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Cooperative Production and Intraspecific Crop Genetic Diversity: The case of Durum Wheat in Southern Italy

Salvatore Di Falco and Charles Perrings
Environment Department, University of York (UK)
Contact Auhtor: sdf101@york.ac.uk

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Abstract

In the standard resouce economics literature, the private solution is always suggested as solution to resource degradation opposed to a common property regime. This because the latter is considered as an open access situation. Larson and Bromley (1990) in a dynamic setting showed that this result does not hold if the common property regime is not a free access one. In this paper we apply a simple impure public good model in oder to show that an agricultural cooperative or (assuming homogeneity) a system of agricultural cooperatives might act as a centralized decision maker which may act toward genetic diversity conservation deciding the land allocation of different cultivar.An application example based upon southern Italy data is provided.

1 Introduction

The environmental and resource economics literature was long dominated by the perception that private property rights are more likely to be consistent with the conservation of natural resources than common property rights. This perception was modified by the recognition that it is the open access nature of many common property regimes, rather than the communal nature of the rights, that is the problem (Larson and Bromley, 1990;) More recently, a number of studies of developing countries have argued that common or communal property rights may actually encourage a higher level of conservation than private property rights. This has been related to the idea that local communities in developing countries have a more direct dependence on the ecological services provided by natural resources, and hence a stronger interest in their conservation. In particular, it has been argued that local communities in developing countries have an interest in the conservation of biodiversity as a local public good (Perrings and Gadgil, 2002; Gadgil et al, 1997). A major element of this argument is the role of biodiversity conservation in the management of risk.

In this paper we consider a related problem. One of the manifestations of biodiversity loss in agroecosystems is the displacement of landraces by newer high-yielding varieties. This is reflected in a reduction both in the number of species being cultivated, and in the number of varieties within each species cultivated. The extreme example of this is the reduction of rice cultivars in production through the displacement of tens of thousands of landraces by a few high yielding varieties in South-Asia and South-East Asia(Heywood, 1995). Of course there are many factors behind the widespread adoption of new technologies in agriculture. Here we focus on only one: the property rights under which farmers operate. We consider whether production decisions taken by farming cooperatives are associated with higher or lower levels of crop genetic diversity than decisions taken by private farmers. This is an empirical matter. Using data from a developed country, Italy, we apply a simple club goods model to show that where income sharing agricultural cooperatives act as centralized decision makers, where intraspecific diversity yields benefits in terms of risk reduction, and where the crop mix is not constrained by farm size, then cooperative production will be associated with higher crop genetic diversity than private production.

2 Genetic diversity in agriculture

The Biodiversity Convention encourages the parties to promote on-farm conservation of agrobiodiversity. Genetic diversity is the sum of genetic information contained in plants, animals and micro organisms. Within an individual species, genetic diversity allows populations to adapt to changes in climate and other environmental conditions. Genes transferred to domestic crop plants from their wild relatives can increase yields, improve quality, provide resistance to pests and diseases and extend growing ranges. This reflects the fact that the wild relatives have properties that are favourable under particular environmental conditions. In a series of widely cited (also widely criticised) set of experiments, Tilman and Downing (1994) showed that the average amount of biomass grown per year in a plot of a given size increases with the diversity of functional groups represented. Because the performance of different species varies with climatic and other environmental conditions, greater species diversity in the grass sward enables the system to maintain productivity over a wider range of conditions (Naeem et al, 1995). An implication of this for natural ecological systems is that no species are 'redundant' even if they appear similar in their ecosystem effects to other species under given environmental conditions (Chapin et al. 1997). Good examples are to be found in the fungal communities associated with plant roots that influence the effectiveness of nutrient uptake (van der Heijden, 19xx, Read 19xx). An implication for arable systems, is that wherever there is natural variation in environmental conditions, the variance (and potentially the mean) level of productivity will be sensitive to the diversity of cultivated plants.

Farmers choose both the number of species or the number of varieties within a species to be cropped, and the area to be allocated to each species or each variety. That is, they choose both the interspecific and the intraspecific diversity of cultivated species. This choice has been extended to the genetic composition of particular varieties, initially through the activities of plant breeders working on related species, latterly through genetic implants from unrelated species. These new variaties incorporate desirable traits from different landraces, both to enhance production and to cope with variation in environmental conditions. Farmers also pursue these objectives by choosing (or at least influencing) the diversity of non-cultivated species through the management regime.Use of pesticides, for example, controls crop competitors and predators. Use of fertilizers or irrigation impacts all species in the system, including sub-soil flora and fauna (Conway,1993).

There are still examples of societies whose primary response to the management of environmental risk lies in the number of cultivars. The WRI cites the examples the Ifugao of the island of Luzon in the Philippines who identify more than 200 varieties of sweet potato by name, and

Andean farmers who cultivate thousands of clones of potatoes, more than 1,000 of which have names . In general, however, risk management has increasingly relied on the incorporation of genetic material from a range of sources into particular cultivars. It has been estimated, for example, that plant breeders' use of genetic diversity accounted for at least one-half of the up to four-fold increased yields in rice, barley, soybeans, wheat, cotton, sugarcane, tomato, corn, sorghum and potato in the second half of the last century (Heywood, 1995). Substantial improvements in yields have also followed the introduction of genetic resistance to certain pests and pathogens. Most cultivated crop varieties and many livestock strains already contain pest or disease resistant genetic material from wild relatives, land races or traditional livestock strains. For example, Mexican beans have been used to improve resistance to the Mexican bean weavil that destroys or damages as much as 25% of stored beans in Africa and 15% in South America. Similarly, wild strains of Barley from Ethiopia have been used to combat yellow dwarf virus in the USA (Heywood, 1995).

Nevertheless, there is a balance to be struck. Improvements in pest or disease resistence are often short-lived, since natural selection helps pests and pathogens to overcome this resistance relatively quickly. Moreover, the use of such landraces in plant breeding programmes has been dramatically reduced since the Green Revolution, during which traditional landraces were largely displaced by 'improved' varieties. As a result, the management of environmental risk in agriculture still includes the choice of both interspecific and intraspecific crop genetic diversity diversity. We have considered the link between biodiversity and risk elsewhere (Di Falco and Perrings, 2002). Here we focus on the Tilman finding therefore we consider the intraspecfic diversity effect on the gorss prodction value (at constant prices) of durum wheat.

3 The choice of crop genetic diversity

In a 1997 paper Heisey et al. used the theory of impure public goods to model farmers' genetic conservation decisions.They showed both that farmers would not crop cultivars that are less susceptible to rusts and that are more similar genetically, and that there is a trade off between yields and genetic diversity conservation. In this paper we use a similar approach but pose a different question. Does the form of property rights under which farmer's choose the genetic diversity of cultivated crops affect that choice? More particularly, taking the case of Italy, we consider whether crop genetic diversity is higher in agricultural cooperatives than in private farmland. We do not consider yields, per se. Crop genetic diversity is hypothesised to act on distributable revenues. Hence we consider the connection between intraspecific crop genetic diversity and revenues. The underlying model is extremely simple. The agricultural cooperative is assumed to act as a club. It is a voluntary group of individuals who derive mutual benefit from the coordination of production decisions, shared access to inputs, enhanced market power and more effective lobbying capacity. The cooperative markets the product and distributes the revenues to members, so pooling the risks faced by individual members.

Genetic diversity is captured by the diversity of cultivars for the main type of wheat grown in Southern Italy, Durum wheate. It is modeled as an impure public good (or a club good). Greater diversity is hypothesised to benefit members through the long run average payout they receive. At the same time it also increases the coordination costs of the cooperative, and hence the cost of cooperative membership. Farmers derive benefits from sale of the output from their own holdings, y^i, and from the price impact of their cropping decisions on the diversity of cultivars in the whole cooperative. The public good, Y, is measured by a diversity index, $G(Y)$. The particular index used is discussed below. The payout to all farmers per unit of output, p , depends on both the diversity index, $G(Y)$, and the size of the cooperative, s. That is $p = p(G, s)$ with $p_G > 0, p_s > 0$. The cost of the cooperative to the ith farmer, c^i, depends on both the costs of producing $y^i$and the size of the cooperative, s. That is $c^i = c(y^i, s)$ with $c_{y^i} > 0, c_s > 0$. Production of y^idepends on the set of inputs $x_1^i...x_n^i$. The profit function for the ith farmer accordingly has the following general form:

$$\pi^i = \pi^i(x^i, y^i, G(Y), s)$$

in which y^i is the ith contribution to the public good Y, which is measured by $G(Y)$; x^i is a vector of inputs to the production of y^i, and s is the size of the cooperative. The size of the cooperative membership confers benefits in terms of market power, lobbying capacity and risk spreading, but also increases coordination, monitoring and knowledge dissemination costs.

The intraspecific diversity measure $G(Y)$ is based on both the number, and abundance of cultivars. There are various candidate indices that differ in the weight given to number and dominance. These include indices due to Shannon, Simpson, McIntosh and Berger-Parker indices (Magurran, 1988). We use the Simpson index for discrete populations:

$$G(Y) = \sum_i \left(\frac{y_i (y_i - 1)}{Y(Y-1)} \right)$$

Suppose for the moment that the individual farmer retains control over their production decisions. The problem for farmers is then to maximise expected profits over their planning horizon through choice of input combinations, output level and composition. For simplicity we present this as a static problem in which the unit of time is the decision-maker's planning horizon. We also suppress expectation operators and the random variables over which expectations are formed. For the ith farmer this decision-problem takes the general form:

$$\max_{x^i} \pi^i = p(G(Y), s) y^i\left(x^i\right) - c\left(y^i\left(x^i\right), s\right)$$

The first order necessary conditions for this problem require that

$$p + p_{y^i} y^i = c_{y^i}$$

If the output of the ith farmer has no impact on the payout to that farmer $\left(p_{y^i} = 0\right)$, then this reduces to the standard condition. The farmer will produce y^i up to the point where marginal cost equals the price of output. If output of the ith farmer improves the payoff to that farmer $\left(p_{y^i} > 0\right)$, they will increase output up to the point at which marginal cost equals the price of output plus the marginal impact of output on the price.

Now consider the problem from the perspective of the cooperative. The cooperative is assumed to have a coordinating function. It aims to maximise profits to its members by choice of y^i and s for all i That is, the cooperative's problem is:

$$\max_{y^i, s} \sum_{i=1} \pi^i = p(G(Y), s) \sum_{i=1} y^i\left(x^i\right) - \sum_{i=1} c\left(y^i\left(x^i\right), s\right)$$

The first order necessary conditions for maximisation of this function include, for each i:

$$p + p_{y^i}\left(y^i + \sum_{j \neq 1} y^j\right) = c_{y^i}$$

and

$$p_s y^i = c_s$$

That is,from the perspective of the cooperative it is optimal for the individual farmer to produce up to the point where marginal cost is equal to the price of the product plus the impact of that farmer's decision on the payoff to all members of the cooperative. It is also optimal to expand membership up to the point where the marginal cost of membership is equal to the marginal benefit measured in terms of the payoff to members.

First note that the terms $p_{y^i} \sum_{j \neq 1} y^j$ capture the benefits/costs conferred by each member on the payoff to all other members. If the cooperative has the power to coordinate production decisions, it will take these benefits into account. More particularly, if the terms $p_{y^i} \sum_{j \neq 1} y^j$ are positive, then a cooperative with the power to coordinate production will lead to higher levels of crop genetic diversity than will the independent decisions of farmers, whether operating independently or in a cooperative. If the cooperative does not have the power to coordinate decisions, these benefits will be ignored by individual farmers. In this case the independent decisions of cooperative members will still lead to higher levels of crop genetic diversity than the independent decisions of private farmers. But the level of crop genetic diversity will be lower than if the cooperative has the power to coordinate decisions. In the following sections we test this hypothesis using data from the Objective 1 regions of Southern Italy.

4 Data and methodology

Durum wheat is historically one of the most important crops produced in southern Italy. Climatic and soil conditions both favour this crop (along with olives and grapes). In 1997 some 1.242.185 hectares were planted in Durum wheat in southern Italy, with an output of 3.383.813 tons. This is some four times the land area committed to Durum wheat in the rest of Italy. Production takes place under two types of property rights: private independent farms on the one side and agricultural cooperatives on the other. Agricultural cooperatives have developed largely since 1945, and are particularly prominent in the south of the country. The majority of agricultural cooperatives, around 70%, are devoted to arable production. Cooperatives are characterised by the central coordination of production decisions, as well as the sharing of access to inputs, marketing of output.

In this paper we use a dataset from ISTAT, the Italian National Institute of Statistics. The data are drawn from periodicals Annuario dell' Agricoltura for the period 1983 - 1991. The observations are on the Southern Italian regions: Abruzzo, Molise, Campania, Puglia, Basilicata, Calabria, Sicilia and Sardegna. These regions differ somewhat in climate and topography, but the agricultural sectors, and particularly the cereals production sectors, are reasonably homogeneous. They all have Objective 1 status in the European Union - i.e. they are considered to be 'backward' and to have high development priority. This implies that the broad characteristics of the sectors are reasonably similar. Nevertheless, the regions do differ in the density of agricultural cooperatives, and this enables us to test the hypothesis described in the previous section.

The data are the following:

- the value of output of durum wheat in the eight regions of Southern Italy;
- fertilizer use per hectare, kg;
- gasoline use per hectare, kg;
- pesticide use per hectare, kg;
- machine capacity (measured in horse power);
- the agricultural labour force;
- rainfall (measured in days of rain);
- available agricultural land, ha;
- an index of the genetic diversity of cultivars;
- the density of agricultural cooperatives.

Of these the only series that requires explanation is the index of intraspecific genetic diversity. We apply a Simpson index for abundance calculated on the acreage devoted to the i^{th} cultivar, y_i, and the total acreage under Durum wheat, Y. Specifically, we use the measure

$$G(Y) = \left(\frac{y_i(y_i - 1)}{Y(Y - 1)} \right)$$

thus as $G(Y)$ increases diversity decreases.

The data set are a combination of cross sectional and time series.This suggests the appropriateness of a panel data analysis, which has the advantage of improving the reliability of the estimates, and can control for individual heterogeneity and unobservable or missing values (Baltagi,1998). Fixed and random effects eliminate problems arising from stochastic trends that are specific to a variable, but cannot eliminate those related to specific regions. In order to eliminate regional stochastic trends in the variables we take the changes in the series between adjacent observations, so we use a First Difference Estimator (See, Stern and Common 2001 for an application):

$$\Delta y_{it} = \beta \Delta x_{it} + \Delta \epsilon_{it}$$

5 The impact of genetic diversity on the value of durum wheat production

In this section we test the impact of genetic diversity, agricultural cooperatives concentrations, and a set of other inputs on the value (at constant prices) of the durum wheat production using the first difference estimator displayed earlier. Recalling the model in section 3 we estimate the value of output, $p(G(Y), s) \sum_{i=1} y^i$, as a function of the set of inputs, x^i, the diversity index, $G(Y)$, and s. Note that there is no direct measure of s. The density of cooperatives is partly a proxy for s, but it is also assumed to be directly related to $G(Y)$. By assumption $p_{y^i} \sum_{j=1} y^j > 0$ implies that cooperative density is also greater than zero. The hypothesis to be tested is that the value of output is higher because of the biodiversity effects of cooperative behaviour. The general form of the function to be estimated is:

$$p \sum_{i=1} y^i = f \left(G(Y), s, \sum_{i=1} x^i \right)$$

We assume that the specific form is Cobb-Douglas, i.e. that;

$$p \sum_{i=1} y^i = A x_1^{\alpha^1} x_2^{\alpha^2} ... x_n^{\alpha^n} G(Y)^{\alpha^{n+1}} C^{\alpha^{n+2}}$$

where the last term captures the density of cooperatives. With both sides in log form the estimated equation is

$$\ln p \sum_{i=1} y^i = \alpha^0 + \alpha^1 \ln x_1 + \alpha^2 \ln x_2 + ... + \alpha^n \ln x_n + \alpha^{n+1} \ln G(Y) + \alpha^{n+2} \ln C + \epsilon$$

A summary of the results follows:

The Estimation Results

Variables	*Coefficients*	Std *Errors*	$t-ratios$	$P-values$
Intraspecific diversity	-.1962002798	.96675106E-01	2.029	.0468
Fertilize	.1873173909	.52966878E-01	3.537	.0008
Gasoline	.2302583199E-02	.91047169E-03	2.529	.0140
Machinery HP	-.1374786228	.25582977E-01	-5.374	0
Agric Surface	1.521556281	.19767747	7.697	0
Cooperatives	2.094632031	.28589662	7.327	0
Employment	.8222436787E-02	.12230042E-02	6.723	0
Island Dummy	.3117894544	.72230504E-01	4.317	0
Constant	1.285010280	.46310082	2.775	0

$$R^2 \, 1\text{pt}{=}\, 1\text{pt}0.76$$
$$Ftest \, 1\text{pt}{=}\, 1\text{pt}24.66$$

the overall fit of the model is satisfactory the adjusted R squared being 0.73. The individual significance of the coefficient is also satisfactory implying that we can reject the null hypothesis for fertilizers, machinery, agricultural surface, cooperatives, employment at the 1% significance level. A dummy variable has been added to take account for island status (Sicilia and Sardegna). For this variable it is also possible to reject the null hypothesis at the 1% significance level. The constant is a "catch all" variable which captures the effect of whatever has been left out of the model. In a production function framework it is often interpreted as the mean effect of technology.

So far as the two key explanatory variables are concerned, intraspecific diversity and the density of cooperatives both have a positive impact on the mean value of output of Durum wheat, and this impact is significant at the 5% and 1% levels respectively. Recall that the diversity index is smaller the higher the level of intraspecific diversity, hence the negative sign of the coefficient implies that biodiversity is positively related to the value of output of Durum wheat Of the other inputs, fertilizers and the amount of available land are positively related to the value of output. The one unexpected result is the negative effect of our mechanisation variable, the horsepower of farm machinery. This is somewhat awkward but may reflect the fact that this is a relatively unmechanised area of Italian agriculture.

We then estimate a reduced form model to test the net effect of cooperatives on the intraspecific diversity of Durum wheat. To this end we run an auxiliary regression of our diversity index against other factors which may well affect it. We consider, in particular, rain days (as our proxy for rainfall) and pesticides per acre. This is because cultivar choices may well be driven by pest resistance or particular climatic sensitivities. The residuals of this auxiliary regression are then regressed against the cooperative density variable. The methodology is the same as before for homogeneity White standard errors are used to correct for heteroskedasticity.

Variables	$Coefficients$	Std $Errors$	$t-ratios$	$P-values$
Cooperatives	-.4948038680	.12842254	-3.853	0
Constant	1.431724608	.37795845	3.788	0

The R-squared is equal to .236218 and the Adjusted R-squared to .22031, and the F test[1, 48] is equal to 14.85. From the available data cooperative density is negatively correlated with the intraspecific diversity of

Durum wheat. This confirms the model prediction that where the cooperative coordinates production it leads to higher levels of intraspecific diversity.

6 Discussion

To summarise, this paper considers the effect of cooperative production on the choice of wheat cultivars in the Objective 1 regions of Southern Italy. Using a simple model of agricultural production with intraspecific biodiversity as a local public good, we consider the effect of cooperative production on intraspecific diversity and the value of output of Durum wheat. We test the hypothesis that the cooperatives in agriculture will promote crop genetic diversity, and that this in turn enhances the mean value of output over a range of environmental and market conditions.

We find that cooperative production decisions are indeed associated with higher levels of intraspecific diversity than the decisions of independent private farmers. Indeed, the relation is positive and significant at the 1 per cent level. We also find that the relation between the value of output and intraspecific crop genetic diversity is positive and significant at the .5 per cent level. This is clear and unambiguous. Where farmers surrender their right to determine the crop mix to a cooperative, the result is both higher levels of at least one measure of biodiversity, and higher mean levels of income. We have not considered the implications for the variance of income in this paper, but we conjecture that cooperative production will be associated with lower variance in farmer incomes. This finding is consistent with the evidence from low income countries that community management of biodiversity as a local public good favours conservation. Of course the measure of biodiversity is very restrictive. It considers only intraspecific crop genetic diversity, but we believe that the finding would apply to other measures of biodiversity.

Some of the policy implications of this are transparent. The conservation of intraspecific biodiversity in agroecosystems is an increasing function of cooperatives, hence policies that reduce the cost of membership of cooperatives, or the cost of coordination will both enhance the in situ conservation of cultivars. Although we have yet to explore the characteristics of cooperative members, it is clear that the density of cooperatives is highest in the poorest regions of Italy. Cooperative membership seems to be a risk management strategy whose effectiveness varies inversely with farmer income. If so, the implication is that cooperatives address two of the objectives of the common agricultural benefits (the stabilisation of agricultural incomes and the enhancement of the mean incomes of poorer farmers). What this study shows is that cooperatives achieve income gains without the negative impact on crop genetic biodiversity observed in other studies of the biodiversity effects of CAP payments (di Falco, 2002).

One final observation is that conservation of cultivars yields both direct and indirect benefits. Direct benefits include the capacity to exploit variation in environmental conditions (where this includes variation in both market conditions and in climate, the pest regime and so on). Indirect benefits include the benefits to future plant breeding activities of in situ as opposed to ex situ conservation. These benefits are not captured in the current data set, and the benefits they offer are much longer term, but they are important nevertheless.

7 References

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8 Data Appendix

codes: frt, fert, pest, gas, cv, income, rain, cer, empl, coop, index

4.770955052 3.531570774 8.981765356 95.3 6.75 151.0920763 na 0.366480439 32.98323948 1.278753601 -1.503658022

4.764527313 3.820700889 10.55761782 94.6 7.31 149.6740868 549.6 0.356028771 32.04258937 1.28780173 -0.619871871

4.79093928 3.88041983 9.997221908 100.2 7.57 150.8897115 734.8 0.355443075 30.21266141 1.26245109 -0.566383672

4.694447245 4.460481374 10.99110142 121.2 8.38 133.6624325 764.4 0.356142552 30.98440199 1.245512668 -0.54936614

4.721637522 3.38185924 12.50683829 133.2 6.403635688 142.0003505 513 0.347014173 29.14919054 1.250420002 -0.559669487

4.707110091 4.352873523 13.55226795 143.8 8.995671181 128.6112037 458 0.349100479 28.62623931 1.217483944 -0.649512128

4.581574222 4.617327959 15.4094632 151.8 11.71113461 121.6706186 713 0.45181071 35.69304612 1.230448921 -0.699429188

4.660077724 4.130086273 13.16005877 163.9 9.811971632 124.6288026 387.6 0.359151277 27.00817605 1.220108088 -0.685246573

4.686511146 5.43301662 10.00866633 152.7 10.16082416 149.9207303 503.8 0.363859469 27.21668827 1.227886705 -0.811072658

3.822168079 1.744998896 3.478796412 60.8 4.03 79.74213293 na 0.494955099 15.34360805 1.489958479 -1.121489952

4.06460772 1.739955912 3.666144729 63.4 4.22 115.609535 na 0.487122668 15.1008027 1.471291711 -0.729105328

3.962321973 1.930561704 2.852014916 65.6 4.48 105.6341015 na 0.491956759 13.77478926 1.474216264 -0.688220145

4.01046957 2.09291371 3.818972977 76.8 4.81 119.902512 na 0.49462799 13.84958371 1.463892989 -0.791311217

4.022387126 1.2269609 3.291768568 83.8 3.824063467 128.2557573 na 0.473254512 15.14414438 1.46834733 -0.781544298

3.890867939 1.854961985 3.724201832 91.4 5.396882563 122.2531711 na 0.471529248 13.6743482 1.45484486 -0.938414217

3.965342836 1.732734128 3.438162992 96.1 5.695040357 108.8019426 na 0.471566679 11.8834803 1.439332694 -0.938316843

3.975615598 1.574045378 3.772738354 103.6 6.046567421 119.8114347 na 0.477679351 12.70627074 1.418301291 -0.91523733

4.011824096 1.565576403 3.14359133 98.2 6.309470212 111.4768697 na 0.494621626 12.4150028 1.419955748 -0.916721462

4.81602244 4.05629123 13.67015699 110.9 5.33 242.725202 na 0.31152766 107.7885705 1.079181246 -1.008665805

4.809371143 4.065693907 14.87401097 105.7 5.42 208.4038503 1478 0.290791021 97.99657425 1.096910013 -0.951527817

4.779083981 4.317319611 15.46316241 123 5.71 204.6588297 1030.4 0.28348046 90.71374732 1.10720997 -0.885765213

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