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Long-run relationship between crop-biodiversity and cereal production under the CAP reform: evidence from Italian regions

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Long-run relationship between crop-biodiversity and cereal production under the CAP reform: evidence from Italian regions

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Abstract

Biodiversity has a prominent role in defining and preserving ecosystem well-being; the analysis of biodiversity effects on agricultural production is well documented. The paper offers empirical evidence on the role of intra-species biodiversity in sustaining cereal production within Italian regions, covering a time span (1989-2007) which accounts for the important CAP policy reforms. A Cobb-Douglas production function that includes both biodiversity and subsidies as control variables is estimated for 20 Italian regions, controlling for both cross-sectional heterogeneity and the dynamic structure of agricultural production. Different estimation methods are compared, including Mean Group and Pooled Mean Group estimators which allow for the possibility of potential non stationarity of the series and heterogeneous parameters across-groups. We find clear evidence of significant long-run relationships between biodiversity and cereal production; moreover, the evidence on the role of PAC intervention measures is less clear-cut, showing a potentially negative effect on production along the period under analysis that can be attributed to the aforementioned policy shift.

1. Introduction

Biodiversity, defined as 'the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems [..]' (UN CBD, 1992), has long been considered a fundamental 'capital' stock to the maintenance of ecosystem stability and the provision of living organism life support. As a consequence, lack of diversity can significantly harm the capacity of ecosystems to recover from natural or induced perturbations (Pascual and Perrings, 2007). From an economic point of view, the importance of biodiversity stems from its functions in determining ecosystem productivity, providing ecosystem services and insurance value (Brock and Xepapadeas, 2003). There is large evidence for the diversity-productivity hypothesis in the context of plant productivity; Tilman et al. (1996) provide evidence for the existence of a positive relationship between productivity in several observed grasslands plots and plant biodiversity; similarly, Hooper and Vitousek (1997) confirm the beneficial effect of plant richness on primary productivity, Fridley (2003) found that higher species diversity positively affect above-ground production after controlling for environmental conditions. Valuation of biodiversity ecosystem services relates to its essential role in guaranteeing the proper functioning of ecosystems; generation and maintenance of soils, climate regulation, the running of biogeochemical cycles, pest control are some examples of biodiversity role in preserving ecosystem functioning (Daily and Dasgupta, 2001). In managed ecosystems, like agro-ecosystems[1], the services provided by biodiversity are more inherently associated to the provision of benefits to the primary production processes, including increased pest resistance, improved soil nutrient balances, the preservation of genetic material, etc. (Bradshaw, 2004; Moonen and Bàrberi, 2008).

The role of biodiversity in providing an insurance value can be gathered from a double perspective: the first, mostly linked to genetic diversity, concerns the information value stemming from the genetic pool of non-commercially used species which can be employed to enrich the state of knowledge for scientific purposes; the second relates to the consideration of species richness as a product of economic agents' production choices which provides the ecosystem service of natural insurance (Baumgartner and Quaas, 2010); in rural contexts, particularly for less developed economies characterised by natural and productive uncertain environments, product diversification is mentioned as one of the principal farmers' income smoothing strategies to cope with risk, especially in the presence of imperfect credit and

[1] Agro-ecosystems are characterised by the intensity of human intervention in the composition of living organisms for the purposes of providing food, fibre and other products.

insurance markets[2] (MEA, 2005; Morduch, 1995). As in portfolio choices, diversification of activities is a rational strategy to protect against risk.

There is large consensus in the agricultural economics literature about the acknowledgment of the risk-reducing role of crop biodiversity.[3] Several empirical studies, focusing on rural low income contexts, have found that a higher degree of crop biodiversity is associated to higher levels of crop yields and to lower levels of yield or income variability (Smale et al., 1998; Widawsky and Rozelle, 1998; Di Falco and Chavas, 2007). As a consequence, genetic diversity within and between species affects the way an ecosystem positively reacts to pest and pathogen invasions, improving stability of both yields and incomes (Sumner et al., 1981; Altieri, 1999; Di Falco and Perrings, 2003).

Furthermore, Di Falco and Chavas (2009), specifically studying barley cultivation, confirm the positive effect of crop genetic diversity on farm productivity and add insight into the risk-reducing role of biodiversity, showing that it protects in particular from downside risk exposure (i.e., the probability of crop failure) after controlling for soil characteristics in a stochastic production function framework.

Turning the attention to developed countries, Di Falco and Perrings (2003) provide theoretical and empirical foundations to both the diversity-productivity and the diversity-stability hypothesis, testing for the existence of such relationship in cereal production within southern Italian regions. Furthermore, Di Falco and Perrings (2005), focusing on a policy perspective, add to previous results the analysis of a potential trade-off between risk-averse farmers' production choices toward diversification and EU CAP (Common Agricultural Policy) stabilization mechanisms; the authors argue that the diversity strategy pursued by farmers to manage production risks may be counteracted by policy intervention directed to sustain farmers' revenues through support mechanisms (price support, product subsidies, financial compensation, import protection). As price instability is one of the most important component of economic risk in agriculture, subsidies on specific cultivations alter market risk conditions and distort farmers' preferences, biasing the composition of the production portfolio in favor of less risky varieties. As a result, a trade-off between subsidies and biodiversity arises.

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[2] Production diversification concerns *on-farm* risk coping strategies together with the choice of conservative production or employment choices; although common in developing rural economies, *off-farm* strategies involving the engagement in other profitable economic activities, are also practiced.

[3] 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).

In this light, starting from the adoption of the MacSharry package in 1992, European agricultural sector underwent a reform program aimed at alleviating market distortions making the sector more market-oriented through the introduction of more decoupled income support measures (payments offered to farmers are based on area under production independently from the type of crop produced).[4] A logical consequence of the envisioned trade-off between the 'diversity strategy' and the 'stability strategy' based on receiving crop-specific income supports, would be the potential increase in crop diversity after the alleviation of 'coupled' intervention measures following the reform process started in 1992.

In their empirical study, Di Falco and Perrings (2005) analyse the effects of alternative risk reducing strategies (subsidy vs. diversity) in the Italian Mezzogiorno during the period 1970-1993, prior to the CAP reform of 1992. With the aim of helping to interpret the effects of CAP reform, this paper explores the more recent time span 1989-2007, that covers the period of the reformed CAP. A Cobb-Douglas production function that includes both biodiversity and subsidies among the regressors, is estimated for 20 Italian regions, controlling for both cross-sectional heterogeneity and the dynamic structure of agricultural production. Further, different estimation methods are compared, while allowing for the possibility of potential non stationarity of the series through a panel error-correction model, as proposed by Pesaran et al. (1997, 1999), to estimate the long-run relationship between the variables of interest.

The core finding of the paper is that there exists a long-run equilibrium relationship linking intra-species biodiversity to production in the cereal sector that is robust to potential non-stationarity of the series considered; moreover, the evidence on the role of PAC intervention measures is less clear-cut, showing a potentially negative and small effect on production along the period under analysis.

The remainder of the paper is structured as follows. Section 2 provides data and variable description; Section 3 and 4 illustrate and discuss respectively the methodological aspects and the results relative to the first empirical model; Section 5 presents an extension of the empirical analysis and the relative results; Section 6 provides a general discussion on limits of the study and future extensions, concluding the paper.

[4] The effective degree of decoupling of income support measures after the MacSharry reform has been questioned relying on the fact that crop-specific aids directed to single commodities still remain even after the reform process (Moro and Sckokai, 1999). Among cereal crops for instance, up to 2004 durum wheat has received a supplementary financial support.

2. Data and Variables

As far as cereal production is concerned, Italy is a net importer of almost all cereal products; it accounts for nearly 2-3% of world production and for 4-5% of EU production (with exception of durum wheat which represents about 35% of European production and 13-14% of world production, Ismea 2009).

To investigate the impact of intra-species crop biodiversity on cereal production we make use of a panel dataset of annual observations over the 1989-2007 period for 20 Italian regions. The panel is slightly unbalanced, as there are some gaps due to lacking information in one of the regressors (agricultural crop subsidies) of the econometric specification. The dataset has been obtained from a sample of farms taken at the regional level along the whole Italian territory; these farms belong to the FADN (Farm Accountancy Data Network) European database which collects annually information from a sample of representative agricultural farms in the European Union. The dataset has been integrated for the series of cereal production and for the information necessary to construct the biodiversity index as will be explained next, which are from the Italian Statistical Office (Istat).[5]

We take aggregate cereal production (in quintals) as our dependent variable in a Cobb-Douglas production function with standard factors (total cultivated land, labour, capital, seeds) and two additional inputs capturing the effect of intraspecies biodiversity and CAP intervention measures (aggregate crop subsidies).[6] The crop biodiversity is captured by the spatial Simpson diversity index accounting for both species richness and evenness, measured as the sum of squared share of area planted to each cereal variety:

$$D = \sum_{i=1}^{s} p_i^2$$

where p_i is the share of land planted to variety i.

The policy variable contains information on the amount of crop subsidies annually received by each region, including compensatory and area payments, decoupled payments and set-aside premiums.

3. Empirical Framework

A well-established assumption in agricultural production analyses is the dynamic nature of the relationship linking some inputs to agricultural output (Chavas et al., 1985); indeed,

[5] The data are drawn from the 'Annuario di Statistica Agraria' (Istat, various years).
[6] Labour input is expressed in annual work unit, capital is measured by gross investment.

production today can be considered the product of choices and decisions made in the past; moreover, as envisioned by Di Falco and Chavas (2008), the effect of biodiversity on productivity is intrinsically dynamic. Additionally, there are several good reasons to include lagged values of the dependent variable in estimated equation; first, as in time-series analysis, to model persistence; second, to allow for the partial adjustment of behavior over time in the variables; third, to reduce serial correlation in the disturbance term (Beck and Katz, 1996).
In order to account for this dynamic structure, we assume that an 'augmented' Cobb-Douglas production function can efficiently capture the relationship between cereal production and factor inputs. Empirical analysis is based on the following panel specification:

$$y_{it} = \alpha y_{i,t-1} + \sum_{j=0}^{q} \beta_j^{'} x_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (1)$$

where i=1,2,…,N indicates the cross-sections (regions); t =1,2,…,T the time periods; x_{it} is a k×1 vector of explanatory variables; β are the k×1 coefficient vectors; μ_i is the group-specific fixed effect, ε_{it} represents the idiosyncratic error term that can vary over time as well as across regions.
The advantages of using panel data structures is well documented in the econometrics and applied economics literature; allowing the identification of group-specific effects (countries, regions, etc.) that can control for missing or unobserved variables, panel data models provide more efficient estimation results; moreover, they enable the study of dynamic relationships linking cross-sectional observations (Arellano, 2003a).
In a static framework, fixed or random effect models and the relative estimation techniques provide consistent and unbiased estimates of the true population parameters, given some necessary assumptions regarding the idiosyncratic error structure and the nature of explanatory variables.[7]
As long as it is assumed that the data generating process (DGP) can be represented by an autoregressive model (AR(p)) with individual fixed effects, the LSDV (within) estimator provides biased and inconsistent results when the panel time dimension is relatively small (that is the case for most macroeconomic panel dataset), due to the induced correlation

[7] The fundamental assumption concerns the exogeneity condition of explanatory variables; the error constant variance and lack of serial correlation are the additional auxiliary assumptions under which classical least-squares results are optimal.

between the lagged dependent variable and both the idiosyncratic and the individual specific error term (Nickell, 1981).[8] Several estimation techniques have been proposed in order to overcome the 'Nickell bias' in panel data models.[9] Here we adopt two alternative dynamic panel model techniques, a difference GMM estimation approach following Arellano and Bond (1991) and a fixed-effect estimator applied to Equation 1 taking deviations from each group mean and corrected for the 'Nickell bias', as suggested by Bun and Kiviet (2003) and extended by Bruno (2005) to unbalanced panels.

The difference GMM estimator uses lagged dependent variables as instruments for the differenced equation and thereby it allows to control for the bias originating also from other non exogenous regressors; it produces asymptotically efficient estimates providing the assumption of serially uncorrelated idiosyncratic error term is met. In order to limit the small-sample problem caused by the use of numerous instruments, as outlined in Arellano (2003b), we restrict the number of available lags to be used as instruments.

The bias-corrected LSDV estimator has resulted to perform better whenever the panel time dimension is relatively small (T=20); Judson and Owen (1999) compare different dynamic panel estimators via Monte Carlo experiments on different panel dimension; on the base of simulated results, they conclude that the bias-corrected OLS fixed-effects estimator provides more precise, efficient and unbiased parameter estimates than the GMM alternative method.

4. Econometric Results

The dynamic production function in (1) is estimated using the previously outlined approaches to dynamic panel models; among the regressors, we include the first lag of both the dependent variable (aggregate cereal production) and the biodiversity index; all variables are taken in natural logarithms. A necessary condition for the difference GMM estimation to produce consistent results is lack of serial correlation in the error term ε_{it}; Arellano and Bond (1991) note that whenever this condition holds, the first-differenced residuals should display negative first-order serial correlation but no second-order serial correlation. We then test for the presence of serial correlated disturbances (expressed in differences) using the proposed Arellano and Bond residual based z statistic which takes value 0.7; given that the test value is in the acceptance region, we fail to reject the null hypothesis of no second order serial

[8] The fixed-effects model is generally more appropriate than the random-effects alternative for macroeconomic data, primarily because if individual effects are omitted variables they will also potentially correlated with the explanatory variables (violating the basic random-effect assumption); second, a typical macro panel can hardly be considered a random sample, since it will be normally made up of most of the observations of interest (being these regions or countries).

[9] See Baltagi (2008) for an in-depth discussion of dynamic panel estimation methods.

correlation in ε_{it} (p-value is 0.485), concluding that our data support the relevant necessary condition. We also test for the validity of the included instruments through the Sargan and Hansen tests of overidentifying restrictions; both tests indicated the presence of some form of misspecification in the original equation assuming strict exogeneity for all regressors apart from the lagged dependent variable; on the base of the Sargan/Hansen test results on the new specification with labor force as endogenous, the new instrument set satisfy the orthogonality conditions required by GMM.

The two-step variant of the Arellano and Bond estimator is employed with corrected standard errors (Windmeijer, 2005).

Table 1 shows estimation results for both GMM and LSDVC (bias corrected within fixed-effects) estimators.

Table 1
GMM and LSDVC Estimation Results

Variable	GMM (N = 278)	LSDVC (N = 360)
y_{t-1}	0.6*** (0.1)	0.22*** (0.06)
Land	-0.23*** (0.07)	-0.2** (0.08)
Lab	0.32** (0.15)	0.2* (0.1)
K	-0.005 (0.008)	0.02 (0.06)
Biodiversity	-0.31*** (0.06)	-0.15** (0.07)
$\text{Biodiversity}_{t-1}$	-0.01 (0.05)	0.1 (0.13)
Subsidies	-0.003 (0.003)	-0.02 (0.02)
Seeds	0.06*** (0.01)	0.05** (0.02)

Sargan Test =13.84 (p-value 0.12)
Hansen Test = 11.5 (p-value 0.26)
Difference in Hansen Tests = 4.85 (p-value 0.43)

Notes: Robust standard errors are in parentheses. Lsdvc SE are bootstrap SE.
The total number of instruments in GMM is 17.
Significance level: ***1%, **5%, *10%.

As outlined in Table 1, the dynamic specification of the production function is supported by estimation results; in fact, the lagged dependent variable coefficient significantly captures the relationship between present and past production levels in the cereal sector, being high in magnitude compared to other variables. As expected, the current level of crop biodiversity is positively related to production, while past levels do not seem to have a significant impact on current production.[10] The negative and significant coefficient on land can be interpreted as a decreasing marginal productivity effect. Other conventional inputs, specifically labor and seeds, bring a positive and significant effect to the production process, as obviously expected. Moreover, neither the coefficient of the investment variable nor that of the policy impact variable is statistically significant using both estimation techniques; the latter result can be explained through the following reasoning; first, under a technical viewpoint, a model which imposes homogeneous slope coefficients between groups in conditions of potential heterogeneity may lead to biased estimates and then unreliable results if this condition does not hold (Baltagi, 2008); however, slope homogeneity for the model is confirmed in the long term (see next section). Second, the 1992 reform of CAP may have changed the 'nature' of the relationship between agricultural subsidies and crop production. As already described in section 1, economic sustain based on production levels has been reduced in favor of a system of income support 'delinked' from production, so partially removing the distortive effects that incentives produce on farmers' preferences as far as the composition of agricultural production is concerned. Under this light, the substitution effect between subsidies and diversification may have been reduced by the new CAP regime - actually, an increase of biodiversity within crop production has been detected following the CAP reform (see Appendix). As a result, the relationship between agricultural subsidization and crop production may have lost stability and statistical relevance.

So, in the next section we extend the econometric analysis carried out so far partially relaxing the assumption of homogeneity between regions and allowing for a more flexible functional specification

5. Long-run and short-run relationships: the ARDL approach

The empirical analysis conducted so far was based on the assumption that the observed regions are homogeneous along the time span considered; a more realistic representation would imply considering some sort of variation both in the slope coefficients and in the error variances across-groups. Among all possible alternative methods developed for the analysis of dynamic panel data, we specifically concentrate on two estimation techniques which allow for different degree of parameter heterogeneity (the 'Mean Group' estimator and the 'Pooled Mean Group' estimator). More specifically, both methods assume that data are generated

[10] Since the index increases with decreasing biodiversity levels, the negative sign of the coefficient must be interpreted as indication of a positive relationship between biodiversity and production.

from a general autoregressive distributed-lag (ARDL) process where dependent and independent variables enter the right-hand side with lags of order p and q:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{l=0}^{q} \boldsymbol{\delta}_{ij}^{'} \boldsymbol{x}_{i,t-l} + \mu_i + \epsilon_{it} \tag{2}$$

Equation (2) can be re-parameterized and expressed in terms of a linear combination of variables in levels and first-differences:

$$\Delta y_{it} = \phi_i y_{i,t-1} + \boldsymbol{\beta}_i^{'} \boldsymbol{x}_{it} + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta y_{i,t-j} + \sum_{l=0}^{q-1} \boldsymbol{\delta}_{ij}^{*'} \Delta \boldsymbol{x}_{i,t-l} + \mu_i + \epsilon_{it} \tag{3}$$

where $\phi_i = -\left(1 - \sum_{j=1}^{p} \lambda_{ij}\right), \boldsymbol{\beta}_i = \sum_{j=0}^{p} \boldsymbol{\delta}_{ij},\ \lambda_{ij}^{*} = -\sum_{m=j+1}^{p} \lambda_{im},\ \boldsymbol{\delta}_{il}^{*} = -\sum_{m=l+1}^{q} \boldsymbol{\delta}_{im}^{'},$ with j=1,2,….,p-1, and l=1,2,….,q-1. After grouping the variables in levels, this can be re-written as:

$$\Delta y_{it} = \phi_i [y_{i,t-1} - \boldsymbol{\beta}_i^{'} \boldsymbol{x}_{it}] + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta y_{i,t-j} + \sum_{l=0}^{q-1} \boldsymbol{\delta}_{ij}^{*'} \Delta \boldsymbol{x}_{i,t-l} + \mu_i + \epsilon_{it} \tag{4}$$

where $\theta_i = -\phi_i^{-1} \boldsymbol{\beta}_i$ defines the long-run equilibrium relationship between the variables involved and ϕ_i measures the speed of adjustment of the error-correction process, which takes a negative and significant value when the variables display reversion to a long-run equilibrium. The vectors $\beta^{'}$ and $\delta^{*'}$ contain respectively the long-run and the short-run model coefficients.

The econometric literature suggests two approaches to consistent estimation of model coefficients in dynamic panels; the first, based on Pesaran and Smith (1995), known as the Mean Group estimator (MGE), is designed to control for ‘complete’ heterogeneity across groups allowing for different intercepts, slopes and error variances; it is based on the estimation of separate equations for each group and the subsequent analysis of the distribution of the estimated coefficients across groups. This estimator, however, does not consider that certain parameters may be the same across groups. To that purpose, Pesaran et al. (1999), design a maximum likelihood-based estimation method, the pooled mean group (PMG) estimator, which combines both pooling and averaging of individual regression coefficients, so that it is possible to distinguish between the degree of assumed heterogeneity in the short-run and long-run coefficients; only the former, along with intercepts and error variances, are assumed to differ freely across groups, while long-run coefficients are constrained to be the same. The authors underline the fact that there are good reasons to believe that long-run relationships between variables are similar (the presence of common technologies affecting all groups in a similar way); on the contrary, it can be reasonably expected that regions react differently to domestic and external shocks, fiscal adjustment mechanisms, local market imperfections, thereby making short-run adjustment group specific and hence function of group characteristics. By comparing the difference between the two estimation methods through a standard Hausman test, one can test the validity of the long-run parameter homogeneity restriction and therefore choose the estimator most conformable to its own data.

The advantages of implementing the above estimation methodologies rely on few considerations; first, as already mentioned, they allow for a better representation of reality relaxing the assumption of parameter homogeneity; second, since both methods are based on a general ARDL model, they exploit the advantages of this specification, namely the mitigation of contemporaneous causation from the dependent to independent variables which might bias the estimates (Banerjee et al. 1993; Pesaran and Shin, 1998); in fact, the selection of an appropriate lag order, by removing error serial correlation, helps mitigate endogeneity bias. Third, provided that there exists a stable long-run relationship between the variables involved, both MG and PMG estimators yield consistent estimates of that relationship independently from the stationarity properties of the series under investigation, since they are valid whether the variables are I(1) or I(0). This latter feature is particularly important in panel data analysis, given the envisaged low power of unit root and cointegration tests in panels (Karlsson and Löthgren, 2000; Gutierrez, 2003). Additionally, the ARDL approach allows to obtain both the short-run and the long-run parameters.

As far as our analysis is concerned, we proceed with the empirical investigation adapting to our original production function the ARDL approach; in choosing the lag structure of our model we rely on the Bayesian Information Criterion (BIC) obtained by comparing models with different lag structures on a country-by-country basis; we find that, for most of the cross-sections, the ARDL(1,1,…,1) is the preferred model.[11] Estimation results are reported in Table 2.

Table 2
Dynamic panel estimates - ARDL approach

	PMGE	Standard Error
Long-run coefficients:		
Land	-0.5***	0.03
K	-0.32***	0.02
Subsidies	-0.007**	0.003
Biodiversity	-1.05***	0.06
Seeds	0.44***	0.02
Short-run coefficients:		
EC coefficient (ϕ)	-0.6***	0.1
ΔLand	-0.02	0.1
ΔK	0.08	0.07
ΔSubsidies	0.09	0.07
ΔBiodiversity	0.45	0.33
ΔSeeds	-0.14**	0.06
Constant	9.8***	1.9
Hausman statistic:	2.33	
p-value	0.8	

Notes: Significance level: ***1%, **5%, *10%.

The result of the Hausman test provides evidence in favor of the homogeneity assumption of long-run coefficients, thus making the PMG estimator more suitable to our purpose. The model excluded the labor force variable which was suspected to be endogenous.

Concentrating on the variables of interest, the existence of a meaningful long-run relationship between biodiversity and cereal production is confirmed by a significantly negative error correction term, leading to the conclusion that the result is robust even in the presence of potential non stationary series. The long-run coefficient of biodiversity is significant and negative, thereby providing sufficient evidence of a positive elasticity between crop biodiversity and production (as already mentioned, the negative sign reflects the fact that the index is inversely proportional to species diversity). Compared to previous estimation models, the magnitude of biodiversity coefficient has substantially increased (from -0.3 to -1.05).

Albeit small in magnitude, the coefficient capturing the effect of the policy variable is now significant, with a negative sign. As already mentioned, the existence of a negative elasticity between an increase in subsidization and the change in cereal production can originate from the structural shift occurred in CAP income support measures after 1992; as the variable

[11] As outlined in Loayza and Ranciere (2006), it is recommended to impose a common lag structure for the whole panel whenever the interest is also in analyzing the short-run parameters; moreover, given our panel reduced temporal dimension, limiting the lag structure to the first lag seems plausible.

measuring the amount of subsidies is relative to the aggregate level of crop subsidies, it seems plausible to think that the reduction of support to specific crops (in particular in the cereal sector) implied a reformulation of crop production choices by farmers; moreover, the variable includes 'set-aside premiums' which can be thought to have negatively affected production levels.[12]

On the contrary, the short-run coefficients are not statistically significant, reinforcing the idea that biodiversity has a long-run and persistent effect on production and that the agricultural policy structural reform deploys its effects over time with a long-term impact that turns out to be negative as far as cereal production is concerned.

6. Discussion and Conclusion

Following a recent line of research, this paper analyses the role played by crop intra-species diversity in sustaining physical production within the cereal sector; compared to previous studies in the literature, we allow for a different time span of the variables under analysis, in order to try to control for the important policy shift which started in 1992 with the McSharry PAC reform. The empirical investigation has been carried out on the whole set of Italian regions; as far as the geographical extension is concerned, cereal production is not uniformly distributed among regions reflecting different weather conditions, in fact middle and southern regions are specialized in wheat production while rise production is more concentrated in northern regions; as a consequence, cereal supply is composed differently across regions.

We explicitly take into account the dynamic structural properties of cereal production function and, relying on the ARDL approach based on Mean Group and Pooled Mean Group estimation methods (Pesaran and Smith, 1995; Pesaran et al., 1997, 1999), look for the existence of a long-run equilibrium relationship between the variables of interest.

As expected, in line with other contributions, we find that biodiversity has a positive impact on production levels. However, unlike previous studies, the policy variable capturing the effect of crop subsidization turns out to be negative, witnessing potential effect of a shift in crop composition by farmers after the occurred policy changes. Additionally, the existence of a long-run equilibrium relationship between biodiversity and production, reinforces the diversity-stability hypothesis suggested by the literature, whereby, a part from external short-term shocks, production returns to its long-run equilibrium fostered by species diversity.

[12] Currently available data source do not provide a direct measure of the amount of subsidies addressed to the cereal sector; at least, the FADN data base distinguishes between aggregate agricultural subsidies and crop subsidies, while other used dataset in the literature (Banca d'Italia) does not allow this distinction.

The study, however, suffers from some drawbacks and limitations; first, the choice to include all regions in the dataset may be questioned for the relative low cereal production coming from some northern regions (namely, Trentino, Valle d'Aosta, Friuli Venezia Giulia); second, focusing only on mean production as the dependent variable, we do not investigate the role of both biodiversity and CAP subsidies on production or yield variability; third, further theoretical and empirical research must be addressed to the analysis of the relationship between biodiversity and CAP intervention measures. At the same time, as far as the insurance value of biodiversity is concerned, it can be interesting to model farmers' production decisions within a portfolio choice framework, making them more dependent from market conditions; in fact, although it is reasonable to assume that in most rural contexts of developing economies harvest failure due to harsh weather conditions represents the most important source of risk exposure for farm households, it is as well documented that in developed economies, production risk is more linked to market fluctuations and price variability (Knutson et al., 1998).

Future extension of the present study will be directed to cover the above mentioned aspects.

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Appendix

Figure 1. Biodiversity Index across regions and time