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# **Crop biodiversity repercussions of subsidized organic farming in Greece**

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## Abstract

This paper analyzes the impact of CAP financial assistance on crop biodiversity under uncertainty. A stochastic production function is employed and estimated to assess whether risk-averse farmers hedge risk by diversifying their portfolio of crops, thus increasing crop biodiversity. The model is applied to farm-level data of organic crop farms in Greece. Organic farming financial assistance poses a double-edged sword: even though it is considered agrobiodiversity enhancing as a cultivation method, subsidizing it can become agrobiodiversity reducing, since farmers may select to cultivate only the subsidized crops. The study shows that risk aversion leads to crop biodiversity conservation. However, providing CAP financial assistance on certain crops appears to decrease the relationship between revenue risk management and crop biodiversity, indirectly resulting in crop biodiversity loss.

**Keywords:** crop biodiversity, agroecosystem, risk management, agricultural assistance

**JEL classifications:** Q12, Q18, D80, Q24, Q57

## 1. Introduction

Agricultural biodiversity, or agrobiodiversity, is a sub-set of biodiversity, which includes all forms of life directly relevant to agriculture. Ecologists have long argued that at the farm level, an increase in on-farm species richness and a diversity of overlapping functional groups of species enhances the level of functional diversity. This, in turn, increases ecological stability and resilience (Tilman, Wedin et al., 1996). Crop biodiversity, the cultivation of a multitude of crops at the farm level, can thus increase agricultural biodiversity, since each crop creates differentiations in soil fauna, weeds, pests, and predators.

In addition, agricultural biodiversity at the farm level provides revenue diversification for the individual farmer, potentially reducing revenue risk. Decentralized decisions regarding the desired level of *in situ* agrobiodiversity, usually depend on conditions in the relevant food, fuel and fiber markets (Smale, Bellon et al., 2001). Market signals affect farmers' private land use decisions by fixing the private net benefits of their individual actions, given their risk aversion and rate of time preference (Pascual and Perrings, 2007). In addition, farmers' agrobiodiversity choices reflect a number of factors aside from market prices, including the social, political, and cultural conditions in which they operate. They are generally exogenous to the farmers' own decisions (Lambin, Turner et al., 2001), but are strongly influenced by policy at the national and international level. From an economic perspective, agrobiodiversity change causes a problem whenever it is socially inefficient. In most cases, this reflects market failures that are due to the existence of externalities and the public-good nature of biodiversity conservation (Pascual and Perrings, 2007).

Furthermore, institutional failures can cause changes in farm-level agrobiodiversity. One clear example of institutional failure lies in the perverse agricultural production subsidies, tax breaks and price controls that not only make a biodiversity-based agriculture uncompetitive, but that have systematically distorted farm-level decisions in both developed and developing countries for decades (Tilman, Cassman et al., 2002). At the beginning of the century, subsidies paid to the agricultural sectors of OECD countries averaged over US\$ 324 billion annually (about one third the global value of agricultural products in 2000) (Pearce, 1999), creating significant distortions to market forces.

Besides agrobiodiversity's effect on agricultural productivity and farm income stability, there are important landscape values of farmland that typically consist of the benefits derived from the scenic beauty generated by a rural landscape (OECD, 1993; Cobb, Dolman et al., 1999). The realization of such values in the European Union has spurred renewed emphasis on the role of multifunctional agriculture to secure such recreational and non-instrumental social values and has provided impetus for the design and implementation of novel agri-environmental policies (Hodge, 2000).

Organic agriculture, based on living ecological systems and cycles, works with them, emulates them and helps sustain them (Birol, Smale et al., 2006; Jackson, Pascual et al., 2007). Organic agriculture can help maintain productivity and increase environmental quality through crop biodiversity (Smukler, Jackson et al., 2008). However, when organic agriculture is subsidized, it can potentially become a double-edged sword: on the one side it can be considered as agrobiodiversity enhancing, while on the other it can reduce agrobiodiversity if farmers choose to cultivate the few crops that are subsidized.

The European Union's Common Agricultural Policy (CAP) has provided financial support for the adoption of specific types of farming, including the promotion of organic farming. This has provided a clear incentive for the increase of land cultivated organically with the most supported crops, potentially leading to a reduction in crop biodiversity. Farmers, may decide in order to manage risk that it is preferable to cultivate the most supported crop instead of maintaining crop biodiversity, therefore delinking crop biodiversity from risk management (Di Falco and Perrings, 2005). In addition, on-farm agrobiodiversity can be viewed as sustainable only if it enables farmers to stabilize and enhance agricultural income (Conway, 1993), posing potential conflicts between CAP financial assistance and sustainable agricultural development.

By eliminating options towards productive diversification, a reduction in agrobiodiversity may also lock farmers into obsolete agricultural technologies (Perrings, 1998). Therefore, maintaining a wider variety of technological and natural resource-based options in agricultural systems will likely maintain and enhance the capacity to respond to short-run shocks and stresses in constructive and creative ways.

A number of recent studies have analyzed the contribution of crop agrobiodiversity to the mean and variance of agricultural yields and farm income (Smale, Hartell et al., 1998; Widawsky and Rozelle, 1998; Schlapfer, Tucker et al., 2002; Di Falco and Perrings, 2003; Di Falco and Perrings, 2005; Birol, Smale et al., 2006). These papers found that

market integration, agro-ecological conditions, the adoption of high yielding varieties and farmers' risk aversion were significant determining factors of crop biodiversity conservation. Di Falco and Perrings (2005) were the first to analyze the impact of agricultural policies on crop biodiversity. They found, using aggregate data, that financial assistance aimed at specific crops delinks crop biodiversity from the management of revenues risk. However, Richard Just (Just and Weninger, 1999; Just, 2003) has emphasized that aggregate sample yield variance underestimates farm-level yield variance, which may be from two to ten times greater than implied by aggregate data estimates. In addition, averaging over farms that takes place in aggregate data distorts the distributional character of farm-level risk and therefore the effect of risk on variance can only be accurately measured using farm-level data.

Following Di Falco and Perrings (2005), this paper related the trade-off between financial farm support and crop selection in the management of production risk. If farmers are risk-averse, they will choose a higher number of crop species to hedge against yield uncertainty, which would result in a more diverse agroecosystem (Di Falco and Perrings, 2003). On the other hand, policies aimed at supporting farmers' revenues provide an alternative means of hedging against risks (Di Falco and Perrings, 2005).

While there is considerable advantage in removing the perverse incentive effects of historic subsidies, few of the agricultural reforms are based on a serious valuation of the social opportunity cost of agrobiodiversity loss, and fewer still involve an appraisal of the allocative effects of the new payment schemes. This is especially true for organic farming, and raises serious doubts about the efficiency of such policies in terms of their impact on crop diversity in the farm level and in sustainable agricultural development at the macro level.

The objective of this study is to analyze farmers' choices regarding crop biodiversity under uncertainty, when agricultural support policies are present, using farm-level data. The following section presents the empirical model specification. Section 3 presents the data and Section 4 presents the empirical results. The final section concludes.

## **2. Model specification**

Two farming strategies are considered by the individual risk-averse farmer in decision-making, aimed at maximizing expected revenue. The first strategy, the "biodiversity" strategy  $\{B\}$ , is assumed to increase revenue and reduce revenue variation by enhancing crop biodiversity. The second strategy, the "financial assistance" strategy  $\{F\}$ , is assumed to increase revenue and reduce revenue variation by providing higher dependence on subsidies, and thus, indirectly, reducing crop biodiversity.

The role of the two farming strategies on revenues is estimated using a Just and Pope (1978; 1979) stochastic specification. The Just and Pope framework has been widely used in previous crop biodiversity studies (Smale, Hartell et al., 1998; Widawsky and Rozelle, 1998; Di Falco and Perrings, 2005; Kato, Ringler et al., 2009). The Just and Pope

parametric approach allows yield-enhancing inputs to have either a positive or a negative effect on the variance of yield, by relating the variance of yield to explanatory variables in a multiplicative heteroskedastic regression model. Let  $y = g(\mathbf{x}, v)$  represent the stochastic production function, with  $y$  representing total farm revenues,  $\mathbf{x}$  is a vector of the two strategies used, the biodiversity strategy  $B$ , and the financial assistance strategy,  $F$ ,  $\mathbf{x} = \{B, F\}$ , and  $v$  the weather conditions and other factors unknown at planting time. Just and Pope (1978) proposed the following specification:

$$g(\mathbf{x}, v) = f(\mathbf{x}) + [h(\mathbf{x})]^{1/2} e(v) \quad (1)$$

where  $h(\mathbf{x}) > 0$  and  $e(v)$  is a random variable with zero mean and variance  $h(\mathbf{x})$ . This implies that  $f(\mathbf{x})$  represents the mean production function and  $h(\mathbf{x})$  is the variance of output, where  $E(y) = f(\mathbf{x})$  and  $Var(y) = Var(e)h(\mathbf{x}) = h(\mathbf{x})$ . Given that  $\partial Var(g(\mathbf{x}, v))/\partial \mathbf{x} = \partial Var(h(\mathbf{x}))/\partial \mathbf{x}$ , it follows that  $\partial Var(h(\mathbf{x}))/\partial \mathbf{x} > 0$  identifies strategies that are risk increasing and  $\partial Var(h(\mathbf{x}))/\partial \mathbf{x} < 0$  identifies strategies that are risk decreasing.

Just and Pope proposed estimating the specified model either by using three-stage feasible generalized least squares (FGLS) or full information maximum likelihood (FIML), estimating equations  $f(\mathbf{x})$  and  $h(\mathbf{x})$  simultaneously. Furthermore, in cases of small samples, Saha et al. (1997) show that FIML is more efficient and unbiased than FGLS estimation. Therefore, we proceed by estimating our model using the FIML estimator.

We assume that the mean function is a transcendental logarithmic:

$$\ln f = \beta_0 + \sum_i \beta_i \ln X_i + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln X_i \ln X_j + u \quad (2)$$

$i, j = B, A, i \neq j$  and the variance function is exponential:

$$u^2 = [g(\alpha, P)]^2 = e^{\phi_0} \left( \prod_{i=1}^2 X_i^{\phi_i} \right) e^v \quad (3)$$

The transcendental logarithmic specification was employed because of its flexible form and because we are interested in the elasticity of substitution between the two input strategies. A Cobb-Douglas specification would restrict the elasticity of substitution between the crop biodiversity strategy and the financial assistance strategy to equal one (Chambers, 1988). Di Falco and Perrings (2005) circumvented this shortcoming by adding an interaction term to the Cobb-Douglas specification, an approach that is half way to employing a full transcendental logarithmic specification.

### 3. Data description

The data were collected through accounting records of 63 farms in the North of Greece. Farmers received subsidies for the cultivation of certain organic crops, given that they adhere to the guidelines and procedures of organic crop cultivation. Using the accounting records, we estimated total farm revenues for the 2009-2010 cultivating period.

The role of crop biodiversity is measured with the use of the Shannon index, which is a spatial crop diversity measure (Magurran, 1988; Meng, Smale et al., 1998; Di Falco and Perrings, 2005). The index is defined as:  $H = -\sum_i p_i \ln p_i$  where  $p_i$  represents the share of land planted with the  $i$ th crop. The Shannon index captures the role of crop biodiversity in supporting and stabilizing revenues (diversity strategy). Finally, the role of agricultural policy in supporting and stabilizing revenues (benefit strategy) is captured by total financial assistance to farms offered under the CAP, in 2010 Euros. Table 1 reports the definition of variables employed.

**Table 1. Definition of Variables**

<i>Variable</i>	<i>Definition</i>
Farm revenues	Total farm revenue in euros
Biodiversity strategy	Shannon index for spatial biodiversity
Assistance strategy	Total financial assistance to farms offered by the CAP in euros

### 4. Empirical Results

The estimation of the stochastic revenue function indicates that the role of the two strategies, the diversity strategy and the benefit strategy, on the mean and variance of farm revenues were statistically significant (Table 2). The results indicate that both strategies are positively correlated to the mean farm revenue and negatively correlated to the variance of farm revenues. These results support the findings of Di Falco and Perrings (2005) on aggregate data, and suggest that crop biodiversity has a significant role in stabilizing farm revenues. Furthermore, the results suggest that both crop biodiversity and CAP financial assistance are risk-reducing strategies.

**Table 2. Estimation results of the stochastic revenue function**

<b>Variable</b>	<b>Mean function</b>	<b>Variance function</b>
<b>Biodiversity strategy</b>	1.605 (0.852)	-1.151 (0.503)
<b>Assistance strategy</b>	-0.577 (0.138)	-0.267 (0.102)
<b>(Biodiversity strategy)<sup>2</sup></b>	-0.735 (0.911)	
<b>(Assistance strategy)<sup>2</sup></b>	0.076 (0.016)	
<b>Interaction term</b>	-0.016 (0.087)	1.126 (0.046)
<b>Constant</b>	8.713 (0.160)	

$N=63$ ;  $\text{Adj-R}^2=0.67$ ;  $\text{Log-likelihood}=-161.68$ ;  $\text{Breusch-Pagan test}=48.07$   
Standard errors are in parentheses.

The tradeoff between the biodiversity and the assistance strategies is estimated by the relevant elasticity of substitution. Given that there are only two variables in the revenue function, the Allen partial elasticity of substitution and the direct elasticity of substitution measures are equal (McFadden, 1978). For the transcendental logarithmic revenue function the elasticity of substitution is:

$$\sigma_{BA} = \frac{\beta_{BA} + S_B S_A}{S_B S_A} \quad (4)$$

where  $S_i = \beta_i + (\beta_{ij} + \beta_{ji}) \ln X_j$ ,  $j = B, A$ . Thus, the estimated elasticity of substitution between the two strategies equals  $\sigma_{BA} = -1.0082$ , suggesting that there is a substantial substitutability between the two strategies. The estimated elasticity is significant, suggesting that increased levels of financial assistance reduce the revenue stabilizing effect of crop biodiversity. The implications of this result regarding organic farming are, therefore, that subsidized organic farming may be reducing crop biodiversity instead of increasing it.

## 5. Conclusions

This paper employs the stochastic revenue function framework employed by Di Falco and Perrings to study the link between crop biodiversity, agricultural assistance and farm revenue under uncertainty. The model is empirically tested using a transcendental logarithmic Just and Pope revenue function using farm-level data from Northern Greece. The analysis finds that both strategies, crop biodiversity and financial assistance, are significant determinants of farm revenues, and that risk aversion is an important determinant of crop biodiversity conservation.

In addition, the results show that both strategies provide equally viable means of stabilizing farm revenue. This creates interesting implications for CAP financial assistance to organic farming, as it presents a double-edged sword. On the one side, it increases crop biodiversity, while on the other it may be reducing it. The evidence presented in this analysis corroborate to the conclusion that financial assistance on organic farming may be delinking crop biodiversity from the management of risk.

Even though removing the perverse incentive effects of agricultural subsidies has clear advantages in agricultural biodiversity conservation, very few of the agricultural reforms, including the currently discussed CAP reform, are based on an evaluation of the opportunity cost of agricultural biodiversity loss. In addition, few studies involve an appraisal of the allocative effects of subsidies, such as the ones on organic farming. A rational design of a market-like mechanism for agricultural biodiversity conservation requires both.



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