Abstract

The main novelty of the most recent Common Agricultural Policy reform is the *greening*, which provides a payment to farmers who respect certain ‘agricultural practices beneficial for the climate and the environment’. The *greening* is part of a framework that includes other changes to the first pillar.

In the present study the possible impact of first pillar reform on a Farm Accountancy Data Network (FADN) sample of Italian farms was carried out using a Positive Mathematical Programming model. This model considers the mechanisms of production choices according to compliance with the greening practices, as well as possible administrative penalties or reductions in payments in the case of non-compliance.

Results showed that while the impact of the greening practices is limited in terms of land use, there were positive effects on environmental indicators. Coupled payments, along with greening practices, determine a larger impact and are effective in achieving environmental goals. Moreover, the system for reducing green payments and levying administrative penalties in case of non-compliance is effective and ensures compliance with practices in almost all farms.

Key words: greening practices; reduction of green payments and administrative sanctions; first pillar reform; positive mathematical programming

1. Introduction

The new Common Agricultural Policy (CAP) integration of more environmental concerns has increased the demand for tools that can be used to help assess the impact of policies aimed at influencing how farmers interact with the physical environment, as well as to provide quantitative environmental indicators (Buysse et al., 2007; Ittersum et al., 2008; Britz et al., 2012; Pelikan et al., 2014; de Frahan, 2016). Achieving these goals is particularly important, as the sustainable management of natural resources and addressing climate change are together one of the three 2014–2020 objectives of the CAP. This objective is being pursued, among other means, by devoting at least 30% of the CAP's financial resources to direct 'green payments' (henceforth, greening) conditional on farmers respecting certain 'agricultural practices beneficial for the climate and the environment'. This attempt to define and fund EU-wide mandatory green standards through the direct payments of the first pillar is novel (Matthews, 2013). Greening is part of a framework that includes other changes to the first pillar, such as the convergence of the basic payment and the coupled payments[1]. Another important aspect of the greening is that non-compliant farmers are subject to reduced payments and administrative penalties.

The paper focuses on two specialised farming systems that are likely to be affected to the greatest extent by the introduction of greening practices: the maize system, localized mainly in northern regions, and the durum wheat system, especially localized in central and southern regions (Cimino et al, 2015).

The purpose of the present paper is to assess the potential impact of the greening, as well as of the overall reform of the first pillar in terms of land use, environmental indicators, and economic results, using the Positive Mathematical Programming (PMP) approach. This assessment is conducted on a sample of Italian farms (312 farms) specialised in the production of cereals, oilseeds, and protein crops of three regions situated in the north (*Lombardia*), centre (*Marche*) and south (*Puglia*) of Italy.

Lombardia is one of the main Italian regions as regards the maize production. This production mainly occurs in specialized farms and with medium-large size, therefore more subject to the greening constraints. The same can be considered for the *Marche* and *Puglia* which are respectively the main producer regions of durum wheat of centre and south of Italy and their production represents 42% of that Italian (MIPAAF, 2013).

[1] Member States that applied the historical Single Payment Scheme (SPS), the value of farm-based unitary entitlements will move towards the national average basic payment. This mechanism, referred to as *convergence*, will either increase or decrease the unitary entitlement of the affected farms. Moreover, Member States can allocate up to 10% (or more, under specific circumstances) of the national ceiling to coupled payments.

Furthermore, the analysis has considered the altitude class to which the farms belong. This is important because the greening has different impacts in mountain, hill and plain. In general, farms located in the plain are more affected by the greening practices in particular by the diversification and Ecological Focus Area (EFA) requirements. In the hill and mountain, farms are less affected except those specialized in alfalfa cultivation (Solazzo and Pierangeli, 2016).

This paper offers a novel methodology regarding the mathematical formulation of administrative penalties and reductions in greening payments. To date, the mechanisms of green payment reduction and administrative penalties for non-compliant farmers have not been explicitly or comprehensively mathematically modelled. Considering that the *greening* is one of the most debated aspects of the new CAP and probably subject to reviews, this paper could contribute to this discussion and inform decision making. Moreover, most of the existing research does not use environmental indicators to assess the impact of *greening* and other changes to the first pillar.

We found that the main impact of the three greening practices is limited in terms of land use and economic results, but is positive in terms of environmental indicators. We also found that the system for reducing green payments and levying administrative penalties is effective and ensures compliance with practices in almost all farms. These results also show that the coupled payments, along with the *greening*, are effective in achieving environmental goals, and that the most significant economic impact of this CAP reform stems from the convergence of the basic payment.

The next section describes the main features of the direct payments policy with regard to greening practices and related reductions and penalties. After presenting recent literature on *greening* and the first pillar of the CAP, the features of the model used in the analysis are described and discussed. The section on the empirical analysis then describes the main characteristics of the farms that were sampled, the policy scenarios considered in the simulations, and the obtained results. The paper ends with discussion and conclusions.

2. *Greening* within the new CAP direct payment scheme

2.1. General aspects

The Common Agricultural Policy (CAP) is currently organized into two pillars, with the first related to direct payments and Common Market Organizations (CMOs) and the second related to rural development policy. Historically, the first pillar is the most important in financial terms and the direct payments system, known as Single Payment Scheme (SPS), has been redesigned by the CAP reform 2014-2020 into different payments including the basic payment, greening payment and coupled payments.

The basic payment has the same characteristics and functions of the SPS, but with less financial resources. In fact, part of the national ceiling is also used to activate greening payments and coupled payments[2]. Member States that applied the historical SPS (e.g. Italy), the value of farm-based unitary entitlements will move towards the national average basic payment. This mechanism, referred to as *convergence*, will either increase or decrease the unitary entitlement of the affected farms.

Coupled payment may only be granted to those sectors or regions in which specific types of farming or specific agricultural sectors deemed to be of particular importance for economic, social, or environmental goals face clear and specific difficulties. Coupled payments can have a significant impact on farmers' land allocation decisions, influence the use of other resources and, thereby can have an impact on the environment.

The requirements for receiving payments for agricultural practices that have been deemed beneficial for the climate and the environment (*greening*) are in addition to *cross-compliance* constraints. *Greening* requirements are intended to protect the basic environmental conditions necessary to agriculture, and comprise three basic elements:

a. diversifying cultivation by growing at least two crops on farms where the arable land exceeds 10 ha (and at least three crops where arable land exceeds 30 ha), and by limiting the main crop to 75% of the arable land (and the two main crops to 95% of the arable land where arable land exceeds 30 ha);
b. maintaining permanent grassland at the national, regional, or farm level;
c. maintaining at least 5% (7% by 2017) of the arable land of farms larger than 15 ha as Ecological Focus Areas; these areas may take the form of fallow land, terraces, landscape features, buffer strips, hectares of agro-forestry, strips of eligible hectares along forest edges, areas with short-rotation coppice, afforested areas, areas with catch crops or green cover, or areas with nitrogen-fixing crops.

Another important aspect of the *greening* is that non-compliant farmers are subject to reduced payments and administrative penalties. Reductions of the greening payment and the levying of administrative penalties have been designed according to the Commission's Delegated Regulation 640/2014 (Vankova and van der Greft, 2015; Louhichi et al., 2015; Solazzo and Pierangeli, 2016). Those aspects are explained in detail in the Appendix.

[2] Italy has allocated the following financial resources to first pillar payments: basic payment (58%), greening payment (30%), coupled payments (11%); payments for young farmers (1%).

2.2.Literature review

Several studies on the possible impact of *greening* within the new CAP direct payment scheme have been conducted in recent years. Some of these studies have been qualitative in nature, while others have been quantitative in nature (e.g. econometric and mathematical programming approaches). Analyses also differ regarding the addressed topics. Some of these studies consider the possible impact in terms of land use (especially the impact of the introduction of EFA and of nitrogen-fixing crops), others consider the impact on farm income and farmers' responses to *greening*, and others its environmental implications such as crop diversification, gas emission and input use. Few studies consider all or more aspects simultaneously.

The literature review is structured by considering first what previous studies have suggested could be the impact of the greening even if by using different methodologies. The second part of the review looks specifically at the analyses that used mathematical programming techniques and, in particular, the Positive Mathematical Programming, that is the approach we used. The review is aimed at underline what our analysis adds to the existing literature on this specific topic.

Hart (2015) argues in qualitative way that greater diversity in cropping patterns could potentially improve biodiversity, particularly if fallow or legume crops are introduced into cropping patterns. More nitrogen-fixing crops may be introduced by farmers, as such crops count both towards EFA compliance and crop diversification. Nitrogen-fixing crops are also seen as desirable in stimulating the production of European-grown proteins, thereby reducing the EU’s dependence on imported soybeans.

Ciliberti and Frascarelli (2015) argue in qualitative way that the whole reform of the direct payments (including *greening* and coupled payments) may help to limit greenhouse gas emissions from agricultural soils and to ensure sustainable food provision, or at least to move in this direction.

Allen et al. (2012) argue in qualitative way that the Ecological Focus Areas have the greatest potential, with much of this potential depending, in practice, on precisely how proposals evolve, the final form they take, the scope for tailoring interventions to local circumstances, the behaviour of EU Member States, and the response by farmers.

The study by PBL Netherlands Environmental Assessment Agency (Westhoek et al., 2012) suggests that the impact of crop diversification and permanent grassland measures will be negligible, as most farms already meet these criteria. They argue that the most effective measure to increase levels of production and reduce greenhouse gas emissions in the EU is EFA criteria.

Chiron et al. (2013) analysed the potential impacts of future CAP land use on the abundance of the 20 farmland bird species included in the French Farmland Bird Indicator (FBI), demonstrating that the relative abundances of specialized farmland bird species depend on both crop-cover type and the total area being cultivated. Model predictions show a general decline in the abundance of farmland birds between 2007 and 2020. The loss of farmland birds is predicted to be less pronounced under the *greening* scenario, although the predicted FBI values have relatively large errors.

Schulz et al. (2014) used discrete choice experiments using a sample of 128 German farmers to explore farmers' prospective responses to *greening*. Participants were asked to choose between a greening option, which had a given set of management prescriptions, and an opt-out alternative, which offered a set cut of the single direct payment. Schulz et al. found that farmers' choices were driven by greening policy attributes, personal and farm characteristics, and interactions between these two groups of variables. While farmers overall perceived *greening* as a costly constraint, not all farmers were equally affected, nor were all greening provisions regarded as equally demanding.

Villanueva et al. (2015) performed an ex-ante assessment of Agri-Environmental Schemes (AES) in permanent cropping, analyzing several issues that have received little attention from researchers, such as Ecological Focus Areas (EFA) and collective participation. For this purpose, a choice experiment was used to assess farmers' preferences toward AES in a case study of olive groves in southern Spain. Results show high heterogeneity among farmers, with different classes being identified, from potential participants to non-participants.

Cimino et al. (2015) analyzed the effects of the greening measures on farm income in Italy, focusing on the two specialized farming systems that will be most affected by the introduction of green payments: those specialized on maize (that are common in northern regions) and on durum wheat (that are common in central and southern regions). The effects of greening requirements were determined, by looking at the change of total gross margin deriving from the introduction of crop diversification and EFA requirements on the Italian FADN farms. The results show that greening requirements will probably cause some significant reduction of gross margin, especially in farms specialised in maize production and located in the plains[3].

Another Regarding those studies that used mathematical programming to investigate the impact of *greening*, many investigations have been conducted in recent years using farm-based Positive Mathematical Programming (PMP; Wąs et al., 2014; Ahmadi et al., 2015; Cortignani and Dono, 2015; Louhichi et al., 2015; Solazzo et al., 2015; Solazzo and Pierangeli, 2016).

[3] The impact of the greening measures was evaluated by comparing a pre-reform scenario with a post-reform scenario. The simulation regarding the post-reform scenario was drawn to show the combined impact of two greening measures: the introduction of the EFA on 5% of the arable area and the crop diversification requirement. The impact of the EFA was introduced by reducing the area of each representative farm by 2,5% for the farms located on the hills and by 5% for the farms located in the plains, while no reduction was applied to the farms located in the mountains. With regard to the crop diversification measure, simulations were carried out by reducing the area cultivated with the specialised crop (maize or wheat) from 100% to 75% of the farm area and by adding two additional crops, which represent 20% and 5% of the UAA. The choice of the second and the third crop was based on the area covered by each crop in each selected area (region/altimetry), as recorded by the 2010 agricultural census data.

Wąs et al. (2014) used a farm-optimization model that employed PMP techniques to estimate the potential effects of *greening* for 218 types of Polish farms. They found that a majority of Polish farms were already compliant with the new requirements, and that the adjustment of the remaining farms to the new requirements created only small changes in cropping structure, resulting in a negligible impact on the income and an improvement of Shannon index.

Ahmadi et al. (2015) used an optimized farm-level model to explore how Scottish beef and sheep farms might be affected by *greening* and flat rate payments under the current CAP reforms. They found that greening measures had little impact on net income margins for most of these farms; the only exception was beef finishing farms where net margins decreased by 3%.

Solazzo et al. (2015) assessed the different regionalisation and *greening* implementation schemes contained in the preliminary proposals presented to the Trilogue, as well as in the CAP reform adopted on 16 December 2013. These authors compared the potential impacts of these proposed reforms on production and land use, and on the economic revenue of farm holders in the Emilia-Romagna region. This assessment was performed using a regional PMP model for individual farms using the Farm Accountancy Data Network (FADN) dataset. They have found that *greening* results in a reduction of maize and durum wheat, which are most commonly substituted by nitrogen-fixing crops.

Finally, Cortignani and Dono (2015) evaluated the impact of *greening* in an agricultural area of southern Italy, as evidenced by economic, environmental, and social indicators. Especially in terms of environmental indicators, they showed that *greening* appears to have a positive impact on curtailing the use of nitrogen and on boosting crop diversification.

In all of these four papers, greening practices are implemented in the programming models as obligatory constraints without the possibility to choose whether or not the respect of the practices. In contrast, Louhichi et al. (2015) and Solazzo and Pierangeli (2016), presented below, have implemented this possibility of choice in the mathematical programming models.

Louhichi et al. (2015) assessed the effects of the crop diversification measure. However, while their model considers how crop diversification may impact the main crop, they do not consider the impact of other practices or of the penalty system. They found that most (80%) non-compliant farms chose to improve compliance following the introduction of the diversification measure, owing to the sizable subsidy reduction imposed. However, the overall impact on farm income was limited.

Solazzo and Pierangeli (2016) developed a two-step modelling approach able to estimate: i) the redistributive effect of direct payments reform for the *greening* and the basic payment scheme; ii) the farmers' behaviour, in terms of land use and income effects, with a positive mathematical programming (PMP) model on a Farm Accountancy Data Network (FADN) sample of Northern Italian farms, implementing the whole set of greening commitments and sanctions. Although the overall *greening* impact is low, some specific areas and productions are affected to a greater extent: greening causes a decrease in maize and, in some contexts, in wheat which are replaced by nitrogen-fixing crops. The consequent average income reduction is lower than 0.5% (−7 €/ha) and almost all farms choose to fully apply the greening constraints in order to avoid sanctions. The weakening of greening measures during negotiations, the amount of greening payments and the sanctions system are strong incentives for farmers to fully comply with the greening practices. However, in Solazzo and Pierangeli's model, it is not clear how the gradualness and exclusivity of the administrative penalties was modelled.

In conclusion, the current literature that has used mathematical programming models to explore the impact of *greening* on farmers does not explicitly or completely consider the mechanisms of green payment reduction and administrative penalties applied to non-compliant farmers. Moreover, most of these studies have not used any environmental indicators to assess the impact of *greening* and other changes.

3. Methodolgy

3.1. Model without *greening*

Farm-level mathematical programming models are important and widely used analytical tools in agricultural economics because they are able to represent farmer responses to changes in policy and market conditions. In the second half of the 1990s researchers moved from the classical linear or quadratic programming to PMP. This latter approach requires a relatively limited amount of data and can be perfectly calibrated to the reference period. It recovers additional information from observed activity levels, allowing researchers to specify a non-linear objective function such that the resulting nonlinear model exactly reproduces the observed behaviour of farmers and can be used for simulation analyses (Arfini and Paris, 1995; Howitt, 1995; Paris and Howitt, 1998; Heckelei and Wolff, 2003)[4]. This method not only automatically and exactly calibrates the model to observed activity levels, but also avoids adding ad-hoc constraints and over-specialised responses of the model to policy changes (de Frahan, 2016).

The standard representation of the problem faced by the farm model can be described by the following quadratic programming model, where the *j* set denotes the crops[5]:

[4] See Heckelei et al. (2012) for a review of the development and utilization of the most important PMP models.

[5] In order to simplify the mathematical formulation, the model specification does not show the sets related to farms (n), regions (reg), or altitude (alt).

$$\text{Max}\, Z = \sum_j \left(R_j \ + CP_j - AC_j(x_j)\right) * x_j + \ NE * VE$$

$$s.to \ \sum_j A_{i,j} * x_j \leq B_i \qquad (1)$$

$$x_j \geq 0$$

where Z denotes the objective function value; x_j represents the production activity levels (i.e. hectares allocated to crop *j*); R_j denotes average revenue per unit of activity; CP_j are CAP coupled payments; and NE and VE are, respectively, the number and unit value of entitlements.

$A_{i,j}$ represents the scalar element of a matrix of coefficients in the resource and policy constraints (Index *i*); B_i is the vector of the available quantities of the resources of land, labour, and water; and $AC_j(x_j)$ denotes average variable cost function per unit of activity. This equation has the following form:

$$AC_j\left(x_j\right) = \alpha_j + \frac{1}{2}\beta_j x_j \qquad (2)$$

where α and β are the parameters to be estimated.

Multiple sets of cost-function parameters satisfy the marginality conditions of Equation (2). One of the options for determining these parameters is the following (Arfini and Paris, 1995):

$$\alpha_j = c_j \ ; \quad \beta_j = \frac{\mu_j}{x_j^0} \qquad (3)$$

where c_j are the observed accounting costs and μ_j are the dual values determined by means of the following calibration constraints:

$$x_j \leq x_j^0 \,(1 + \varepsilon) \qquad \left[\mu_j\right] \qquad (4)$$

where x^0_j are the observed variable levels and ε is a small positive number (Howitt, 1995).

Especially in the last ten years, the PMP approach has been utilized in various types of analysis, which has led to a number of improvements. In 2012, Heckelei et al. reviewed the development and utilization of the most important PMP models. As pointed out by various authors, the use of prior information can improve the recovery and estimate of cost function parameters (Heckelei and Wolff, 2003; Cortignani and Severini, 2012; de Frahan, 2016). Reflecting these advancements, our analysis incorporated prior information on land value, and a common quadratic function for each homogeneous territory was estimated (Cortignani and Severini, 2012; Solazzo et al., 2015).

3.2. Introducing greening in the PMP model

Model (1) can be adjusted to account for greening requirements, greening payments, and greening payment reductions due to non-compliance in the following way:

$$\text{Max}\, Zg = \sum_j \left(R_j \ + CP_j - AC_j\left(x_j\right)\right) * x_j + Eland * VEb + (Eland - rtot) * VEg \qquad (5)$$

$$s.to \sum_{j} A_{i,j}\, x_j \leq B_i \tag{6}$$

$$rtot = \sum_{jrg} rdiv1_{jgr} + \sum_{jrg,jjgr} rdiv2_{jgr,jjgr} + rpast + refa \tag{7}$$

$$rtot \leq Eland \tag{8}$$

$$rdiv1_{jgr} \geq (x_{jgr} - 0.75 * Aland) / (0.25 * Aland) * 0.5 * Aland \quad \forall\, jgr \;\; if\; Aland > 10\, ha \tag{9}$$

$$rdiv2_{jgr,jjgr} \geq (x_{jgr} + x_{jjgr} - 0.95 * Aland) / (0.05 * Aland) * 0.5 * Aland \quad \forall\, jgr, jjgr \;\; if\; Aland > 30\, ha \tag{10}$$

$$rpast \geq x^0_{'past'} * 0.95 - x_{'past'} \tag{11}$$

$$refa \geq [0.07 * Aland - (\sum_{jefa} CF_{jefa} * PF_{jefa} * x_{jefa} + FA + LEA)/(0.07 * Aland)] * 0.5 * Aland \quad if\; Aland > 15\, ha \tag{12}$$

where VEb is the basic payment value; VEg is the greening payment value; $Eland$ is the eligible land; $rtot$ denotes total non-compliant area; and $Aland$ is the arable land. The sets *jgr* and *jefa* refer, respectively, to crops subject to diversification and crops recognized as EFAs.

The constraints (7) – (12) refer to the calculation of total non-compliant area (*rtot*), as well as the calculation of non-compliant area for the main crop (*rdiv1*), two main crops (*rdiv2*), permanent grassland and pasture (*rpast*), and EFAs (*refa*; See Table A.1).

To model administrative penalties, PMP models must be designed as mixed integer models that include three binary variables (y_1, y_2, y_3).

The objective function therefore becomes:

$$\begin{aligned}\mathrm{Max}\, Zg = \sum_{j} \left(r_j + CP_j - AC_j(x_j)\right) * x_j + Eland * VEb + (Eland - rtot) * VEg \\ - VEg * rtot * 2/4 * y_1 * (1 - y_2) * (1 - y_3) \\ - VEg * (Eland - rtot)/4 * y_2 * (1 - y_3) \\ - VEg * Eland/4 * y_3\end{aligned} \tag{13}$$

where the added components refer to the three levels of penalties defined for each of the three intervals: >3-20%, >20-50%, and >50%; see also Table A.1). y_1, y_2 and y_3 are binary variables that assume values equal to either 0 or 1; they are also governed by the following constraints:

$$(1 - y_1) * (rtot / (Eland - rtot)) \leq 0.03 \tag{14}$$

$$(1 - y_2) * (rtot / (Eland - rtot)) \leq 0.20 \tag{15}$$

$$(1 - y_3) * (rtot / (Eland - rtot)) \leq 0.50 \tag{16}$$

Constraints (14) – (16) refer to the proportion of non-compliant area in the case of the three reference values of 3%, 20%, and 50%. Note that if a reference value for the proportion of non-compliant area is not respected, the binary variable assumes a value equal to 1 and the constraint is deactivated. If this happens, the related penalties are activated in the objective function. As these penalties are not cumulative, the previous penalty is deactivated by multiplying $(1 - y_2)$ and $(1 - y_3)$.

4. Empirical analysis and simulation results

4.1. Farm characteristics

The analysis was conducted on arable farms that specialize in the production of cereals (except rice), oilseeds, and protein crops (COPs). These farms are located in three Italian regions: Lombardia (northern Italy), Marche (central Italy), and Puglia (southern Italy). Farms in northern Italy tend to specialize in the production of maize, while specialization in durum wheat is more common in central and southern Italy; farms with these specializations were selected because they have been identified as being among the most affected by *greening* (Cimino et al., 2015).

On average, farms have a size of around 30 ha of Utilised Agricultural Area (UAA) in Lombardia, and around 45–50 ha of UAA in the other two regions (Table 1).

Table 1

Farms in Lombardia tend to specialize in maize production, on average, planting maize on more than 50% of their UAA, while the rest of the UAA is used to grow minor crops such as common wheat and soybeans (Table 1). Farms in Marche and Puglia tend to specialize in durum wheat, but to very different degrees: In Marche, this crop is planted on more that 34% of their UAA, while in Puglia, more than 70% of UAA is devoted to this crop (Table 1). Other less important crops include sunflowers, alfalfa and barley in Marche, and fava bean, field bean, barley and rapeseed in Puglia.

Table 1 shows the number of FADN farms sampled for each region and altitude in the year 2013.

Of the 312 farms that make up this sample, 136 are from Lombardia (mainly from plain-type areas; henceforth, *Plain*), 99 are from Marche (mainly from hilly areas; henceforth, *Hill*), and 77 are from Puglia (equally distributed between Plain and Hill).

By applying FADN sample weights to extend the result for this sample to the entire farm population, this sample represents 28,278 farms and 614,575 ha of UAA (Table 1).

4.2. Scenarios

The baseline (i.e. pre-reform scenario) was observed in 2013, while the post-reform simulation scenarios are *greening* and *coupled payments and greening*. Both scenarios consider the convergence of the basic payment that will take place by 2019 and the introduction of *greening*.

With regard to convergence, Italy has decided to apply the Irish model, which creates a single region at the national level. The Irish model will provide a smooth transition from the current levels of basic payments towards more homogeneous levels by 2019 but not a uniform value.

The *greening scenario* does not account for the coupled payments that have been designed by the Italian government based on Art. 52 of Reg. (UE) No. 1307/2013.

The *coupled payments and greening* scenario (also referred to as the *whole reform scenario*) assumes that 11% of the national ceiling for direct payments has been devoted to coupled payments. Coupled payments have been introduced for sugar beets, processed tomatoes, and rice all over Italy. Northern Italy has also introduced a payment for soya, while other parts of Italy now offer payments for cereals (durum wheat), oilseeds (rapeseed and sunflower), and legumes (grain and fodder). The structure and levels of coupled payments have been assigned for each region based on the analysis conducted by Pupo D'Andrea (2014)[6].

The results generated by applying the whole reform scenario allow us to assess the impact of all of the main elements of CAP first pillar reform, while the results generated by applying the *greening scenario* allow us to assess the impact of *greening* alone, without coupled payments. Comparing the results for these two scenarios will allow us to assess the role of coupled payments and to verify how these payments interact with greening requirements.

4.3.Results

The impact of CAP first pillar reforms has been evaluated in terms of land use (both for main crops and for other crops), environmental indicators (Shannon index, use of irrigation, and chemical inputs)[7], and economic results. Results regarding each of these three dimensions are discussed mainly by focusing on the trends common to all considered regions and areas. The analysis aims to highlight, first, the impact of the reforms as a whole and, second, the specific role played by *greening*. The results derived from the application of the whole reform (which accounts for both the

[6] It is important to recall that these are simulated projective values and that the final level of such payments will be identified at the end of the growing season according to the number of hectares on which such payments will be claimed.

[7] The Shannon index was developed in 1948, and is one of the most frequently used indicators of biodiversity or crop diversity (Shannon, 1948). In the conducted analysis, the formula used is: $\text{Shannon Index} = -\sum_i \text{sh}_i \ln(\text{sh}_i)$, where sh_i is the share of crop *i* within the arable land. Higher values indicate a greater number of different crops or a more diversified crop structure on that farm. In the case of monoculture, the Shannon index assumes a value equal to zero. If an area is split equally between 8 crops, the Shannon index is equal to 2.08. The used Shannon Index is based on the numerosity of crops in farms and this information is included in the data FADN and in the simulation results. This indicator could identify and assess biodiversity with further developments (e.g. individual species on pastures and EFAs). The FADN data also provide indications about the uses of water and chemical inputs. In fact, the uses (per hectare) for each crop are present in the FADN database. The land use changes in the simulation scenarios determine an impact of uses of these factors (water and chemicals).

introduction of coupled direct payments and *greening*) are therefore compared with those derived from the application of the *greening scenario* (which does not include the coupled direct payments). Reforms were found to affect land use by significantly reducing cultivation of the main crop. Relative to the baseline, the area devoted to maize declined by more than 15% in Lombardia, while durum wheat declined by more than 12% throughout Marche and Puglia (Table 2). Land that was previously used by the main crop is converted to cultivate other crops, especially those eligible for coupled direct payments (Table 2). This reform is also expected to increase EFA crops and grassland to meet greening requirements. However, in a few cases, EFA areas (e.g. mountainous areas in Marche) and grasslands (e.g. hilly areas in Marche) will probably decline due to the effect of the introduction of coupled payments (Table 2).

Table 2

It is clear that these changes are due, to some degree, to the introduction of coupled payments; this was evidenced by the fact that the application of the *greening scenario* generates, in most of the cases, a smaller reduction of the main crop. Especially, under the *greening scenario*, maize production in Lombardia decreases by only around 1/3 as much as by the application of the whole reform scenario. Reductions in durum wheat production in Marche had a similar pattern. Overall, under the *greening scenario*, the area devoted to crops eligible to coupled payments declines less than under the whole reform scenario; in a few cases, such as in Marche, this area even declines in comparison with the baseline (Table 2). A similar result was found regarding EFAs. These results clearly show that coupled payments strongly influence land allocation and determine a larger impact respect to the *greening scenario*.

Changes in land allocation were found to affect the considered environmental indicators, with a strong reduction in the land devoted to the main crops resulting in a non-negligible increase in the Shannon Index in all considered areas (Table 3). This effect occurs because a share of the land devoted to the main crop in the pre-reform condition is now used to grow other crops, increasing crop diversification. This trend is reinforced by the increase in the amount of crops eligible for coupled payments.

Table 3

The reform was projected to also have implications on environmentally sensitive factors such as irrigation and the use of chemical fertilisers. In our model, the application of the whole reform scenario results in a reduction of water use in three of the five areas in which irrigation is currently used (Table 3). However, in the remaining two areas (i.e. hilly areas in Lombardia and Marche), the opposite occurs. This occurs because in these two areas the crops substituted for the main crop also require irrigation. As the main crops (i.e. maize and durum wheat) both require relatively high levels of nitrogen fertilization, the projected changes in cropping patterns result in a decline in nitrogen use in all considered areas (Table 3). In most cases, this reform also generates a decline in the use of phosphorus and potassium, with the notable exception of plains areas in Lombardia.

Most of the previously described impacts on environmental indicators reflect the introduction of both coupled payments and *greening*, meaning that *greening* alone is responsible only for part of the observed changes. Indeed, *greening* alone increases the Shannon Index level only in some of the considered areas, while in other areas the index remains similar to the baseline. However, this is not always the case: in the plains areas of Puglia, the index following *greening* only was higher than the index after applying the whole reform scenario (Table 3).

Similarly, adhering to greening requirements alone generates reductions in irrigation water and fertiliser use that are generally lower than those generated by the joint effect of greening requirements and the introduction of coupled payments. This finding suggests that, in these cases, coupled payments may be a useful tool in pursuing environmental goals. However, this is not so in the case of the plains areas of Lombardia, where the use of phosphorus and potassium fertilisers declines only under the *greening scenario* and not under the whole reform scenario; this because with the application of the coupled payments, especially increases the area devoted to soya and rice, crops more exigent in terms of phosphorus and potassium.

Overall, the reform is expected to have negative consequences on the economic performance of farms. The application of the whole reform scenario generates a particularly severe reduction in gross margins in Lombardia (greater than 13% in both considered areas); however, this reduction was much less severe in Puglia (just over a 3% reduction) and Marche (just over a 1.8% reduction; Table 4).

This loss of farm revenue reflects a number of factors relating to revenues, direct payments, and costs. While farm revenues decline in all areas, this decline is most severe in Marche – Mountain and Puglia – Hill, where there are few profitable alternatives to durum wheat. The opposite is true in the case of Lombardia – Plain and Marche – Hill, where revenue losses due to the application of the whole reform scenario are negligible.

Most of the decline in farm economic outcomes is due to a large reduction in direct payments. This is clearly due to the convergence mechanism, which is particularly negative for farms located in Lombardia and in Puglia – Plain. In Lombardia declines in direct payments exceed 20%, and in

Puglia – Plain declines exceed 8%, as compared with the level of direct payments received at the baseline (Table 4).

Table 4

It is important to underline that this reduction in payments is also due to the reduction of green payments and to the administrative penalties linked to greening requirements. However this is the case only for the two groups of farms located in plains areas (i.e. Lombardia and Puglia), where a reduction in green payments and a levying of administrative penalties is observed. In all of the other four areas the farms are fully compliant with the greening practices. This means that in almost all considered cases, the greening practices have been designed in a way to ensure a very high level of compliance.

These two non-compliant farms have three very peculiar characteristics. First, these farms have a very high level of specialisation in their main crop, using more than 98% of their UAA at baseline. Second, for these farms, the main crop is much more profitable than any alternative crop. Finally, for these farms the new (i.e. post-reform) greening payment level is relatively small. The last two characteristics make that the ratio greening payment over the gross margin of one hectare of the main crop is lower in these farms than in most of the other farms. Hence, it is worth forgoing part of the direct payments to avoid a reduction of gross margins caused by a further reduction of the main crop.

The application of the whole reform scenario provides an incentive to switch to a less intensified cropping pattern, which tends to reduce farm costs. While these reductions were overall minor, in Marche – Mountain and Puglia – Hill cost reductions exceeded 9% relative to the baseline (Table 4).

The introduction of coupled direct payments seems to mitigate the negative impact of the reform on farm economic performance, with the application of the *greening scenario* resulting in a more significant reduction in gross margin than the application of the whole reform scenario (Table 4). While this was true for all considered groups of farms, this effect was particularly marked in the regions of Marche and Puglia, which experienced decreases in gross margin in excess of 9% and 14%, respectively. This finding suggests that the coupled payments determine an increase of the gross margin. In fact, in the absence of coupled payments, farms in all six groups experience a reduction in direct payments greater than for the application of the whole reform scenario and this is particularly true for farms located in Marche and Puglia (Table 4). This suggests that coupled payments make crop diversification less costly by increasing the relative profitability of crops that substitute for the main crop.

However, the elimination of coupled payments does not drastically change compliance, as the same two farms were non-compliant in both cases. The only difference is that the farm located in Puglia – Plain is expected to have slightly more reduced payments and to experience higher administrative penalties under the greening scenario than under the full reform scenario (Table 4).

5. Discussion

The results of our analysis are generally in line with those of other recent studies, while adding new insights to the discussion. Like other studies, we found that the impact of *greening* is limited in terms of both changes in land use and income. The current study also found differences between farming systems from different regions and altitude zones. The impact of *greening* was greater for farms located in the plains and more limited in hilly and mountainous areas; this was because, even at the baseline, farms in hilly and mountainous areas already have relatively less intensive and diversified production patterns. Moreover, in the hills of central Italy, the large choice of crops that do not require irrigation makes diversification less onerous.

From an economic point of view, the most significant negative impact of the CAP reform stems from the convergence of the basic payment. In all of the areas considered in the present study, considering the past production decisions and pre-reform coupled payment levels, initial basic payments are higher than the national average, with the impact of the convergence differing by area according to the initial level of decoupled payments. Generally, in the plains areas, decoupled payments are larger, making the impact of CAP reform greater, while in hilly and mountainous areas the opposite effect occurs.

As with Cortignani and Dono (2015), in the present study *greening* appears to have a positive impact on curtailing the use of nitrogen and on boosting crop diversity. The present paper also considered the use of other chemical inputs (such as phosphorus and potassium) and irrigation, with the finding that irrigation decreases with *greening*, particularly in areas such as Lombardy – Plain, where it is used particularly intensively.

Other studies conducted in Italy, in particular those by Solazzo et al. (2015) and Solazzo and Pierangeli (2016), have found that *greening* results in a reduction of maize and durum wheat, which are most commonly substituted by nitrogen-fixing crops. We found that this impact was amplified in the scenario with coupled payments, as such crops are also recognized as EFAs.

To explore penalties, specifically, a mixed integer model was developed. The results of the proposed model show that most of the farms studied find it economically beneficial to comply with *greening*. The weakening of greening requirements, the size of greening payments, and the effectiveness of the sanctions system all represent strong incentives for farmers to fully comply with greening practices. Recently, this has also been shown by Solazzo and Pierangeli (2016). However, as mentioned above, in Solazzo and Pierangeli's model, some characteristics of the administrative penalties were not modelled. To overcome this, in our study a mixed integer model was developed in order to explicitly consider the gradualness and exclusivity of the administrative penalties in the farms' choices.

Only two farms within our sample did not fully comply with greening practices and were subject to reductions and penalties[8]. In addition to having an altitude location of ‘plains’, other characteristics that appear to influence the choice to not adhere to *greening* are a high level of specialization in the main crop and a low ratio of greening payment to gross profit margin per hectare.

6. Conclusions

The present study analyses the impact of changes to the first pillar of the CAP using an FADN sample of specialized arable farms in Italy. These farms were drawn from the regions of Lombardia (northern Italy), Marche (central Italy), and Puglia (southern Italy). The analyzed farms are specialized in the production of maize (in northern Italy) and durum wheat (in central and southern Italy).

Positive Mathematical Programming was used to conduct the analyses. This analysis was innovative in that the proposed model represents production choices resulting from both compliance with the three greening practices and from possible reductions in the greening payment combined with the levying of administrative penalties in the case of non-compliance. Especially, in order to explicitly consider in the farms' choices the gradualness and exclusivity of the administrative penalties, a mixed integer model was developed in our study. Moreover, several farm-relevant environmental indicators were taken into account.

The explicit model representation of the system of administrative penalties and green payment reductions in the case of non-compliance suggests that these tools are effective, ensuring compliance with such practices by almost all farmers.

Coupled payments not only support production in key sectors of Italian agriculture, but also bring significant positive environmental benefits. This result seems in line with the strategic guidelines of the Italian Ministry of Agriculture, providing coupled support to those sectors or regions where specific types of farming or agricultural sectors have been deemed particularly important for

[8]One farm is located in the Lombardy plain, with a representative weight of 33 farms out of a total of 8,846; the other is located in the Puglia plain, with a representative weight of 122 farms out of a total of 2,313

economic, social, or environmental reasons. Coupled payments for nitrogen-fixing crops that are also recognized as EFAs could play a particularly key role in the strategic plan to enable the EU to reduce its heavy dependence on proteins imported from foreign countries. Although it is not possible to know in advance the exact optimal level of coupled payments[9], this tool appears promising in encouraging crop diversification, and could complement and strengthen *greening* to achieve environmental goals.

However, reform of the direct payment policy had notable negative impacts on two very important production sectors of Italian agriculture: maize and durum wheat. New production opportunities can arise only if a decrease in national supply causes the market prices of these two products to rise, giving the specialized farms considered in this analysis an incentive to produce maize and wheat.

This analysis could be improved and expanded in different ways. First, simulations of scenarios could be more detailed, including different market conditions (i.e. output and input prices, production contracts) and different climate scenarios; under some of these condition, the impact could be different, making the system of administrative penalties and green payment reductions potentially less effective. Second, additional environmental indicators could be included. In the present analysis, the Shannon Index and the use of chemicals and irrigation all indicated some pressure on the environment. Other indicators may be added in order to consider the impact on various environmental components, such as biodiversity, CO_2 emissions, landscape, and the nitrogen cycle. The construction of composite indicators, particularly, could permit an analysis of cost-effectiveness for different levels of greening payment. Finally, the aspects related to the monitoring system are not been considered. The monitoring system requires administrative checks (100% of the applications for payment) and on-site checks on a sample of at least 5% of farms. In case of irregularities, the percentage of the sample subjected to on-site checks increases. Moreover, farmers must return the obtained payments and are subject to additional penalties. An imperfect monitoring could have implications for the effectiveness of the penalty system. Further developments to the model are needed to consider the monitoring system in the farmers' choices and consequently on the simulation results.

[9] The level of coupled payments considered in this analysis was estimated by the Italian Ministry of Agriculture on the basis of allocated financial resources and assumptions about the future crop choices. Therefore the estimate may be inaccurate and the unit level of payments might be different. In any case, beyond the unit level, directions and trends emerge clearly from the conducted analysis.

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Appendix: Reduction of the greening payment and levying of administrative penalties in the case of non-compliance

Reductions of the greening payment and the levying of administrative penalties have been designed according to the Commission's Delegated Regulation 640/2014 (Vankova and van der Greft, 2015; Solazzo and Pierangeli, 2015; Louhichi et al., 2015). Table A.1 explains those aspects and defines the parameters used in the model specifications to describe these greening-related reductions and penalties.

Table A.1

Regarding the crop diversification and Ecological Focus Areas (EFAs; Art. 24 and 26 of the Delegated Regulation), the non-compliant area is obtained by multiplying the ratio of difference by 50% of the total area of arable land. The ratio of difference is calculated differently for different *greening* practices, as described in Table A.1. For the main crop, this ratio is calculated as the area of the main crop that goes beyond 75% of the total arable land over the total area required for the other crops (25%) (ratio_rdiv1). Similarly, if the area of the two main crops covers more than 95%, the ratio of difference is calculated as the area of the two main crops that goes beyond 95% of the total area of arable land over the total area required for the other crop groups (5%) (ratio_rdiv2)[10]. For the EFA, the ratio of difference is calculated as the difference between the ecological focus area required and the ecological focus area that is present over the required EFA (ratio_refa).

Article 25 defines that, if a non-compliance with the pasture area has been determined, the area to be used for the calculation of the greening payment shall be reduced by the area determined as non-compliant with the requirement considering a maximum allowed reduction of 5% (95% of permanent grassland and pasture).

The sum of these four components is the total non-compliant area[11] (*rtot*). This determines the reduction of the greening payment (*rtot * VEg*), where *VEg* is the greening payment entitlement value (Table A.1).

The levels of administrative penalties are defined according to Article 28. These are defined based on four intervals of the proportion of non-compliant area (*nca*) respect to eligible land, as defined in Table A.1. These penalties are not applied if the proportion of non-compliant area is not greater than 3%. For the other three intervals, in accordance with Article 77(6) of Regulation (EU) No. 1306/2013, the calculated administrative penalty shall be divided by 4 and limited to 25% of the greening payments for claim years 2018 and onwards.

[10] The sum of the two ratios of difference relating to the crop diversification shall not exceed 1.

[11] The total non-compliant area shall not exceed the total number of hectares of eligible land. Agricultural areas used for arable crops, vegetables, nurseries and land used to grow grass, be it naturally occurring grass or grass grown from seed, is eligible.

Table 1. Distribution of FADN sampled farms by region and altitude and represented farms in terms of number of farms and Utilised Agricultural Area by region. Main crops for each region. (baseline = 2013).

		farms number		UAA				main crop	other crops	% main crop on UAA	crops number*
		sampled	represented	total	average	min	max				
Lombardia	Plain	119	8,846	171,211	32.5	3.0	181.0	maize	common wheat, soybean, alfalfa, barley, triticale	62.5	23
	Hill	17	1,272	24,411	29.7	5.6	82.6			51.3	13
Marche	Hill	88	6,861	144,269	49.0	4.2	242.6	durum wheat	sunflower, alfalfa, barley, common wheat, faba bean, field bean	43.5	31
	Mountain	11	1,143	16,623	46.8	2.8	210.0			34.2	12
Puglia	Plain	30	2,313	86,272	51.6	10.6	238.0	durum wheat	faba bean, field bean, barley, rapeseed cabbage, chickpea	70.7	14
	Hill	47	7,840	171,788	44.6	8.9	163.0			71.9	14
Total		312	28,278	614,575							

* "Crops number "means the total number of crops observed in the baseline for each considered area

Table 2. Impact of the application of the CAP reform scenarios on cropping patterns (hectares) in each region. Absolute values in the baseline and percentage changes in the CAP reform scenarios.

	Baseline	Greening	Coupled payments and greening	Baseline	Greening	Coupled payments and greening
Lombardia	Plain			Hill		
Maize	107,058	-9.1	-28.5	12,518	-6.0	-15.2
Other crops	64,153	13.8	47.0	11,893	6.3	16.0
EFA crops	16,045	46.2	123.3	3,603	18.3	69.7
crops with coupled payments	892	31.0	2,602.9	-	-	-
permanent grassland and pasture	1,529	19.2	1.5	1,039	18.3	5.0
Marche	Hill			Mountain		
Durum wheat	62,809	-3.9	-20.8	5,691	-0.6	-12.1
Other crops	81,460	3.0	16.0	10,932	0.3	6.3
EFA crops	23,780	13.3	25.2	6,243	1.4	-14.8
crops with coupled payments	42,465	-2.8	28.9	1,310	-5.1	89.8
permanent grassland and pasture	34	8.2	-5.0	-	-	-
Puglia	Plain			Hill		
Durum wheat	60,995	-15.0	-15.7	123,507	-11.5	-25.3
Other crops	25,277	28.9	37.8	48,282	29.3	64.8
EFA crops	9,664	42.7	126.6	19,317	35.3	205.6
crops with coupled payments	-	-	-	-	-	-
permanent grassland and pasture	-	-	-	-	-	-

Table 3. Impact of the application of the CAP reform scenarios on the Shannox index and input use in each region. Absolute values in the baseline and percentage changes in the CAP reform scenarios.

	Baseline	Greening	Coupled payments and greening	Baseline	Greening	Coupled payments and greening
Lombardia	Plain			Hill		
Shannon index	1.36	1.54	1.78	1.58	1.65	1.64
water - 1,000 m^3	853,555	-3.3	-3.0	65,099	-1.8	2.9
nitrogen - tons	27,556	-2.2	-7.0	4,115	-2.8	-8.1
phosphorus - tons	12,819	-1.8	5.1	2,141	-3.6	-9.3
potassium - tons	13,223	-2.4	2.3	2,566	-4.0	-11.1
Marche	Hill			Mountain		
Shannon index	1.69	1.76	1.77	1.74	1.74	1.98
water - 1,000 m^3	2.1	3.4	7.0	-	-	-
nitrogen - tons	14,859	-1.6	-4.6	1,257	-0.8	-1.6
phosphorus - tons	5,825	-1.6	-0.9	163	-0.2	-19.8
potassium - tons	3,316	-2.0	-4.8	211	-0.2	-17.1
Puglia	Plain			Hill		
Shannon index	1.15	1.38	1.27	1.16	1.47	1.59
water - 1,000 m^3	11,064	9.7	-6.2	38,430	1.0	-11.7
nitrogen - tons	6,903	-7.1	-15.3	16,693	-4.6	-12.6
phosphorus - tons	4,477	-13.7	-14.9	8,106	-7.3	-20.7
potassium - tons	184	10.2	-3.6	5,140	-11.3	-25.0

Table 4. Impact of the application of the CAP reform scenarios on economic results in each region. Absolute values in the baseline (000 €) and percentage changes in the CAP reform scenarios*.

	Baseline	Greening	Coupled payments and greening	Baseline	Greening	Coupled payments and greening
Lombardia	Plain			Hill		
Gross margin	116,421	-21.9	-18.4	21,044	-15.3	-13.5
Revenues crops	307,672	-3.1	-0.8	36,025	-1.4	-2.3
Direct payments	81,844	-30.1	-22.1	10,852	-29.2	-24.8
coupled	0	*0*	*6,497*	0	*0*	*477*
decoupled	81,844	-30.0	-30.0	10,852	-29.2	-29.2
reduction of greening payments	0	*34*	*34*	0	0	0
administrative penalties	0	*17*	*17*	0	0	0
Costs	273,095	-3.2	0.4	25,833	-1.8	-2.7
Marche	Hill			Mountain		
Gross margin	72,985	-15.4	-3.6	9,923	-9.3	-1.8
Revenues crops	151,431	-0.8	-0.5	16,204	-0.2	-7.9
Direct payments	51,191	-21.7	-3.9	5,968	-15.4	-1.3
coupled	0	*0*	*9,154*	0	*0*	*841.4*
decoupled	51,191	-21.7	-21.7	5,968	-15.4	-15.4
reduction of greening payments	0	0.0	0.0	0	0.0	0.0
administrative penalties	0	0.0	0.0	0	0.0	0.0
Costs	129,637	-0.9	-0.1	12,248	-0.3	-9.7
Puglia	Plain			Hill		
Gross margin	48,176	-17.1	-6.7	90,078	-14.5	-3.2
Revenues crops	84,119	-4.3	-4.6	172,121	-4.5	-10.2
Direct payments	33,288	-23.9	-8.1	62,785	-20.1	-2.8
coupled	0	*0*	*5,270*	0	*0*	*10,908*
decoupled	33,288	-23.9	-23.9	62,785	-20.1	-20.1
reduction of greening payments	0	*10*	*13*	0	0.0	0.0
administrative penalties		*5*	*6*	0	0.0	0.0
Costs	69,231	-4.8	-4.8	144,829	-5.0	-11.3

* Considering that in the Baseline the coupled payments, the reduction of greening payments and the administrative penalties are equal to zero, in the CAP reform scenarios the absolute values are shown (000 €) .

Table A.1. Greening payment reduction and administrative penalties in the case of non-compliance with the greening requirements

Reduction of the greening payment	***Description***
Non-compliant area for: - crop diversification:	
main crop (rdiv1)	ratio_rdiv1 * (50% of arable land) *ratio_rdiv1 = area of the main crop beyond 75% of arable land / area required for the other crops*
two main crops (rdiv2)	ratio_rdiv2 * (50% of arable land) *ratio_rdiv2 = area of the two main crops beyond 95% of arable land / area required for the other crops*
- permanent grassland and pasture (rpast)	non-compliant area (95% of permanent grassland and pasture)
- ecological Focus Area (refa)	ratio_refa * (50% of arable land) *ratio_refa = missing EFA / required EFA*
Total non-compliant area (rtot)	rdiv1 + rdiv2 + rpast + refa
Reduction of the greening payment	rtot * greening payment entitlement value (VEg)
Administrative penalties	***Description***
Proportion of non-compliant area (nca)	rtot / (eligible land - rtot)
nca ≤ 3%	no penalties
3% < nca ≤ 20%	VEg * rtot * 2 / 4
20% < nca ≤ 50%	VEg * (eligible land - rtot) / 4
>50%	VEg * (eligible land / 4

Source: based on Commission's Delegated Regulation 640/2014