objectives related to the European Green Deal, thereby addressing gaps in existing datasets (Pope & Vrolijk, 2016). Acknowledging the need for such improvements, the Commission recently launched a process to convert the FADN survey into the "Farm Sustainability Data Network (FSDN)" by including more environmental and social variables. A better linkage to other data sources is also envisaged, for example, with national statistical offices, and with geospatial data through the European Space program.[22]

A final word of caution is needed as one needs to be aware when drawing conclusions that our findings also depend on modeling assumptions. First, although the scenarios have been parameterized around some key policy elements, the actual implementation of the CAP post-2020 across MS will likely include a broader set of mandatory and voluntary measures than the ones considered in this study, which can also differ in terms of environmental stringency or the eco-scheme payment design. Given this uncertainty, the scenarios examined serve as a limited sensitivity analysis exercise, which allows to test specific policy assumptions and improve our understanding of their potential farm-level impacts. Further, the scenarios do not fully consider the complete green architecture of the CAP post-2020, particularly organic farming and AECMs which are financed through Pillar 2 and are anticipated to play an important role in achieving the climate and environmental objectives of the new CAP. Our analysis also does not consider the impact on output markets and therefore it ignores price feedback effects. For example, the decrease in production, particularly for some high-value commodities like vegetables and permanent crops, would lead to higher prices and consequently to smaller income effects than what we report. Another limitation, intrinsic to all static farm models, is that IFM-CAP assumes a fixed organizational structure, implying that farm exit/entry decisions are not modeled, and that land is reallocated only within farms, ignoring interactions between agricultural holdings. Modeling farmers' cooperation is beyond the scope of the IFM-CAP model due to the lack of appropriate data. Finally, the self-selection of farms into eco-schemes is based on a pure profit-maximization criterion, meaning that farms that gain from the measures become adopters. However, this choice can also be affected by other factors like demographics, farmers' attitudes and beliefs, and the institutional environment (Dessart et al., 2019), which are not captured by our modeling approach. In addition, due to the lack of farm-specific data, we rely on information at MS level to characterize existing farm practices (e.g., default soil cover shares) and to estimate any additional costs of eco-scheme adoption. This may bias the estimation of the policy effects, depending on how close these values are to the real practices applied by the modeled farms.

Despite its limitations, our analysis shows the environmental potential of the CAP post-2020 and the interesting choice conundrum that its decentralized design presents to MS. It remains to be seen how strategic plans will reflect the national priorities and the degree of heterogeneity of farm response, which will determine the economic and environmental performance of the policy. The evaluation of the potential impact of these plans is a prominent avenue for future research when the relevant information and data become available.

DISCLAIMER

The authors are solely responsible for the content of the paper. The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

ENDNOTES

[1] Press release: Political agreement on new Common Agricultural Policy: fairer, greener, more flexible https://ec.europa.eu/commission/presscorner/detail/en/ip_21_2711.

[2] The nine EU-level CAP objectives include: (1) ensuring a fair income to farmers; (2) increasing competitiveness; (3) rebalancing the power in the food chain; (4) tackling climate change; (5) fostering sustainable development and efficient management of natural resources; (6) preserving landscapes and biodiversity; (7) supporting generational renewal; (8) supporting vibrant rural areas; and (9) protecting food and health quality (EC, 2018a).

[3] According to the June 2021 agreement, the performance of the CAP strategic plans will be monitored and reviewed by the European Commission based on a set of pre-defined indicators.

[4] The CAP consists of two "Pillars" of agricultural support. Pillar 1 includes direct payments to farmers and market measures, whereas Pillar 2 covers Rural Development Measures targeting both the farming sector, and more broadly the development of rural areas.

[5] BISS is granted to farmers in two forms: as land-based subsidy — mainly applied in Eastern MS — or as payment linked to entitlements. Under the second system, each farm is allocated a number of entitlements, which can be activated (i.e., thus receive BISS) only if accompanied by eligible land.

[6] External convergence requires that MS with DP payments per hectare below 90% of the EU average will gradually close 50% of the gap to 90% of that EU average. Internal convergence, on the other hand, aims at farm payment entitlements per hectare that are at least 85% of the MS or regional average payment value by 2026. https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/new-cap-2023-27/key-reforms-new-cap_en.

[7] Other smaller DP within Pilar 1 in the CAP post-2020 include the Young Farmers and Small Farmers schemes. The former is mandatory for MS and represents complementary income support for young farmers. The latter is voluntary for MS and represents a payment (lump sum or per hectare) to small farmers replacing all DPs.

[8] Towards a post-2020 common agricultural policy, Fact Sheets on the European Union, European Parliament. https://www.europarl.europa.eu/factsheets/en/sheet/113/towards-a-post-2020-common-agricultural-policy.

[9] A detailed description of the mathematical structure of the model, together with all variables, parameters, constraints, and the environmental indicators are provided in the accompanying supplementary material.

[10] The baseyear does not include data for Croatia whose accession to the EU was finalized in 2013.

[11] CAPRI model documentation 2014. https://www.capri-model.org/docs/capri_documentation.pdf.

[12] An analytical table with all DP envelopes per MS can be found in the accompanying supplementary material.

[13] Voluntary coupled support. Review by the Member States of their support decisions applicable as from the claim year 2020. https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/voluntary-coupled-support-note-revised-july2020_en.pdf.

[14] List of potential agricultural practices that eco-schemes could support. https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/key_policies/documents/factsheet-agri-practices-under-ecoscheme_en.pdf.

[15] Agri-environmental indicator—soil cover. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_soil_cover.

[16] The costs for additional cover areas (EUR/hectare) are national averages, thus assumed homogeneous across farms in the same MS. They are approximated following the approach implemented in the CAPRI model as 50% of seed costs and 25% of machinery and other costs of the activity "OFAR – Other fodder on arable land."

[17] Income is calculated as the difference between total revenues (output value and subsidies) and variable costs (e.g., fertilizers, pesticides, seeds, feeding), including the additional costs for complying with the enhanced conditionality and eco-scheme obligations.

[18] We assume that farms adopting eco-schemes and receiving the eco-scheme payment in the parent scenario retain this payment in the sub-scenarios.

[19] A functional crop group is defined as a set of crops that show similar responses to changes in environmental conditions (e.g., nutrients, water stress) or have similar effects on major ecosystem services (e.g., nitrogen fixation, biological diversity, soil health).

[20] Some examples of EU datasets, besides FADN, include: the Farm structure survey (FSS), the Integrated Administration and Control System (IACS), the Land use and land cover survey (LUCAS), and the Copernicus Land Monitoring Service.

[21] For example, FADN collects information on income and production activities of farmers; FSS collects only structural farm information, and some farm management practices; IACS contains detailed special information of CAP subsidies disbursement to farmers.

[22] Conversion to a Farm Sustainability Data Network (FSDN). https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12951-Conversion-to-a-Farm-Sustainability-Data-Network-FSDN-_en.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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