Agro – Biodiversity and Agricultural Policies in an Uncertain Environment

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Abstract

Recently, financial assistance to farms has been widely under scrutiny. Agricultural assistance has an important impact on farmers' production decisions and those decisions in turn affect resources use or environmental quality. Surprisingly, the impact of agricultural policies on agro-biodiversity has been relatively neglected. This paper purports a novel framework to analyze the role of crop biodiversity on the mean and the variance of farm revenues. Further, the potential use of this framework in studying the impact of farm financial assistance to crop biodiversity loss is investigated.

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1. Introduction

In the last decade financial assistance to farms has been widely under scrutiny. Agricultural assistance has an important impact on farmers' production decisions and those decisions in turn affect resources use or environmental quality, such as land, water or chemical use (Just and Antle. 1990, Just and Bockstael, 1991; Abler and Shortle, 1992; LaFrance, 1992). And, some empirical evidence has been provided on the perverse effect of agricultural policies on environment. For instance, Lewandrowsky et al., 1997, using

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data from farm sector assistance in the OECD countries, showed that fertilizers use is positively correlated to agricultural intensification. Surprisingly, the impact of agricultural policies on agro-biodiversity has been relatively neglected. The connection between agricultural assistance and biodiversity considered in this paper relates to the trade-off between farm price or income support and crop choice in the management of production and marketing risks. For example, Chavas and Holt (1990) used an acreage supply response model to show that risk and wealth variables are key factors in acreage allocation decisions. Leathers and Quiggin (1991), using a method proposed by Meyer (1988), analyzed the role of farmers' risk attitude in the interaction between agricultural and resource policy. They showed that if farmers are risk averse they will use more of the risk reducing input than the risk neutral farmer. Traditionally, risk plays a pivotal role in determining agro-biodiversity. If allocating land to different species is a risk reducing strategy the risk averse farmer's cropping strategy will lead to more diverse agro-ecosystems.

This is because farmers hedge uncertainty by diversifying their crop choices (Smale et al. 1994, Di Falco and Perrings, 2003). At the same time, policies aiming to support or stabilize farmers income -- such as price support, grants, financial compensation -- offer an alternative means of hedging risks.Hence, a by product of financial assistance to farmers may be to 'delink' risk aversion from the diversity of the agro-ecosystem. Uncertainty may be hedged by planting those species that attract more support, rather than those species that minimise the variance of yields. This paper develop a framework to analyse the role of inter species crop diversity on the mean and the variance of yields. An application example, using data from the south of Italy is presented. Finally, an analysis of the potential use of the framework to infer the impact of financial assistance to farmers using to diversity loss is also investigated.

2. Framework

Consider a production process involving netputs $\mathbf{y} = (y_1, \ldots, y_n) \in \Re^n$, where inputs are negative and outputs are positive. The underlying multi-input multi-output production technology is denoted by the set $Y \subset \Re^n$, where $\mathbf{y} \in Y$ means that the netputs $\mathbf{y}$ can be feasibly produced. We assume that set Y is closed. We are interested in providing a simple representation of the frontier technology given by the boundary of Y. Such a representation is given by the shortage function proposed by Luenberger. Let $\mathbf{g} \in \Re^n_+$ be a reference bundle satisfying $\mathbf{g} \geq \mathbf{0}$, and $\mathbf{g} \neq \mathbf{0}$. For a given $\mathbf{g}$, the shortage function $S(\mathbf{y})$ is defined as

$$S(\mathbf{y}) = \min_\alpha \{\alpha: (\mathbf{y} - \alpha\, \mathbf{g}) \in Y\}.$$

The shortage function $S(\mathbf{y})$ measures the number of units of the reference bundle $\mathbf{g}$ that can be generated starting from $\mathbf{y}$ and moving to the frontier technology. It has some useful properties (see Luenberger):

1. $\mathbf{y} \in Y$ implies $S(\mathbf{y}) \leq \mathbf{0}$,
2. If the technology exhibits free disposal (where $\mathbf{y} \in Y$ and $\mathbf{y'} \leq \mathbf{y}$ implies that $\mathbf{y'} \in Y$), then $Y = \{\mathbf{y}: S(\mathbf{y}) \leq 0\}$,
3. The function $S(\mathbf{y})$ is convex in $\mathbf{y}$ if the set Y is convex,

Properties 1 and 2 show that $S(\mathbf{y}) \leq 0$ is associated with the feasibility of the netputs $\mathbf{y}$. And under free disposal, $S(\mathbf{y}) \leq 0$ provides a complete characterization of the technology. And $S(\mathbf{y}) = 0$ when $\mathbf{y}$ is on the boundary of the feasible set Y, with $S(\mathbf{y}) = 0$ providing a representation of the multi-input multi-output frontier technology.

(Note: In the special case where $\mathbf{g} = (1, 0, \ldots, 0)$, $\mathbf{y} = (y_1, \mathbf{y}_2)$ and the first netput y_1 is an output, then $S(\mathbf{y}) = \min_\alpha \{\alpha: (y_1 - \alpha, \mathbf{y}_2) \in Y\} = y_1 - F(\mathbf{y}_2)$, where $F(\mathbf{y}_2) = \max \{y_1: (y_1, \mathbf{y}_2) \in Y\}$ is the largest possible output y_1 that can be obtained given other netputs $\mathbf{y}_2$).

Consider the case where $\mathbf{y} = (\mathbf{x}, \mathbf{v})$, where $\mathbf{x}$ are controllable netputs, while $\mathbf{v}$ are stochastic variables representing uncontrollable netputs (e.g., weather effects). Then, the frontier technology can be represented by $S(\mathbf{x}, \mathbf{v}) = 0$. Treating $\mathbf{v}$ as random variables, the frontier technology can be represented by the moments of $S(\mathbf{x}, \mathbf{v})$. Focusing on the first two-moments, let $f(\mathbf{x}) = E[S(\mathbf{x}, \mathbf{v})]$ and $[\sigma(\mathbf{x})]^2 = E[(S(\mathbf{x}, \mathbf{v}) - f(\mathbf{x}))^2] > 0$, where E is the expectation operator with respect to the random variables $\mathbf{v}$. It means that the shortage function $S(\mathbf{x}, \mathbf{v})$ can be written as

$$S(\mathbf{x}, \mathbf{v}) = f(\mathbf{x}) + \sigma(\mathbf{x})\, e,$$

where $e = [S(\mathbf{x}, \mathbf{v}) - f(\mathbf{x})]/\sigma(\mathbf{x})$ is a random variable with mean zero and variance 1.

This formulation allows to analyze the exsistence of economies of scope in both the mean and the variance functions. For instance, let $\mathbf{x} = (\mathbf{x}_a, \mathbf{x}_b)$ where $\mathbf{x}_a = (x_{a1}, \ldots, x_{am})$ are m outputs and $\mathbf{x}_b$ are inputs. First, consider a diversified firm using inputs $\mathbf{x}_b$ to produce outputs $\mathbf{x}_a = (x_{a1}, \ldots, x_{am})$ such that $f(\mathbf{x}_a, \mathbf{x}_b) = 0$. Letting $\mathbf{p}_a$ denote the unit price for outputs $\mathbf{x}_a$, the associated expected revenue is

$R^D(\mathbf{x}_b) = \mathbf{p}_a \cdot \mathbf{x}_a$.

Next, consider that the outputs $\mathbf{x}_a = (x_{a1}, \ldots, x_{am})$ are produced by m specialized firms, where the i-th firm produces only the i-th output, i = 1, …, m. Define the quantity produced by the i-th specialized firm by x_{ai}^i that satisfies $f(0, \ldots, 0, x_{ai}^i, 0, \ldots, 0; \mathbf{x}_b) = 0$, i = 1, …, m. The associated expected revenue is

$R^S(\mathbf{x}_b) = [\sum_{i=1}^{m} p_{ai} \cdot \mathbf{x}_{ai}^i]/m$.

It follows that $[R^D(\mathbf{x}_b, \mathbf{p}_a) - R^S(\mathbf{x}_b, \mathbf{p}_a)]$ is a measure of the expected benefit of diversification. (Note: there are other measures that may be worth exploring as well…)

Similarly, consider the effects of diversification on the variance of production uncertainty. Let p_g denote the unit price of the reference bundle **g**. The variance of production risk for the diversified firm is $[\sigma(\mathbf{x}_a, \mathbf{x}_b)]^2$, with associated variance of revenue

$V^D(\mathbf{x}_b) = p_g^2\, \sigma(\mathbf{x}_a, \mathbf{x}_b)^2$.

Under specialized production, the corresponding variance of revenue from m specialized firms is

$V^S(\mathbf{x}_b) = p_g^2\, [\sum_{i=1}^{m} \sigma(0, \ldots, 0, x_{ai}^i, 0, \ldots, 0; \mathbf{x}_b)/m]^2$.

It follows that $[V^D(\mathbf{x}_b) - V^S(\mathbf{x}_b)]$ is a measure of the benefit of keeping interspecies diversity in the farm. Therefore, the pay off derived from the negative impact of biodiversity on the variance of revenues is calculated. If constant prices are assumed, then the source of uncertainty is only on the production side[3]. Therefore, the role of diversity on the variance of the revenues. However, the role of biodiversity on the stability of production provides information not just on the risk property of biological diversity but also on the ability of a diversified farm to withstand external shocks. And, to compare the analogous response of a farm that instead has very little inter species diversity. In other words, this framework can highlight the relationship between diversity and resilience of the agro ecosystem[4] when a long enough time spa is available.

4. Data and diversity metrics

To estimate the shortage function data from the south of Italy are used. The observations are on the Southern Italian regions: Abruzzo, Molise, Campania, Puglia, Basilicata, Calabria, Sicilia and Sardegna from 1985 to 1993. South Italy cereals production accounts for major share of national production. For instance, in the past twenty years 68% of national durum wheat production, a staple product in Italy, came from southern regions. For Instance, in 1997 some 1,242,185 hectares were planted in Durum wheat in southern Italy, with an output of 3,383,813 tonnes. The choice of the level of regional aggregation is driven by the nature of the problem and data availability. In the standard literature on crop biodiversity many measures of diversity have been proposed. Most of these indices are drawn form ecological literature on the calculation of diversity at both interspecies and intra species level. Magurran (1988) classifies species diversity measures

[3] Uncontrollable factors such as weather, pest infestations or disease outbreaks all affect yield (*production uncertainty*). The time taken for the crop to mature leads a gap between the market price when production decision are taken and when the goods are actually sold (*price uncertainty*)

[4]

in three categories based on the weights assigned to the concepts of abundance and richness underlying the measurement of diversity:

1. species richness indices;
2. Species abundance models;
3. indices based on the proportional abundance of species.

The richness indices measure the number of species existent in one area, while the second category focuses on abundance or evenness of species and measures the distribution of an existing species in a given area. Although the abundance or evenness indices provide the most complete use of the information they do require fitting a particular distribution to the data. Magurran s third category is composed by indices that are based on proportional abundance and incorporates elements of both richness and abundance. Since no assumptions are made regarding distribution, these indices are considered to be non parametric (Meng et al., 1998). Previous studies relied upon indices of spatial diversity therefore exploiting information on land allocation over different crops or varieties (e.g. Smale et al, 1997, Smale 2000).

One of the indices commonly used to measure spatial diversity is the Simpson index (Pardey et al.,1996; Hartell et al.,1998; Smale et al 1997, Hesey et al, 1998), that is equal to $D=\sum p_i^2$ where p_i is the proportion of land planted to the *i - th* species. As D increases, diversity decreases, therefore the Simpson index is usually expressed as 1-D or 1/D. However, this index is "heavily weighted towards the most abundant species in the sample wile being less sensitive to species richness" (Magurran, 1988, p.40). Given that the diversity data used in this thesis refers to a single species, durum wheat, that is spread widely a Simpson's index is used. When data referred to interspecies diversity a Shannon Index is used. The Shannon index has the following form:

$$H = - \sum p_i \ln p_i$$

Assumptions underlying use of the Shannon index include random sampling from an infinitely large population and the representation of all species from the defined area in the sample.

However, the choice of a suitable index to capture the complexity of biodiversity is a hard task. This choice is always arbitrary. Further, in productivity analysis these measures are potentially endogeneous then leading to biased estimates. One important feature of this study is that basically overcome this problem. The interaction between crop biodiversity and productivity can be captured by the multi output framework and by exploiting information deriving from an interaction term. The latter is q_iq_j where i is different from j.

5. Application

This section will provide an application example of the features of the approach developed in section 2. The potential role of crop biodiversity on the mean and the variance of production is provided. In order to do this investigation three different steps are provided. First, the representation of the multi output technology is estimated by using the shortage function. It is assumed a flexible quadratic form. Second, the estimated coefficients are used to produce some simulations. Third, to analyze the role of crop interspecies diversity on the variance of production and to study the link between diversity and resilience the simulation is implemented on the variance of production. The following tables reports the estimation of the shortage function where the reference bundle is hard wheat:

Tab.1 Shortage function estimation fixed effects model

Variable	Coeffs	Standard Error	t-ratio	P[|T|>t]
Tender wheat	.1679	.9458E-01	1.776	.0806
Tender wheat ^2	-.47210E-02	. 2286E-02	-2.065	.0431
Oat	-.4491674924	.9032E-01	-4.973	.0000
Oat^2	-.10987E-01	.3486E-02	-3.151	.0025
Pesticides	-.1629973100	.14426	-1.130	.2629
Pesticides^2	.2277E-02	.1947E-02	1.169	.2467
Tender *Oat	.37242E-01	.284E-02	13.098	.0000
Horse power	-.967901E-01	.5199	-.186	.8529
Horse power ^2	.68758E-03	. 3824E-01	.018	.9857

The relevant diagnostic for the above model is:

Fit: R-squared= .981001, Adjusted R-squared = .97537

Model test: F[16, 54] = 174.27, Prob value = .00000

Diagnostic: Log-L = -106.9412, Restricted(b=0) Log-L = -247.6409

LogAmemiyaPrCrt.= .663, Akaike Info. Crt.= 3.491

Tab.2 Shortage function estimation random effects model

Variable	Coeff	Standard Error	b/St.Er.	P[|Z|>z]
Tender wheat	.90021E-01	.625E-01	1.438	.1503
Tender wheat ^2	-.30786E-02	.1653E-02	-1.862	.0626
Oat	-.498228	.83841E-01	-5.943	.0000
Oat^2	-.10987E-01	.29138E-02	-3.771	.0002
Pesticides	-.29102E-01	.9928E-01	-.293	.7694
Pesticides^2	.78216E-03	.1446E-02	.541	.5888
Tender *Oat	.39064E-01	.2592E-02	15.066	.0000
Horse power	-.12683	.4703	-.270	.7874
Horse power^2	.10995E-01	.3391E-01	.324	.7457
constant	19.377	1.598	12.125	.0000

To avoid collinearity the application is presented with respect to just three different crops. Further, some aggregations have been implemented. For instance, pesticides are aggregated with fertilizers. Let q_1 be the quantity produced of crop 1, q_2 the quantity produced of crop 2 and q_3 the quantity produced of crop 3. Conventional inputs are horse power, pesticides and fertilizers. To our knowledge this is the first empirical application of the shortage function using data from agricultural systems. Anyway, for the purpose of this study the estimated coefficients are used in order to implement a simulation analysis. Let's consider a farm that has high inter species crop biodiversity. Let us assume that the number of crops is three. Then, the farm will have revenues as $R^d = \sum p_i q_i$ where i = 1,2,3 and its technology will be represented by $q_1 = f(q_2,q_3,z)$ where z is a vector of conventional inputs. A farm that does not have inter species biodiversity will employ all the available land to one single crop. And, will have as technology representation:

$q_1 = f(0,0,z)$, $q_2 = f(q_2,0,z)$ and $q_3 = f(0,q_3,z)$. Under the assumption of constant return to scale, it is possible to calculate the economies of scope in having interspecies biodiversity. In fact, the revenues will be $R^s = \sum p_i q_i / 3$. Therefore, the potential diversity benefit on revenues can straightforwardly assessed from the comparison between R^d and R^s. Assuming price constant and a flexible quadratic form the scope test can be performed as:

Diversity

$$q_1 = a_0 + a_1 q_1 + a_2 q_1^2 + a_3 q_2 + a_4 q_3^2 + a_5 z_1 + a_6 z_1^2 + a_6 z_2 + a_7 z_2^2 + e$$

One single crop

$$q_1 = a_0 + a_4 z_1 + a_5 z_1^2 + a_6 z_2 + a_7 z_2^2 + e$$

$$q_1 = a_0 + a_1 q_1 + a_2 q_1^2 + a_4 z_1 + a_5 z_1^2 + a_6 z_2 + a_7 z_2^2 + e$$

$$q_1 = a_0 + a_3 q_3 + a_4 q_3^2 + a_5 z_1 + a_6 z_1^2 + a_7 z_2 + a_8 z_2^2 + e$$

Using a the estimated parameter from the regression model and the mean values for the variables we have that the revenues for the farm with interspecies diversity is $R^D = 495360$, and the revenues for the farm with a single crop is $R^S = 345770$. Therefore, there is a scope for interspecies diversity because $R^S < R^D$.

In order to infer the role of diversification on the variance of production and the resilience of the agro ecosystem a simple simulation model has been implemented. The procedure is similar to the previous one. Data are generated from the sample in order to calculate the variance of revenues through quantity uncertainty. Let V^D be the variance of the revenues of the farm with inter species diversity, and V^S be the variance of the firm that grow just one crop. Hence,

V^D = Var $p_i \sigma q_i e$ and assuming constant return to scale V^S = 1/n (Var $\sum p_i \sigma q_i e$) where i = 1,..,n. The comparison between the two variances informs us about the value of the relationship between biodiversity and resilience.

The calculation output is V^S = 15790491263 and V^D = 6714400222, therefore $V^S > V^D$ implying that the variance of the single crop farm is higher then the farm with interspecies diversity. The difference is circa 40%.

6. **Crop biodiversity loss: the role of agricultural policies**

The Common agricultural Policy of the European Community is a complex set of instruments and regulations that covers price support measures, production subsidies, conservation policies, income transfers etc. The establishment of an integrated common market for agriculture was the priority of the first six members of the EC. Art. 39 of the treaty emphasized that the objective of the EC action must be toward an "increase agricultural productivity by promoting technical progress" and "to ensure a fair standard of living for the agricultural community". Further, the EC was charged to take actions needed to stabilize markets, assure availability of supplies, and ensure reasonable consumer prices. The guidance principles of the EU interventions are the following:

· Uniqueness of the market; thus integration toward a single agricultural market in Europe.

· Preference; which implies that home production should be preferred versus agricultural import.

· Financial solidarity; complete sharing among EU countries of the costs of farmer income support.

A fundamental feature of agricultural production income is its exposure to environmental risk which in turn results in income instability and low average incomes. In order to address this trend of low average farm incomes (with respect to other sectors income) the EU targeted its intervention in the agricultural sector as the stabilization of incomes. A set of measure has been used in order to accomplish this task.

In the standard literature on biodiversity loss the relevance of market integration, risk aversion and so forth as explanatory variables that play a key role in farmer decisions to conserve diversity. However, no consideration has been given to the role of farm financial support. In a European country the impact of policy, namely the CAP (Common Agricultural Policy), is important. It follows that analyzing farmers choices without regard for public intervention ignores an important part of the story. Price support, grants, financial compensation for crop losses etc. are all tools used the by the Agricultural Commission in order to support and stabilize farm incomes. Farmers may reduce crop diversity because they change their production plans to favor those species that receive more support for the CAP. Alternatively, they may reduce crop diversity because other mean of hedging risks are available. Unfortunately the data at hand are aggregated so is not possible to distinguish the specific type of support being received. However, from the analysis in the previous sections it is clear that reductions in interspecies diversity lead towards a higher variance of farm revenues. Therefore, assistance packages that have supported one species more than the other are a clear incentive for diversity reduction.

7. Conclusions and future research

This paper presented a framework to analyze the impact of crop biodiversity on the mean and the variance of farm revenues. It is found that conserving interspecies diversity has an important and positive impact in supporting and stabilizing farm production. This analysis can also shed light on the relevance of agricultural police in determining crop diversity loss. In fact, policies that protect one crop might provide an incentive to farmer to devote their production to that supported crop.

Agricultural intensification is not the only potential "side effect" of agricultural policies. There is a potential role of farmers risk attitude on land management strategies and on crop choices when is uncertainty is taken into account. Different policies impact in different way on this link. The call for coordination between agricultural and resource policies needs also to recognize other complications triggered by farmers risk aversion and the intrinsic risky nature of agricultural production

References