Computing opportunity costs of growing local varieties for on-farm conservation: illustrations using sorghum data from Ethiopia

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Contributed paper prepared for the presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006.

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1. Introduction

The success of Ethiopian agriculture is closely related to the potential of crop varieties to perform in marginal areas and under stress conditions. The crop genetic resources (CGRs)[2] that the country is endowed with possess various useful attributes suited to low-input agriculture (Worede, 1997). They are the building blocks for sustainable agricultural development for their role not only as inputs for variety development but also as indigenous crop insurance mechanisms (Wale, 2004; Wale *et.al*, 2005). Despite having such importance, loss of genetic resources is recognized as one of the major problems in the country (FDRE, 1998).

To deal with this problem, on-farm conservation (a subset of in-situ conservation) has recently attracted considerable attention by various public stakeholders. Its capacity to conserve not only the genetic resources but also the indigenous knowledge and its dynamic features are among the desirable attributes of this strategy for this huge interest. More over, on-farm conservation offers a unique opportunity to engage local organizations for the implementation of community-based conservation strategy (Mburu and Wale, 2006). However, due to lack of working principles to implement on-farm conservation, it is not unusual to find conflicting recommendations (Wood and Lenne, 1997).

[2] CGRs in this paper refer to farmers' varieties (hereafter FVs) which have evolved on farmers' fields during the course of their farming experience.

Despite the importance farmers' contribution in maintaining agro-biodiversity for decades (Teshome *et. al*, 1999, Worede, 1997), their on-farm conservation cannot be expected to maintain all aspects of crop diversity because of the impure public goods nature of crop genetic resources (Wale, 2004). How can policy deal with this problem so that farmers can maintain the required level of crop diversity?

To deal with this problem, few years ago, Ethiopia's Institute of Biodiversity Conservation signed agreements with farmers to the effect that they would conserve specific crop varieties and the Institute would compensate[3] them for the yield loss compared with the yield from improved variety (ies) (hereafter IVs) (Demissie and Arega, 2000). Compensation was then paid based on yield differences. This approach, however, has many problems. The Institute was using an incentive scheme that depends on the yields harvested *i.e.* if a farmer gets higher yield from the varieties maintained on-farm, he/she will ultimately get lower compensation. This clearly creates a *moral hazard* problem because farmers will not have incentive to productively use the targeted varieties as good yield means less compensation. Moreover, considering only yield differences in quantity terms without considering input levels and prices will either over- or under-estimate the opportunity costs[4].

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[3]The idea of compensating farmers may be politically controversial in the policy circle. However, if the government is prepared to pay the opportunity cost of conserving crop diversity at the national level, there is no reason why targeted farmers should not be compensated for their contribution based on what they are sacrificing. Expecting farmers to maintain varieties of policy interest without compensating them the loss is forcing them to cooperate with policy without their will. This, clearly, does not work.

[4] Any loss (which can be monetary or non-monetary) faced by farmers when they change their variety choice behavior (for policy reason) is what we call the opportunity cost of changing variety use.

To handle such practical problems, this paper argues that the level of compensation should be decided *ex ante* and it should be a function of the opportunity cost. To generate information for this purpose, it has got the following objectives:

- To quantify and estimate the opportunity costs of maintaining local varieties of sorghum; and
- To understand the contextual factors affecting the magnitude of the opportunity costs in Ethiopia and derive implications for the design of on-farm conservation schemes.

2. Estimation of opportunity costs of on-farm conservation

The choice and use of any variety, be it local or modern, involves trade-offs and opportunity costs (Wale *et. al*, 2005). While choosing certain variety (ies) to meet certain objective (s), a farmer loses other important traits from the set of varieties not selected.

Considering the gross margin (hereafter GM) from the improved seeds as the next best alternative use of farmers' sorghum land and correcting for self-selection problem (Heckman, 1979), the financial opportunity cost can be computed as:

$$OPPORTUNITY\ COST = (IVGMPH - FVGMPH) \quad (1)$$

where *IVGMPH* and *FVGMPH* refer to GM per hectare (in Birr[5]) of the IVs and FVs, respectively. Computing the opportunity cost will serve as an input in the design of incentives for on-farm conservation because the bargaining power of the farm households is mainly a function of the opportunity costs they face.

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[5] Birr is the Ethiopian local currency.

The GMs of the improved and local varieties is computed as the gross revenue from the respective crops minus costs of variable inputs (seeds, fertilizer, labor used for different cultural practices – land preparation, sowing, cultivation, weeding and harvesting, bullock labor, chemicals and bird scaring).

The magnitude of the opportunity cost depends on the suitability of farmers' environment to the production and marketing of local and improved seeds. In theory, the factors determining the suitability include access variables (markets and extension); level of input use (fertilizer, chemicals and oxen); resource endowment (education, labor and cash crop farming); experience in growing improved seeds and natural factors (plot quality and rainfall). The more favorable these conditions are to the production and marketing of the improved seeds compared to local seeds, the higher the magnitude of the opportunity cost. Accordingly, inputs and local conditions affecting both varieties equally do not affect opportunity costs.

How can we use opportunity costs to design incentives for on-farm conservation? The incentives theory literature suggests that many incentive schemes are by and large based on cost data (Laffont and Tirole, 1993). To serve the purpose envisaged, the incentive scheme should be strong enough to encourage farmers to exert the effort required to attain the conservation objective. Since the opportunity cost reflects the loss farmers face, compensating farmers based on opportunity costs would mean fulfilling farmers' expectations. While estimating opportunity costs gives an indication of the magnitude of the competition, analysis on the factors affecting opportunity costs can guide the choice of farmers to be targeted and inform on the determinants of the size of the incentive.

Despite their huge role in national conservation policy making (Wale, 2004), studies on opportunity costs (to the farmers) of crop genetic resources conservation are almost non-existent. The empirical results of this paper are meant to solve the problem of information asymmetry (between farmers and policy makers) and reveal to policy makers what happens to the welfare of the farmers when on-farm conservation is in place.

3. Theoretical motivations of the econometric models

Obviously, the GM difference cannot be attributed to the use of improved seeds *per se*. There are other household and environment related factors that affect the GM outcomes from using improved or local varieties. However, these factors are not randomly distributed among users of IVs (hereafter UIVs) and users of FVs (hereafter UFVs).

Due to non-random distribution of the non-variety observable factors and unobserved variables, there is selection bias (Heckman, 1979). For the selection on the observables, better educated farmers, better quality land and better farm management practices could be skewed towards the UIVs. Regarding selection on the un-observables, the essence of the problem is that UIVs and UFVs are not the same with respect to variables relegated to the error term (Huang *et. al*, 1991).

Splitting the data-set into two, a simple Chow test was run to test whether coefficients differ across by variety use status. The test rejects the hypothesis that the two regressions are the same and this supports the use of a heterogeneous treatment effects model. For the purpose of this paper, a switching regression model, one of the heterogeneous treatment effects models which can be used to deal with the selection bias (Freeman *et.al*, 1998) is used. To estimate the average opportunity costs, different homogeneous treatment effects statistical models are used.

4. The methods of data analysis

To see the sensitivity of the estimation results to the choice of the method, the paper uses a variety of econometric methods to estimate average opportunity costs.

4.1. Matching

Matching is an evaluation method based on the intuitively appealing idea of contrasting the outcomes of UIVs (denoted y_1) with the outcomes of 'comparable' UFVs (denoted y_0) so that the differences ($\Delta = y_1 - y_0$) in outcomes between the two groups can be attributed to the use of improved seeds. In this sense, matching is selection on the observables which puts the farmers of the two groups on the same footing and aims to make them the same except by the type of variety (local versus improved) used. It is a technique that attempts to draw a similar 'partner' for each UIVs from the group of UFVs so that the gross margin difference (given in equation 1) can be attributed to the use of improved seeds. Using logit or probit models in the first step, matching uses the predicted value of the first step estimation for finding a counterpart for each farmer using improved seeds from among those farmers using local varieties (Rosenbaum and Rubin, 1983).

4.2. Instrumental variable and treatment regression models

Before running 2-stage least squares (2SLS), we have tested the endogeneity of one suspected variable: '*impexep*' (experience in growing IVs in years). It is found that endogeneity does not exist for this variable.

Unlike the instrumental variable regression which estimates linear probability model in the first stage (Baltagi, 1999), the treatment regression considers the improved variety use dummy (z_j) as dichotomous by fitting a probit equation model. The reason to use treatment regression is the belief that the random shocks which affect a farmer's GM also affect whether or not that farmer is using IVs.

4.3. The switching regression model

All the above methods assume that every farmer faces the same opportunity cost which is not necessarily the case. The more interesting question could be 'Who pays higher / lower opportunity cost?' 'Why?' or 'What factors determine the size of the opportunity cost?' Addressing these questions requires estimating the effect of using improved and local seeds on the GM of each specific farmer. Thus, the switching regression model has been used for the following compelling reason *i.e.* the use of improved seeds does not have only an intercept effect but also a slope effect. In other words, the coefficients differ according to variety use status as well (Goldfeld and Quandt, 1973; Quandt, 1988). This model allows full set of interactions between variety use status and the x's.

Let us consider the usual linear regression problem:

$$y_i = x_i \beta_i + e_i \tag{2}$$

Taking this basic equation, we can split it into two regimes and the GMs generated by the two regimes can be given as (Maddala, 1983):

$$y_{1i} = \sum_{j=1}^{k} \beta_{1j} X_{ji} + u_{1i} \quad \text{(Regime 1 which holds if } C = 1\text{)} \tag{3}$$

$$y_{0i} = \sum_{j=1}^{k} \beta_{0j} X_{ji} + u_{0i} \quad \text{(Regime 0 which holds if } C = 0\text{)} \tag{4}$$

$$C^* = \gamma_j Z_{ji} + u_i \tag{5}$$

where the errors, u_{1i} and u_{0i}, are assumed to be distributed normally and independently, with mean zero and constant variance, σ^2. The g_j's are unknown coefficients to be estimated and Z_{ji}'s determine in which regime the i^{th} observation is generated. The X_{ji}'s refer to factors described in Table 1. C is the function that determines the regime. The size and sign of the GM difference in the two regimes ($\hat{y}_{1i}$ - $\hat{y}_{0i}$) is the indicator for the magnitude of the opportunity cost.

5. Data generation and description

5.1. The data generation process

To generate the data, the study has adopted a multi-stage stratified sampling technique. Three agro-ecologically contrasting and neighboring zones in Eastern Ethiopia (East Hararghe, West Hararghe and Dire Dawa) were considered. From each zone, the Districts were ranked based on the relative importance of sorghum and three Districts were considered in each Zone. From each District, 2-3 peasant associations (PAs) were selected based on their agro-ecological representative-ness and importance of the crop. A total of 198 farmers were randomly sampled of whom the heads of 185 of them were male. The survey was undertaken from July 2001 to April 2002 using a structured questionnaire.

To study the effect of prices on the opportunity cost, input and output price indices are computed. Output price index is computed as the ratio of the price of output that the i^{th} household faces to the overall average price. To construct the input price index, for n inputs used in producing sorghum, the *weighted input price index* is computed in two steps. First the individual input price indices (γ_{ij}) are computed for each household using the same procedure as the output price case. Following that, the ratios of the i^{th} input cost to total cost (h_{ij}) are computed for each household to be used as weights in the computation. For each household, the ratio tells the contribution of the i^{th} input in the total cost structure of the household to produce sorghum. Thus, the input price indices (k_{ij}) will be: $k_{ij} = \sum_{i=1}^{n} y_{ij} h_{ij}$ where j indexes inputs and i indexes households.

5.2. Data description

Table 1 reports descriptive statistics for the variables used later in the regression.

HERE TABLE 1

The variables which significantly distinguish UIVs from UFVs are number of visits by the extension agent, package participation, experience in growing IVs, fertilizer use, plot quality, and gross margin per hectare.

6. Results and discussion

6.1. Magnitude of opportunity costs computed

Table 2 shows the average opportunity costs generated from different homogeneous treatment statistical procedures discussed in Sections 4.1 and 4.2.

HERE TABLE 2

Depending on the method of analysis used, average opportunity cost ranges from 168 to 659 Birr/Ha. From these results and assuming 100 landraces for each crop with three replications of 1 hectare each, compensation cost for on-farm conservation of traditional sorghum varieties ranges from 50,460 Birr (≈ €5,046[6]) to 197,760 Birr (≈ €19,776). In

[6] During the time of data collection (2002), 1Euro (€) was about 10 Birr.

other words, maintaining one landrace of sorghum would cost about 504 Birr (≈ € 51) to 1,978 Birr (≈ € about 198) annually. This kind of information on costs of conservation has far reaching role to get idea on the financial requirement, generate the deficit from international sources, optimize costs, allocate resources among alternative conservation methods, allocate resources among the various genetic resources, set conservation priority, and set fees for users of genetic resources.

The above cost estimation is very small compared to the annual sorghum production of over 12 million quintals per annum (NSIA, 2001). If their plots have to be used for on-farm conservation purpose, the amount of compensation that sorghum farmers can expect is 803.76 Birr /Ha (the average GM per hectare earned from the improved seeds).

6.2. Factors influencing magnitude of opportunity costs

In general, the mean GM/Ha of UIVs is greater than the mean GM/Ha of UFVs. However, computing the opportunity costs for each household using the procedures above reveals that there are UFVs who have earned a GM greater than the average of the UIVs and the opportunity costs vary across farmers. Table 3 reports full information maximum likelihood (FIML) estimates of a switching regression model run to explain this variation.

HERE TABLE 3

According to the results above, opportunity costs increase with access to market and extension, number of visits by the extension agent, participation in the extension package, fertilizer use, and experience in growing improved seeds. On the contrary, opportunity costs decrease with rainfall distribution, land quality, education level of the household head, input price, oxen ownership, sorghum price, and cash crop farming (cht'at – *Catha Edulis*)[7]. Cash crop farming reduces the opportunity cost because farmers growing cht'at are typically better-off and sorghum is relatively less important to them.

The effect of plot quality on the opportunity cost is negative implying that better quality plots can reduce the GM difference and make the local seeds more advantageous. Unlike frequent claims, the local seeds are more advantageous with better quality plots than the improved ones implying that the local seeds have even a better comparative advantage with good quality plots. The negative impact of input prices on GM is more pronounced for farmers growing improved seeds reflecting the capital intensity of their production.

7. Conclusions and policy implications

The motivation for calculating and analyzing opportunity costs is that farmers' bargaining power and the level of compensation for contextual on-farm conservation schemes is a function of opportunity costs. To this end, the government can design conservation schemes in such a way that identified farmers maintain local varieties and the government compensates their opportunity costs.

Having estimated the opportunity costs, the paper has shown that household level on-farm compensation costs can be used to estimate national level on-farm conservation costs. The comparison of the costs with the importance of the crop, the use value of CGRs to breeding (crop productivity improvement and pharmaceutical industries), and their contribution to yield stability and crop insurance justify the compensation costs.

[7] This is an important stimulant cash crop in the study area. Consumers chew the leaves.

The regression results have shown that access to market and extension, marketing surplus, participation in the extension package, farmers' experience with the package, fertilizer use, and experience in growing improved seeds are the most important factors increasing opportunity costs. On the contrary, land quality, input prices, education level of the household head, rainfall suitability, output prices, and oxen ownership decrease opportunity costs.

The results suggest that farm households found in localities where factors increasing opportunity costs prevail will have to get better compensation. Moreover, compensations should, in principle, be flexible depending on the variability of opportunity costs temporally and spatially. Differentiated compensation is cost-effective and in line with farmers' expectations.

Since the opportunity costs are functions of agricultural development, as agriculture becomes more productive and commercialized, the level of compensation will increase. Cash crops and high value crops call for higher compensation. Accordingly, in a farming system where high value cash crops (like cht'at) prevail, it will be more expensive to maintain local varieties of food crops like sorghum.

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Table 1: Descriptive statistics of the variables used in the regression

Variable	*Description*	*Mean (SD) – users of both*	*Mean (SD) – UFVs*	*Expected effect on opportunity costs*
GMM	GM per hectare (Birr) - Dependent variable	427.58 (943.2)	-65.8 (533.3)	NI
Visits	Number of visits by the extension agent during the last cropping season	2.98 (3.1)	1.27 (2.8)	+
Access2	The average time required to reach (on foot) the extension agent, dry weather road, and local market (Minutes)	49.47 (28.7)	51.1 (27.9)	-
Package (dummy)	1 if the household is taking part in the package during the survey year	0.62 (0.5)	0.26 (0.4)	+

	and 0 other wise			
Impexep	Experience in growing IVs (years)	3.5 (2.1)	1.27 (1.5)	+
Educate1	Education level of the HH head	1.27 (2.2)	1.48 (1.9)	+
Chat1	0 – no cht'at at all; 1 – only for own consumption; 2 – also for village sales; 3 – also for sales in the cities	1.33 (1.2)	1.26 (1.1)	+
Allfert	Fertilizer used per hectare (kg)	161.68 (515.2)	86.4 (178.8)	+
Rainfall	Rainfall distribution (3 – bad, 2- medium, 1-good) during the survey year	2.21 (0.7)	2.30 (0.6)	+
Oxen	Number of oxen owned by the household during the survey year	0.86 (0.9)	0.69 (0.8)	+
Inputindex	Input price index	0.99 (0.2)	1.01 (0.3)	?
Allquality1	Plot quality index (3 – good, 2- medium, 1-bad)	1.22 (0.8)	0.86 (0.7)	?
Sorgindx	Sorghum price index	1.03 (0.4)	0.97 (0.3)	+

Source: 2001/2002 own survey

Notes: For users of both varieties, the GM is referring to UIVs. NI = not important.

Table 2: Average opportunity costs of growing indigenous varieties of sorghum

Method	***Opportunity costs in Birr /Ha***
Simple OLS[a]	168.2
Matching	433.8
IV regression	537.7
Treatment regression	659.2

Source: See table 1.

[a]In this case, variety use is considered as an exogenous variable.

Table 3: FIML estimates of a switching regression model

Variable	*Coefficient*	*Variable*	*Coefficient*
Regime 1 – Users of IVs		Regime 0 – Users of FVs	
Constant	696.7 (1.7)	Constant	1412.6 (3.0)
ACCESS2	-6.4** (-2.3)	ACCESS2	-1.1 (-0.34)
CHAT1	72.9 (1.1)	CHAT1	94.3 (1.4)
RAINFALL	-189.6* (-1.8)	RAINFALL	-266.6*** (-2.7)
EDUCATE1	9.4 (0.25)	EDUCATE1	18.1 (0.51)
ALLQUALI	-91.1 (-0.88)	ALLQUALI	-351.3*** (-3.4)
INPUTIND	-919.5*** (-3.0)	INPUTIND	-684.3* (-1.9)
ALLFERT	0.24 (0.93)	ALLFERT	-0.23 (-0.74)
VISITS	51.0** (2.3)		
IMPEXEP	266.5*** (7.3)		
PACKAGE	342.2** (2.1)		
OXEN	79.4 (1.0)	OXEN	195.3** (2.3)
SORGINDX	598.4*** (3.2)	SORGINDX	644.8*** (3.1)
Sigma(1)	603.3 (13.0)	Sigma(0)	678.7 (10.9)
Dependent variable	GMM	Number of observations	175
Log likelihood function	-1440.82		

Source: See Table 1

Notes: ***, **, and * refer to significance at 1%, 5%, and 10%, respectively. Values in parentheses are the ratio of the coefficient to the estimated asymptotic standard error.