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Biodiversity and risk management in agriculture: what do we learn from CAP reforms? A farm-level analysis

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Spatial Diversity in Cereal Crops. What do we learn from CAP reforms? A farm-level analysis

Fabian Capitanio°, Elisa Gatto*, Alba Marino*, Emanuele Millemaci*, Guido Signorino*

Abstract

On-farm agricultural biodiversity conservation has long been recognized as a fundamental resource to the maintenance of ecologic and economic functions. Among the factors affecting biodiversity, institutional failures at different scales are reported as potential causes of biodiversity loss both in developed and developing areas. In this paper, we hypothesise the existence of a potential relationship linking CAP support measures and crop-diversity. To assess this hypothesis we construct a diversity function in which a measure of spatial diversity among cereal species is expressed as a function of a set of economic and agro-ecological variables. Using a panel dataset for the period 2004-2010, we compare the results obtained from the pooled estimator with Fixed Effects results. The empirical analysis shows the existence of a stable relationship between our measure of spatial diversity and CAP support measures.

Jel Classification: Q12, Q18

Key words: crop-diversity, risk management, CAP reforms

1. Introduction and objectives

Planned on-farm biodiversity represents an economic asset providing a flow of ecological services to direct use for farmers. In particular, crop-biodiversity, measuring diversity within and among wild and domesticated species, has been found to contribute significantly to the

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productivity of agricultural systems through its beneficial effects on agricultural yields and incomes (Smale et al., 1998; Di Falco and Chavas, 2007; Di Falco and Chavas 2009; Gatto and Signorino, 2011). It is ascertained that resilient agro ecosystems are characterized by a high degree of crop diversity (Heal, 2000) and that crop diversification improves the capacity of agricultural systems to positively react to environmental fluctuations (Lin, 2011). On-farm crop diversity may be captured by both inter-specific (among crops) and infra-specific (within a crop) components depending on types and natural characteristics of species. Natural, agro-ecological and economic factors have been reported as important determinants of crop diversity at the farm level (Meng et al., 1999; Benin et al, 2004); Smale et al. (2003), applying economic models of farmer preferences to variety choice, offer a model of spatial varietal diversification within a commercial environment; farmers' decision about variety choice can be modeled as being affected by a set of components observed by farmers that include all those traits embodied in crop varieties which determine farmers' profit expectation.

The natural insurance function of crop diversity is at the origin of the desire for farmers to diversify their productive choices as a means to protect against risk; this result is largely supported by recent theoretical and empirical studies showing that, in the presence of uncertainty, farmers tend to employ a higher level of diversity (Baumgärtner and Quaas, 2010). Farmers' risk attitude and its impact on productive choice are affected, among other things, by the institutional context in which farmers operate: a more 'protected' environment may offset the adoption of risk-reducing strategies by risk-averse farmers, weakening, in the context of farmers' decisions about land allocation, the link between crop diversification and risk coping.

In this paper we further investigate the effects of the institutional context on farmers' productive choices by concentrating on the potential effects of the CAP reform toward decoupling. As is well documented, measures directed to sustain production in the form of 'coupled' payments addressed to specific crops, which characterized the basis of the EU CAP support until the 1993 MacSharry and the 2003 Fischler reforms, may hurt a diversified production as they create an incentive for farmers to specialize in the production of 'protected' crops; as reported by Di Falco and Perrings (2005), and more recently by Nastis et al. (2013) relatively to organic crops, coupled payments may offset the risk reducing role of farmers' diversification strategy. However, these studies, while assessing the role of biodiversity in sustaining and stabilizing revenues, provide only partial and indirect evidence of the relationship between the diversity strategy and the policy variable.[1]

In spite of the variety of researches focused on the impact of CAP reforms on farms' economic and structural characteristics, to the best knowledge of the authors, few studies deal with the impact of decoupling on crop-diversity; Brady et al., (2009), within a simulated optimization framework, assess the effect of different policy scenarios along the period 2001-2013 on farm structure, land use and biodiversity referred to a set of regions across Europe, selected on the basis of different criteria; results concerning the impact on the biodiversity variable cannot be considered conclusive; in fact, the study shows that, while for some regions the introduction of single farm payment has little impact on biodiversity, in other contexts the reform has either positive or negative effects. Miettinen et al. (2004), simulating the impact of different policy scenarios on land cover diversity in Finnish regions within a dynamic regional sector model, find a general decrease in diversity of agricultural land-cover.

In this paper we further develop the analysis of the effect of decoupling on inter-specific crop-diversity between cereal species observed on Italian agricultural farms; we expand upon the existent results by providing an overview on Italian farms of the determinants of diversity with particular attention to the policy shift occurred at the level of European agricultural policy covering a longer time span that allows to take into account the shift from coupled to decoupled economic sustain; this shift may have caused a change in farmers' production choices regarding the possibility of 'investing' in diversity as a risk-reducing strategy.

To that purpose, a crop diversity function is estimated along a sample of Italian cereal producing farms, drawn from the RICA database for the period 2004-2010; biodiversity, measured as inter-specific diversity among the cereals commonly grown in Italian farms, is expressed as a function of a set of variables capturing socio-economic farm characteristics, land and agronomic conditions, and CAP support system. The empirical analysis is based on panel data estimation methods. We make use of Pooled OLS estimator with cluster-robust standard errors using data for all individuals in all years, and then we compare the results with those produced by a fixed effect estimator. The analysis shows that decoupling significantly affects spatial diversity among cereal species.

The remainder of the paper is organized as follows. In the next section we review the literature on the impact of decoupling focusing, in particular, on the assessment of the

[1] Both Di Falco and Perrings (2005) and Nastis et al. (2013) after having estimated a stochastic production function measure the elasticity of substitution between the diversity and the support strategies which, having a significant and negative value, is used to prove the existence of a trade-off between the two strategies.

economic and ecological effects. In Section 3 we present the methodology used in this paper, followed by the description of the data used in the econometric analysis. In Section 4 we illustrate the results. Section 5 concludes the paper.

2. The institutional framework

2.1. The effects of decoupled support measures on agricultural firms

Starting from the introduction of the MacSharry reform in 1992, European agricultural sector underwent a reform program to alleviate market distortions making the sector more market-oriented through the progressive introduction of a system of decoupled income support measures not tied to production targets; in particular, under the Mid Term Review (MTR) of CAP in 2003 (EU Reg. 1782 to 1788/03) all compensatory payments were replaced by a Single Farm Payment (SFP) based on historical payments and decoupled from the type and the level of production (OECD, 2004); the payment is only conditioned on the tenure of land and the its maintenance under good agricultural and environmental conditions. The 2009 Health Check reform (Reg. EU 72 to 74/2009) further reinforced the decoupling of support. Starting from 2005 Italy conform to the new payment regime and from 2007 Italian farmers start receiving the sustain under the form of SFP.

A strong research effort has been centered on the effects of decoupling policies on the economic performance of agricultural farms and on farmers' choices (see Bhaskar and Beghin (2009) for a comprehensive review up to 2009). A wide set of researches, using different arguments and methodologies, test the existence of multiple mechanisms through which decoupled support may affect production; among the different firm dimensions that have been investigated by the literature, the effect of decoupled subsidy scheme seems to be not neutral in the following aspects: risk aversion, crop patterns and allocation of resources, exit decisions, investment behavior, specialization and diversification.

In particular, decoupled payments are found to affect farmer risk profile through: 1. a 'wealth effect', as in the presence of decreasing absolute risk aversion (DARA), increases in wealth implied by direct payments cause a reduction in the coefficient of absolute risk aversion, and 2. an 'insurance effect', linked to the reduction in income variability brought by the income support (Sckokai and Moro, 2006). Nevertheless, according to Rude (2008), a decoupled payment scheme tied to fixed-criteria does not affect farmers' risky decisions: the 'insurance effect' appears to be not statistically significant and to have a rather little influence, as verified also by Moro and Sckokai (2011). On the contrary, the 'wealth effect' is more pronounced because it can be linked to a major ability of farmers to obtain credit as a consequence of the SFP: an increase in income, as well as a greater income stability, could relax liquidity constraints and encourage production and/or investment decisions (Goodwin and Mishra, 2005). For what concerns investment decisions, some empirical analysis highlight a wide diversification of reaction to CAP reform and decoupling; Viaggi et al. (2010, 2011) assess the impact of decoupling on farm investment behavior within a dynamic programming model applied to farms located in Northern Italy; the authors find a great heterogeneity of results depending on the structural characteristics of each farm. This result is consistent with a dynamic perspective, according to which the decoupling of farm payments may result in both positive and negative changes in income and investments, especially in the mid-term.

Decoupled payments have also influenced farm specialization and diversification decisions. Several farms, in fact, have changed their specialization showing not only an interest in extensive agricultural methods, but also ‘the possibility, given the decoupling of direct payments, to shift to other types of production without losing the support and moving towards more remunerative products, following market signals (Cisilino et al., 2012).

Turning the attention to firms’ exit decisions, in general they are affected by socio-demographic aspects like age of firm manager, family composition, number of household members working on the farm, as well as firm structure (measured by income, land allocation and use, the amount of subsidies, specialization and hired labour) in a not univocal direction (Raggi et al., 2013). The Single Farm Payment could increase agricultural income linked to arable areas and it may induce firms, which otherwise would prefer to leave production, to stay in business.

As expected, the analysis of the impact of CAP decoupling offers an heterogeneous overview from the point of view of results as well as methodologies; nevertheless, it is possible to trace a common line that goes in the direction of recognizing the existence of significant effects of decoupling on several farm dimensions including economic and resource allocation decisions. In this paper, we further develop the issue of the impact of decoupling on one particular aspect that pertains to farmers’ production choices about land allocation decisions through the inspection of the diversity pattern among cereal species.

The spatial diversity model

3.1. General framework

As a sub-category of agricultural biodiversity, crop-diversity refers to the variety of 'productive biota', measuring diversity within and among crop species in wild or domesticated environments (Altieri, 1999). In managed systems, crop biodiversity accounts for a great portion of overall agrobiodiversity (Di Falco and Chavas, 2008).

More specifically, the allocation of cultivated land to different crops or to varieties within each crop defines the diversity pattern at the farm level; this information can be used as a proxy of planned spatial diversity capturing the pattern of inter or infra-specific crop diversity. Focusing on the determinants of crop diversity, several studies have concluded that different dimensions contribute to define the diversity profile at both the regional and farm level; in a case study conducted in Ethiopia on cereal producing farms, Benin et al., (2004), drawing from the theory of farm household, underline the role of market characteristics (population density, farm distance to road and town), as well as farm and household agro-ecological and socio-economic features (i.e., number of farm plots, irrigation, fertility, age and education of farm head). Smale et al. (2003), focusing on genetic diversity among wheat varieties, recognize the importance of some agronomic (e.g., variety yields, days to maturity) as well as agro-ecological features of the production environment (soil quality, erosion, rainfall) which are supposed to influence farmers' decisions by affecting crop performance differently. The authors test the hypothesis that the variation in spatial diversity is affected by the same variables driving farmers' choices about the selection of crop varieties. This hypothesis is based on the assumption that farmers' demand for specific varieties is based on characteristics or qualities that they observe as well as on supply-side market conditions which affect farmers' choice about the use of modern or traditional crop varieties, especially in less developed countries.

The theoretical and conceptual approach on which we base our empirical analysis is borrowed from the existing literature on the theory of households' optimal choice about production decisions; farmers' choice about which crops and varieties to grow is the outcome of a maximization process in which the farmer maximizes utility over a set of consumption combinations, leisure and different dimensions capturing farmers' preferences and characteristics of household members subject to a set of technological and natural constraints (Benin, 2004). In this context, the diversity pattern is the outcome of farmer's behavior toward utility maximization subject to income, production and market constraints (Van Dusen et al, 2005). Following the authors, in the presence of perfect markets, diversity can be expressed in the following general form:

$$D = D\left(Q^{*}(p, \Phi_{prod})\right) \qquad (1)$$

where the diversity pattern is the outcome of farmer's utility maximization and hence a function of the optimal production level Q* which depends on a vector of prices and on a set of exogenous farm characteristics (total land, agro-ecological and agronomic conditions).

We expand upon this conceptual framework by stressing the role of the policy context on diversification decisions; the spatial diversity pattern, measured as the distribution of cereal species over cultivated land at the farm level, either considered or not considered as a choice variable in the optimization model, is affected by the policy framework as highlighted by several studies (Di Falco and Perrings, 2005; Di Falco et al., 2010. Hence, we suggest to include among the determinants of spatial diversity a variable capturing the effects of the agricultural policy in the specific form of European agricultural economic sustain to farmers. In order to account for this dimension, our spatial diversity model for farm *i*, is expressed in the following form:

$$D_i = D(X_i, Y_i, z_i) \qquad (2)$$

Diversity is expressed as a function of a vector of agro-ecological attributes X_i (soil fertility, altitude level, irrigation system coverage, cropping intensity, land heterogeneity), socio-economic farm characteristics Y_i (farm size, age of farm manager, education level of farm manager), and a variable (zi) capturing the CAP economic support measure.

Since the focus of this analysis is diversity among most commonly produced cereal crop species, the size of the price differential among species is of little significance for influencing farmers' choice about which species to prefer; this is the main reason for not including price differentials among regressors in the diversity function.

3.2. Data source

The empirical analysis is conducted on a sample of 14,628 cereal producing agricultural farms drawn from the Italian FADN (RICA) database for the period 2004-2010 along the whole Italian peninsula.[2] RICA database collect annual information on the structure and economic performance of national agricultural firms selected through a stratification process that accounts for territorial location, economic dimension and technical-economic orientation of farms.

The sample consists of about 7,500 yearly units of cereal producing farms for the period 2004-2007 and about 4,800 yearly units for the period 2008-2010.

The sample representativeness of the underlying population is maintained by the rotating panel technique, where a portion of the sample is periodically updated (every 4-5 years, with annual renewal of 20-25% of the survey units). This leads to discontinuity in observations and, as a consequence, only for a reduced number of firms we have information throughout all the period under consideration (984 firms, 6.73 %).

3.3. Dependent Variable

The dependent variable is an inter-crop spatial diversity index constructed from the vector of land shares allocated to different crop species at the farm-level. Spatial diversity, capturing the distribution of species over space, is often reported in the ecological and applied economics literature as a good representation of the three diversity dimensions, i.e. richness, abundance and evenness (Magurran, 2004). Following Buckland et al. (2005), biodiversity can be defined as 'the variety and abundance of species in a defined unit of studies'. A good indicator of spatial diversity capturing both relative abundance and evenness of species is represented by the Simpson's index, defined to be the proportion of individuals present in a specific space that belong to species *i*. Being low values associated to high diversity levels, it is common usage to transform the index in order to make it increasing with increasing diversity. In our analysis we use a modified version of the Simpson's index. We define $p_{ij} = d_{ij} / \sum_i d_{ij}$ to be the proportion of land (ha) share allocated to species *i*; the index is then expressed as:

$$D_j = \sum_i p_{ij}^2 \tag{3}$$

[2] The selection of cereal producing firms reduces production heterogeneity within the sample and allows to concentrate on a sector that has been largely interested by the CAP reform toward decoupling.

Magurran (2004), suggest to take a transformation of the index which makes it more sensible to species modification in relative abundance and evenness; in this light, we use the following Simpson's index form:

$$S_j = -\ln D_j \tag{4}$$

where high values of the index correspond to high levels of diversity.

3.4. Independent Variables

Independent variables have been selected on the basis of their potential role in determining farmer's realization of his production choices; a common finding in the literature on economic determinants of crop-diversity is the significant role of agro-ecological farm characteristics, household characteristics, and market conditions of the production environment. In choosing which dimension deserve to be included among regressors in our empirical analysis, we exclude the third dimension (market characteristics) given the relative homogeneity of our sample in terms of market conditions, like openness to market or market infrastructure, and considering that these aspects are probably more relevant in less-developed country contexts.

Agro-ecological features, defined in Table 1, include soil quality, altitude, coverage of irrigation system, and a proxy for land heterogeneity. Soil quality, measured in terms of the proportion of land in one of the three envisioned fertility class (low, medium, high), is expected to be an important factor that affects crop characteristics and the way in which they react to cultivation practices. Altimetry, as measured by the medium altitude level of farm land, is an agro-ecological variable that is associated to specific climatic and agronomic conditions affecting crop performance and, as a consequence, farmers' decisions.

We use an indicator of the homogeneity of land moisture condition, represented by the level of irrigation system coverage within each farm, in order to assess the hypothesized negative effect on crop diversity of uniform moisture conditions (Benin et al., 2004). In fact, it is ascertained that higher heterogeneity in farm conditions favour crop diversity, mainly because it can be hypothesized that a more heterogeneous environment is associated to a more diverse environment, in the presence of which farmers would be more encouraged to diversify crop species in order to match different land conditions. From this perspective, assuming that a greater number of plots within each farm also implies a higher degree of land heterogeneity, we use this variable as a proxy for land conditions' heterogeneity.

The vector of household characteristics and other farm physical measures include the level of cropping intensity measured as the ratio of cultivated land over total land area, the age of farm holder and his education level in order to provide some indicator of risk preferences and to account for the effect of a ‘diversity attitude’ of younger people; we account also for a ‘scale effect’, measured by the ratio of value added to total labor units and also total labor units, that may influence the link between crop diversity and CAP support. We include a dummy variable indicating the adoption of organic cultivation, as a measure of farmer attitude toward good environmental practices.

Finally, we include the policy variable in the form of the amount of European contribution belonging to the First Pillar of the CAP granted to each farm along the observed period.

3.5. Model specification

An empirical counterpart of the theoretical model presented in section 3 can be expressed in simple form by the following equation:

$$d_{it} = \alpha_i + \beta \mathrm{change_t} + \gamma \mathrm{CAP_{it}} + \delta \mathrm{X_{it}} + \theta \mathrm{Y_{it}} + \omega \mathrm{C_{it}} + \mathrm{u_{it}} \quad (5)$$

where *d* is a transformation of the *Simpson's index* as defined in section 3.3; *change* is a dummy variable that takes value 0 for the years before the latest reform (2004-2006) and 1 in the subsequent years (2007-2010); *u* is an error term. This specification allows heterogeneity in firm's fixed effects (α_i), while $\beta, \gamma, \delta, \theta$ and ω are the parameters to be estimated. We express production function variables in logs and in terms of total units of labor (*labor*). Variable *CAP* is the log of the *1st Pillar CAP support* and *labor* ratio. Vectors *X* and *Y* consist of variables related to agro-ecological farm characteristics and farm/household characteristics, respectively, as described in the section above. Vector *C* includes the log of value added and *labor* ratio, the log of *labor* and time and regional dummies.

The longitudinal nature of the RICA dataset allows us to employ panel data models to estimate parameters of interest. As a starting point, we consider the pooled (population-averaged, PA) OLS estimator with cluster-robust standard errors using data for all individuals in all years. This model relies on the assumption that intercepts are the same for all firms i ($\alpha_i = \alpha$), or, at least, that $u_i = \alpha_i + \varepsilon_i$ is uncorrelated with regressors. Even if OLS gives consistent estimates under these assumptions, inference needs to control for likely correlation of the error u_i over time for a given individual (within correlation) and possible correlation over individuals (between correlation). To address the within correlation problem, we rely on cluster-robust standard errors to check statistically significance of parameters[3]. As a term of comparison, we also consider the fixed effect (FE) estimator to understand how results vary when we relax the assumption that regressors and term u_i are uncorrelated.

Since year 2008, questionnaire and collected information were updated: some previously collected variables of the database have been discarded while other variables have been newly introduced. An example of the former case is the fertility variable, while an example of the latter is the education variable. Given the time invariant nature of these variables, lacking information could be deducted from other years information from the same firm. However, as the panel is unbalanced, information would remain unknown for a nontrivial share of firms. Our strategy is not to consider these variables in our main specifications to preserve the largest sample dimension and limit the attrition problem.

In our empirical exercise, the evaluation of the effect of the policy reform is allowed by considering sign and significance of the two parameters β and γ. A significant parameter β implies a structural break in farmers' decisions on biodiversity. A significant γ would suggest that the effect on farmers' diversity decisions depends on the magnitude of reduction in CAP determined by the policy reform. An interesting exercise is to understand whether the reform has changed the terms of this possible relationship between biodiversity and CAP. To answer this question, we modify equation (5) by adding an interaction term between variables change and z.

There can be an identification problem when estimating the coefficient on variable change (β) as this variable might also capture the economic and financial downturn that hit Italian regions since the second half of year 2008. Hence, to better identify the effect of the policy reform, we also estimate equation (5) using only observations for the period 2004-2007.

[3] We have also considered the "between correlation" problem by employing the pooled FGLS estimator but found similar estimates of parameters.

4. Results

4.1. Descriptive analysis

Figure 1 shows the two quadrants: i. in the top, the time evolution of the average biodiversity index (D) computed over all sampled cereal producing firms; ii. in the bottom, the time evolution of the average per total labor unit CAP computed over all sampled firms.

On the basis of this aggregate picture, biodiversity and CAP seem to follow a quite different time path. Biodiversity seem to increase until 2008 and then begin to decrease. CAP reduces in the time interval between 2006 and 2008 and then have a more stable behavior. The graphs of figure 1 does not allow to understand whether the change in regime taking place since 2007 and new regulations on CAP are responsible of a structural change in biodiversity preferences of farmers.

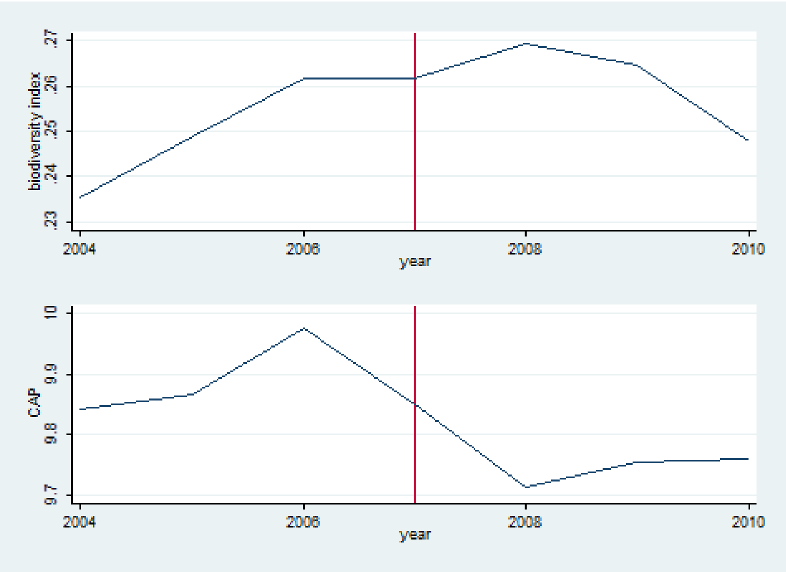

Figure 1: All sample means of biodiversity index (top) and CAP (bottom) over time

Table 1 reports for each variable name, a short description, mean, standard errors, minimum and maximum.

Table 1

Variable description and summary statistics

Variable name	Description	Obs	Mean	Std. Dev	Min	Max
Biodiversity index		43519	0.26	0.34	0.00	1.68
Agro-ecological conditions						
Medium fertility	Proportion of farmland characterized by a medium fertility level	39159	0.88	0.33	0.00	1
High fertility	Proportion of farmland characterized by a high fertility level	39159	0.08	0.27	0.00	1
Altitude	Average altitude of farmland	43519	241.98	220.49	0.00	2500
Irrigation	Proportion of farmland that is covered by an irrigation system	43519	0.33	3.66	0.00	1
Fragmentation	Number of farm plots	43519	4.79	7.23	0.00	100
Farm characteristics						
Age	Age of farm manager	38691	60.80	14.00	6.00	104
Education	Dummy on whether manager has completed at least secondary school	27537	0.30	0.46	0.00	1
Intensity	Ratio of cultivated land to total farmland	43519	0.92	0.11	0.00	1
Labor	Log of total labor units	43514	1.93	2.61	0.01	79.69
Organic	Dummy for the presence of organic cultivation	43519	0.05	0.22	0.00	1
Value Added	Log of the ratio of value added and total units of labor	41892	9.82	1.13	1.80	15.61
Policy variable						
CAP	Ratio of European 1st Pillar CAP support to total units of labor	43514	8.50	1.33	1.43	14.55
change	Dummy for regimes 2004-2006 and 2007-2010	43519	0.50	0.50	0.00	1
years						
2004		43519	0.17	0.38	0.00	1
2005		43519	0.16	0.36	0.00	1
2006		43519	0.17	0.38	0.00	1
2007		43519	0.17	0.38	0.00	1
2008		43519	0.11	0.32	0.00	1
2009		43519	0.11	0.31	0.00	1
2010		43519	0.11	0.31	0.00	1

The total dimension of the sample amounts to 43,519 observations with only a few cases of missing information in some variables. The biodiversity index has a mean value of 0.26 and is characterized by a low degree of variability. With reference to the agro-ecological conditions, the sampled firms are characterized by: i. the average share of farmland covered by irrigation system accounts to about 1/3; ii. the average number of farm plots is about 5. For what concerns the farm and manager characteristics, in our sample the average age of the farm manager is rather high (60.8); ii. the education level is very low as only 30 % has completed secondary school; iii. the utilization of the farmland in the cultivation activity appears very intensive (92 %); iv. only 5 % of farmers produces some organic crops.

4.2. Estimation results

Results of the empirical analysis are shown in Table 2 and Table 3 below. The former, reporting the results obtained by pooled OLS regressions, presents several specifications relative to: i. the base model (column 1); ii. the model with, in turn, the omission of the *change* dummy and the CAP variable (column 2 and 3); iii. the model including the interaction term between the CAP variable and the change dummy (column 4). Columns 5 to 8 show the same specifications applied to the restricted sample (2004-2007) in order to trace any difference that may be attributed to the 2008-2010 economic crisis.

Starting from the base model, the effect of the policy shift is captured by the coefficients of *change* and *CAP* variables. Both coefficients are highly significant, which implies that: i. the break occurred in 2005-2006 in CAP support regime, captured by the *change* dummy, affected farmers' decisions about diversification of cereal crops; ii. the nature of this effect, captured by the *CAP* variable, depends on the magnitude of the variation occurred in the total amount of CAP support received by farmers along the observed period. The positive sign of the *CAP* variable coefficient implies the existence of a positive correlation between the amount of support received by farmers and their diversification choice. This result implies principally that decoupled support measures, despite of the delinking from production, still have a significant effect on production choices. Moreover, the time-span considered in the analysis does not allow to go back to the full-coupled policy regime in which economic sustain to farmers included different support measures (guaranteed prices, export subsidies and import restrictions) that were supposed to strongly orient farmers' decisions by inducing farmers to choose between two alternative risk-reducing strategies, i.e., the support and the diversification strategy. The inclusion of the interaction term between *CAP* and *change* (column 4 of Table 2) allows to assess further the effect of the policy shift on diversity. The significant coefficient of this term, by allowing to distinguish between the pre-reform and post-reform period, suggests that the policy shift occurred after the MTR reinforces the positive correlation between the *CAP* variable and crop-diversity. The variables measuring value added (in terms of labor units) and labor are included to account for the other factors that affect the production function and to account for 'scale' effects. While being both significant, they enter with opposite signs: a higher level of farm *Value Added* is associated with less crop-diversity while variable labor enters positively. This evidence suggests that diversity patterns are chosen by firms with relatively larger scale production levels and relatively less labor intensive techniques.

Variables related to agro-ecological conditions are also important determinants of spatial diversity. In line with previous studies, estimation results show that a farm located at a higher altitude is more likely to present a more diverse system. As expected, a more heterogeneous environment in terms of moisture conditions (captured by irrigation system coverage) and number of plots is associated to greater crop-diversity. The intensity of production, measured as the ratio of cultivated land to total land, is positively related to diversity. This finding is consistent with the fact that a higher level of cropping intensity is linked to better soil conditions, as a large portion of total land is under cultivation.

The coefficient of the *Age* variable is not stable. While it is almost not significant in the enlarged sample, it becomes significant when the sample is reduced to the 2004-2007 time-span. It enters with a negative sign, suggesting the possibility that older farmers are less inclined to diversify their cereal production. This result can be associated with the fact that younger manager may be more attentive to efficiency arguments and to general ecological conditions of the farm.

The comparison between the unrestricted (2004-2010) and the restricted (2004-2007) model does not reveal any significant difference in estimation results, thus confirming the little impact of the economic and financial crisis shock on overall estimates.

Table 2. Pooled OLS with cluster robust standard errors

Variables	1	2	3	4	5	6	7	8
Change	.0224***	-	-0.03	-.161***	.0235***	-	.0249***	-.0525**
	3.88		-1.46	-5.4	5.23		5.58	-2.31
CAP*change	-	-	-	.012***	-	-	-	.00895***
				4.9				3.41
CAP	.0393***	.0393***	-	.0341***	.0362***	.0362***	-	.0339***
	19.17	19.17		14.76	16.02	16.02		14.41
Value Added	-.0251***	-.0251***	-0.00377	-.0254***	-.0236***	-.0236***	-.0062**	-.0236***
	-10.44	-10.44	-1.63	-10.59	-8.87	-8.87	-2.41	-8.87
Labor	.0474***	.0474***	.0326***	.0476***	.0452***	.0452***	.0331***	.0453***
	13.43	13.43	9.54	13.49	11.65	11.65	8.79	11.67
Age	-0.00027	-0.00027	-.000362**	-0.000275	-.000446**	-.000446**	-.000519***	-.000456**
	-1.54	-1.54	-2.05	-1.57	-2.33	-2.33	-2.69	-2.38
Altitude	.000202***	.000202***	.000195***	.000202***	.000186***	.000186***	.000181***	.000186***
	12.68	12.68	12.36	12.67	10.73	10.73	10.43	10.72
Fragmentation	.00213***	.00213***	.00297***	.00216***	.00183***	.00183***	.00262***	.00183***
	4.57	4.57	6.38	4.64	3.76	3.76	5.4	3.77
Irrigation	-0.000574	-0.000574	-0.000578	-0.000606	-0.000481	-0.000481	-0.000481	-0.000493
	-1.52	-1.52	-1.5	-1.62	-1.28	-1.28	-1.24	-1.33
Intensity	.0636**	.0636**	.11***	.0626**	0.0449	0.0449	.0873***	0.0446
	2.52	2.52	4.46	2.48	1.59	1.59	3.15	1.58
Organic	-0.0182	-0.0182	0.00821	-0.0168	-0.0147	-0.0147	0.0133	-0.0149
	-1.63	-1.63	0.73	-1.5	-1.21	-1.21	1.1	-1.23
R-squared	0.12	0.12	0.1	0.12	0.13	0.13	0.11	0.13
N	37594	37594	39390	37594	28285	28285	29626	28285

Note: *** Statistically significant at 1% level with t statistics. **Statistically significant at 5% level with t statistics. Time and regional dummies are not reported for the sake of simplicity. Columns 1-4 refer to 2004-2010 time period, columns 5-8 refer to 2004-2007. CAP*change is the interaction term.

Table 3 reports the results obtained through the Fixed Effects estimator. Columns 1, 2, and 3 show results relative respectively to the base-model, the model without the *change* dummy, and the model with *change* but without *CAP*. Columns 4, 5, and 6 report results of the same specifications but relative to the restricted sample. The coefficient of the *CAP* variable is almost stable across the models, as can be seen by comparing the magnitude of the coefficient along the three specifications reported in column 1 to 3, in which the *change* and *CAP* variables are included alternatively to check for the stability of the *CAP* coefficient. The dummy for the policy shift (*change*) shows smaller coefficients with the full-sample estimates and is statistically significant only in the restricted sample.

Variables related to the production scale of farms (Value added and labor units) are also significant (a part from the labour coefficient in the restricted sample) and, although with similar signs, they are inferior in magnitude with respect to the pooled model. The set of variables describing farm agro-ecological conditions are almost all not significant. This is not surprising given their low level of within (firm) time-variability which is the only variability accounted in the fixed-effects model context.

Table 3. Fixed Effects

Variables	1	2	3	4	5	6
Change	0.00533	-	0.0031	.00855**	-	.00794**
	1.6		0.96	2.54		2.42
CAP	.0173***	.0167***	-	.0119***	.0114***	-
	5.54	5.38		3.35	3.2	
Value Added	-.00919***	-.0087***	-.00695***	-.0109***	-.00985***	-.00926***
	-4.09	-3.9	-3.14	-3.74	-3.46	-3.26
Labor	.0118**	.0114**	-0.00278	0.00834	0.00921	0.000421
	2.44	2.35	-0.77	1.12	1.24	0.07
Altitude	-0.00003	-0.0000307	-0.0000261	-.000198**	-.0002**	-.000187**
	-0.54	-0.56	-0.5	-2.18	-2.2	-2.05
Fragmentation	-0.00032	-0.000432	-0.000161	.00247*	.00249*	.0029*
	-0.7	-0.94	-0.35	1.7	1.71	1.94
Irrigation	0.000166	0.00015	0.000379	0.000132	0.000114	0.000288
	0.95	0.87	1.51	0.74	0.65	1.17
Intensity	0.0165	0.0157	0.0219	0.0533	0.0497	0.0585
	0.37	0.36	0.51	0.79	0.73	0.9
Organic	0.00601	0.0054	0.0137	.049***	.0497***	.0535***
	0.46	0.42	1.08	2.84	2.88	3.12
N	41892	41892	43941	28285	28285	29626

Note: *** Statistically significant at 1% level with t statistics. **Statistically significant at 5% level with t statistics. * Statistically significant at 10% level with t statistics. Time and regional dummies are not reported for the sake of simplicity. Columns 1-3 refer to 2004-2010 time period, columns 4-6 refer to 2004-2007. CAP*change is the interaction term. Variable age has been omitted because within firm deterministic.

In other estimates we added dummies for soil fertility and education levels (not reported for the sake of brevity). We have found that association between fertility and crop-diversity is positive and significant at 10 % of confidence level. Somewhat surprisingly, education dummy appears significantly negatively correlated with diversity.

To check for the sensitivity of results reported in tables 2 and 3 with respect to the chosen model specification, we considered specifications with alternative definitions of some variable of interest. For instance, we defined *CAP* as the log of the 1st Pillar support in euro, and, within the *C* matrix, we eliminated variable *labor* and defined variable *value added* as the log of value added. Alternatively, we considered a specification with *CAP* defined as the ratio between the support and value added, and, within the matrix C, replaced variable *labor* with the log of value added. In all these cases, we found similar coefficients respect to those reported in tables 2 and 3.

5. Conclusions

Since 1992 the general architecture of the CAP has been the object of a reform process that progressively changed the nature of the EU support to agricultural incomes. From a support completely targeted to production levels and type of crops cultivated, the 2003 Mid Term Review provided a new support scheme that unified all previous measures in a single farm payment (SFP), delinked from production and based on historical entitlements. This paper assesses the effects of this new policy scheme on farmers' diversification choices by estimating a spatial diversity function for the cereal sector. The empirical analysis is conducted on a sample of Italian cereal producing farms drawn from the RICA database for the period 2004-2007. The longitudinal nature of the dataset allows us to employ panel data models to estimate parameters of interest. The model is estimated with pooled OLS estimator controlling for the within and between error correlation. Results are then compared to the results obtained from a fixed effect estimator. The effect of the policy shift is captured by the introduction of a dummy (*change*) splitting the sample on the time dimension, and an interaction term between the CAP variable and the change dummy. We find statistically significant evidence of an increase in diversity after the policy shift and of the existence of a positive relationship between CAP support and crop-diversity. Moreover, the intensity of this relationship seems to have increased since 2007. In this light, despite the fact that income support measures are decoupled from production, they still have an impact on farmers' diversification decisions.

The negative counterpart of this result is the fact that, in the presence of an observed decrease in the amount of first pillar payments, we may expect a decrease in crop-diversity for the cereal sector. This prevision calls for the need of specific policy measures directed to provide incentives for farmers to invest in crop diversification.

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