Biodiversity Conservation under an Imperfect Seed System: the Role of Community Seed Banking Scheme

Mintewab Bezabih[¥]
Environmental Economics Unit
Department of Economics
Göteborg University
October 2005
Mintewab.bezabih@economics.gu.se

Abstract

The study is an empirical investigation of agrobiodiversity conservation decisions of small farmers in the central highlands of Ethiopia. The primary objective is to measure the effectiveness of Community Seed Banking (CSB) in enhancing diversity while providing productivity incentives. The analytical framework draws from the synergetic nature of the possible improvment of the working of the seed system and enhanced diversity. We employ Amemiya's GLS estimator to investigate simultaneity between participation and the level of diversity. Our results indicate a significant impact of participation in CSB on farm-level agrobiodiversity. However, farmer knowledge and experience associated with biodiversity conservation were not found to have the expected reinforcing impact on the degree of biodiversity. CSB participation also led to a moderate productivity increase consistent with the need for such incentives to enhance diversity at a farm level. Our assessment of the performance of the GLS estimator yielded a significant discrepancy between the GLS and bootstrap estimates. This led to the conclusion that bootstrapping asymptotic estimations might be required for appropriate inference even when sample sizes are reasonably large.

JEL classification: C35, Q12, Q29

Key words: Agrobiodiversity; Seed system; Amemiya's GLS; Bootstrapping

[¥] The author gratefully acknowledges comments from Fredrik Carlsson, Gunnar Köhlin, participants at the Workshop for Sustainable Natural Resource Management, Hangzhou, China, participants at the 3rd International Conference on the Ethiopian Economy, Addis Ababa, Ethiopia, participants at the 99th seminar of the European Association of Agricultural Economists, Copenhagen, Denmark, and financial support from Sida.

1. Introduction

The provision of public goods is commonly financed by direct taxation or subsidies to private expenditure or action (Roberts, 1987). However, in poor developing countries, imposing taxes on individual households based on the 'polluter pay principle' may be questionable as it would enhance poverty (Holden et al., 2003). On the other hand, state subsidy is, in many cases, justified for a very narrow range of public goods due to priority reasons.

In cases where the goods do not fall into this range, one way of ensuring their provision is through exploiting possible synergies between private incentives and public good generation. Lamb (2002), for instance, suggests that orienting individual country development assistance towards the creation of global public goods could enable a developing country to contribute to the provision of such goods. In their village CGE analysis of policy options for better land management, Holden et al. (2003) found that ploughing back agricultural output tax into fertilizer subsidy would lead to internalizing the intertemporal externality from land degradation with minimal negative impacts on productivity.

In line with this, the study focuses on agrobiodiversity[1] as a quasi-public good and assesses possible synergies between improvement in the working of the local seed system, and its conservation. Since the provision of agrobiodiversity is largely *in-situ*[2], the level of conservation is highly dependent on individual farmers' decisions. Under the condition where the working of the existing seed system is imperfect, easy-access seed source will provide incentives for adoption of seeds from the particular source. If farmers' decisions are such that the seeds adopted do not displace the existing seeds, farm-level of diversity will be enhanced.

The aim of the paper is to assess the potential of a scheme called Community Seed Banking (CSB) which intends to correct imperfections in the local seed system by easy access to local seeds, and to enhance farm level agrobiodiversity (Lewis and Mulvany ,1997;Demissie and Tanto, 2000). The efficacy of CSB is based on two premises. One is that the CSB seed system expands the availability of local varieties to individual farmers, and therefore increases diversity. The other premise is that given imperfections in the already existing seed system, the provision of seed varieties would ease constraints to seed access. In turn, this would lead to improved resource allocation and increased productivity.[3] Based on this, we set out to investigate the role of CSB in enhancing agrobiodiversity and in increasing farm-level productivity. We hypothesize that CSB participation will have a positive impact on biodiversity. Also, its impact on productivity will be positive.

---

[1] The component of biodiversity that contributes to food and agriculture production. It encompasses within-species, species and ecosystem diversity (European Environmental Agency, 2005).

[2] In situ conservation is the conservation of ecosystems and natural habitats and the maintenance and recovery of viable population and species in their natural surrounding and in the case of domesticated or cultivated species in their surroundings where they have developed their distinctive properties (Article2, Convention on Biodiversity, 1994).

[3] It should be noted that for the increase in productivity to be realised, the varieties need not be inherently more productive than the other available varieties; the productivity increase comes about because of improvement in access to seeds and the resulting improvement in the allocation of resources. Moreover, households may adopt local varieties to reduce the risk of crop failure. Since we do not control for this effect the overall observed productivity effect may be understated.

Previous studies analyzing participation in agri-environmental schemes looked into farmer (e.g. Wilson, 1997) and scheme factors (e.g. Vanslembrouk et al., 2002) as important determinants of the decision to participate and of the degree of participation. In addition, other aspects not captured by 'farmer' and 'scheme' factors, at least not directly, are also indicated to be important in explaining participation in such programmes. Wossink and van Wenum (2003) found that perception of environmental risks is an important additional reason to participate in agri-environmental schemes. In his analysis of the determinants of participation in unsprayed crop edges program in the Netherlands, Van der Muleun (2001) found that perceptions regarding the environment significantly differ between participants and non-participants.

Since knowledge and experience in managing biodiversity are directly related with the level of diversity, participation in the CSB and the level of biodiversity are endogenous to the diversifying and participation decisions respectively. Endogenous variables in the respective equations imply simultaneity. Thus, assessment of the impact of Community Seed Banking on agrobiodiversity requires a simultaneous estimation of an equation system with participation and biodiversity measures as endogenous variables. Single equation estimation of such relationships causes bias and inconsistency (Greene, 2000), but appropriate instrumental variable estimators are generally asymptotically valid. We employ Amemiya's GLS estimator, which is believed to be efficient(Lee, 1981) among the class of asymptotic simultaneous equation estimators.

While asymptotic estimators[4] are widely applicable, they generally suffer from the problem of accuracy. As Horowitz (1997) argues, standard errors computed from asymptotically valid covariance matrices could seriously understate true estimator variability in finite samples possibly leading to type I errors in inference.

In line with this, a number of studies have applied bootstrapping[5] to improve the performance of asymptotic estimators. However, the use of bootstrapping has been far from consistent and has largely been biased towards small samples. Indeed, previous studies (applied to small samples) assessing the performance of asymptotic estimators vis-à-vis the bootstrap have confirmed that bootstrap improves the accuracy of asymptotic estimates (e.g. Freedman and Peters, 1984; Dies and Hill, 1998). With relatively larger sample sizes, however, bootstrapping is less commonly applied to improve the performance of asymptotic estimators. While this might be attributed to the perception that with larger sample sizes the true characteristics of the test statistics are better observed, we are not aware of any studies confirming that this is necessarily the case. Thus, to assess the performance of bootstrapping vis-à-vis asymptotic estimators in such a context, we employ a sample of 381 observations, which is reasonably large compared to previously tested samples.

The rest of the paper is organized as follows. In Section 2, we present the mechanisms by which CSB would work to enhance diversity and increase productivity. Section 3

[4] Asymptotic estimators are estimators with known properties that apply to large samples and whose finite sample behavior is approximated by what is known about their large sample properties (Greene, 2000).
[5] The bootstrap method is a resampling method whereby information in the sample data is 'recycled' for estimating various properties of statistics through drawing random samples from the original sample (Jeong and Maddala, 1993). Sample sizes used in previous studies, which assessed the performance of asymptotic estimators using bootstrapping, ranged between 30(Freedman and Peters, 1984) and 128(Dies and Hill, 1998).

follows with a description of the setting and sampling procedure. Section 4 presents the econometric model and estimation techniques. The results and discussion are presented in section 5. Section 6 concludes the paper.

2. CSB, Seed System Imperfection and Agrobiodiversity

In poor, smallholder agriculture, the seed system is comprised of two sources. The primary seed source is what farmers save from previous harvests, usually local varieties. Another component of the seed system is the modern component, associated with the provision of improved varieties. Traditional seed sources are characterized by costly storage (Lewis and Mulvany, 1997). Their reliability as sources also depends on the ability to save from previous harvests. The modern component of the seed system is also characterized by positive transaction costs to access, indicated by factors like costly supplementary inputs, costly experimentation, seasonal liquidity and family labour constraints (Moser and Barrett, 2003). Positive transaction costs in the already existing seed system (at least for some) constitute an imperfect seed system, which leaves room for improvement in terms of provision of a relatively easily accessible source.

CSB is a scheme which aims at improving the working of the existing seed system by availing easy-access seeds. The scheme involves identification, collection, multiplication, storage and distribution of local seeds. Farmer groups engage in the task of identifying local varieties that are desired by farmers. The selection criteria is based on the local availability and distribution of the identified variety, availability of the variety in other localities or in the central Gene Bank and assessment of the individual farmer's demand for it. Varieties from the gene bank are multiplied on rented farmer plots and stored in the CSB storehouse. Participants can borrow local seeds of available types and amounts. Participants are also entitled to interest on deposited seeds (Demissie and Tanto, 2000).

In our study, the main source of CSB varieties is the central gene bank of the Institute of Biodiversity Conservation and Research. Another source of CSB seeds is the required 10 kg deposit by CSB participants. The varieties from CSB will be of such a nature that they are either currently planted by some farmers but others do not have access to them or they are varieties that are not currently planted by farmers in the locality but are either available in other localities or in the central gene bank (Lewis and Mulvany, 1997).

By increasing the availability of local seeds to farmers, CSB facilitates easier seed flow among farmers, thereby widening their varietal choice. It also expands the variety basket available at the village level since CSB varieties could originate from other localities or the central Gene Bank storage. In addition, CSB provides farmers with modern storages which give the seeds longer shelf-life and better protection against pests and diseases.

Thus, provision of CSB seeds would increase productivity given the imperfections in the already existing seed system. In line with this we hypothesize CSB to be a seed source which improves the already existing seed system, thereby enhancing productivity.

On the other hand, households with higher demands for local varieties would tend to diversify more. Within-farm heterogeneity with respect to physical farm characteristics is one reason. Given appropriate combinations, planting a diverse set of varieties would lead to higher overall productivity. Particularly, local varieties do well on marginal fields. In line with this, Meng et al. (1998) found that households managing farms with diverse characteristics tend to grow more landrace varieties.

Another reason for the association between local varieties and diversity could be the transaction costs of accessing varieties with particular qualities. Smale et al. (1994) noted that Malawian maize farmers tend to grow local varieties for quality reasons (since the local maize varieties have superior consumption qualities) and especially because it is not certain that the particular local varieties will be available in the market. Thus, households who face higher transaction costs of accessing wider range of varieties from the market tend to diversify production. This is in line with Meng and Taylor's (1998) observation that quality issues become relatively unimportant for households that have given up traditional varieties, while high transaction costs of obtaining desired qualities in a particular variety contribute to the continued cultivation of landrace varieties.

Thus, increased biodiversity would come out as a positive externality[6] from individuals taking advantage of improved seed access. As a result, CSB which provides local seeds would increase individual level diversity.

3. Setting, sampling procedure and data used

The study was conducted in an area within the broad agroecological zonation of Ethiopia known as the Central Highlands. The study site is Chefedonsa, a *woreda*[7] with 30 *kebeles*, located in the Eastern Oromiya Zone of the Oromiya National Regional State. The site is a center of origin and diversity for many wheat and pulse varieties. Therefore, one of the eleven community seed banks across the country is located in the woreda. Agroecologically, the study area has a good agricultural potential and is located on a plateau as high as 2800m above sea level, which makes it frost prone. Main produces include durum and bread wheat, *teff*[8] and pulses.

The CSB is located in the southeast corner of the woreda. The scheme targets twelve of the thirty kebeles of which six were effectively reached, as reported by the staff managing the bank. Out of the six kebeles, a random sample of 381 households was interviewed and about a quarter happened to currently be borrowing seeds from the community seed bank i.e. they are CSB members.

The dependent variables in our analysis are participation in the CSB, diversity in crop choice and the level of productivity. Participation is a dichotomously observed variable representing whether or not the respondent household has borrowed seeds from the Community Seed Bank in the current production year. Diversity is measured by the Shannon's index[9] measured as $D = -\sum \alpha_i \ln \alpha_i$, where α_i is the area share occupied by the i^{th} crop variety in a household. Although we consider all the crops and their varieties

---

[6] Farm households might adopt the CSB varieties for reasons of yield stability. Our data did not allow us to explore whether such a possibility exists.

[7] Woreda corresponds to a district while kebele corresponds to a village.

[8] *Teff* is a cereal with tiny grains and is used for making *Injera*, a staple for Ethiopians.

[9] Since diversity has many dimensions, a number of measures have been used to represent it. In this study, we started by using two measures: the count (representing richness) and Shannon's indices (representing richness and relative abundance). However, since the results were similar, we opted to report the results based on the Shannon's index.

in our diversity and participation equations, we base our productivity analysis on both total yield and on wheat yield values. This is because we only have information on seed sources for wheat varieties.

Wheat is the most widely grown crop covering (51%) of the total number of plots. Teff is the next most widely grown crop followed by pulses and other cereals, which represent smaller proportion of the total number of plots compared to the two crops. An average of 4.6 varieties are grown per household, the most diverse household growing ten varieties and the least diverse just one.

Socio-economic and physical farm characteristics are among the variables that are included in the participation, diversity and productivity equations. Specifically, we consider age, gender of the household head, and whether the household head has attended any religious or formal education as important measures of demographic characteristics in the participation equation. We also include livestock ownership, converted into the number of tropical livestock units, as a proxy for wealth. Radio ownership and whether the head received any raining during the year, are included as measures of access to information.

Location of the CSB, measured by distance from homestead to town, is included in the participation equation as a feature of the CSB while access to improved seed and fertilizer as well as other sources of seed are included as seed system characteristics.

The diversity equation also includes kebele dummies, intended to primarily capture factors that systematically differ across kebeles and that are left uncaptured by any of the variables used at the household level. One set of such factors concerns agro ecological conditions which include general soil fertility conditions, precipitation, temperature, elevation, disease, pest/ frost incidence and the like. Market access and transaction cost comprise another set of factors that could systematically vary across villages (kebeles).

In the productivity equation we have the different sources of seeds as explanatory variables. In addition, we include age, gender of the household head, wealth and oxen ownership as socioeconomic characteristics. The categories of physical farm and agroecological variables included in the diversity equation are included in the productivity equation.

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

Variables	Description	Mean	Standard deviation
SOCIOECONOMIC	**VARIABLES**		
TRAINING	Head with any training (1=yes; 0=otherwise)	.234	.424
WEALTH	Livestock holdings (in tropical livestock unit)	6.748	3.417
OXEN	Number of oxen	2.495	1.478
AGE	Age of the household head	45.45	12.015
FEMALE	Sex of household head (1=female; 0=male)	0.029	0.167
RADIO	Radio ownership (1=yes; 0=otherwise)	0.567	0.186
FORMAL EDUCATION	Head's formal education (1=yes; 0=otherwise)	0.076	0.265
RELIGIOUS EDUCATION	Head's religious education (1=yes; 0=otherwise)	0.389	0.488
SCHEME	**VARIABLE**		
LOCATION OF CSB	Location of the Bank (measured in terms of Distance to from homestead to the Bank (minutes)	73.744	36.920
PHYSICAL FARM	**VARIBLES**	2.115	2.316
FARM SIZE	Farm size (ha)	0.761	0.326
FLAT LAND	Proportion of flat land in the total farm area	0.117	0.216
MEDIUM SLOPE	Proportion of hilly land in the total farm area	0.119	0.251
STEEP SLOPE	Proportion of gorgy land in the total farm area	0.537	0.351
FERTILE	Proportion of land with good fertility	0.217	0.306
MODERATELY FERTILE	Proportion of land with moderate fertility	0.243	0.298
INFERTILE	Proportion of infertile land		
AGROECOLOGICAL	**VARIABLES**	0.297	0.457
GORO	Kebele dummy (1=Goro)	0.241	0.428
ADDADI GOLE	Kebele dummy (1=Addadi Gole)	0.122	0.327
BUAE TENGEGO	Kebele dummy (1=Buae Tengego)	0.082	0.275
KERSA	Kebele dummy (1=Kersa)	0.161	0.368
MENJIKSO	Kebele dummy (1=Menjikso)	0.090	0.287
KOREMTA	Kebele dummy (1=Koremta)		
SEED SYSTEM	**VARIABLES**	26.82	84.126
IMPROVED SEED	Amount of improved seeds borrowed in year 2003 (kg)	234	453
FERTILIZER	Amount of modern fertilizer borrowed in year 2003 (kg)	1.339	0.543
SEED SOURCE	Number of sources a household has secured seeds from (both traditional and modern)	.216	0.388
OWN SEED	Proportion seeds from own storage in the total farm	.072	0.196
CSB SEED	Proportion seeds from CSB in the total farm	.040	0.179
BORROWED SEED	Proportion seeds borrowed from fellow farmers	0.016	0.111
EXCHANGED SEED	proportion seeds exchanged with fellow farmers	0.217	0.359
EXTENSION SEED	Proportion seeds from the extension system	0.437	0.422
MARKET SEED	Proportion seeds from the market		
DEPENDENT	**VARIABLES**	0.271	0.445
PARTICIPATION	Participation in CSB (1=yes;0=otherwise)	1.251	0.464
SHANON	Richness measured in terms of Shannon's index	8574	6643
YIELDV	Value of total yield per ha (Br[10]/ ha)		

[10] 1 US dollar is about 8.76 Ethiopian Birr (Br.)

4. The Econometric Framework and Estimation Procedure

Our analysis of the impact of CSB participation on the level of diversity maintained by households is based on a simultaneous estimation of participation and diversity equations. For the i^{th} individual, the participation equation is thus given by:

$$P_i = \begin{cases} 1 \; if \;\; \beta^P X_i + \gamma^P D_i + u_i > 0, \\ 0 \quad otherwise \end{cases} \qquad (1)$$

Where P_i is an indicator variable equal to 1 if the respondent participates in the CSB, X_i is a vector of socio-economics and physical farm characteristics, D_i is the level of crop diversity and u_i is an error term. The level of diversity maintained by the household is, in turn, given by:

$$D_i = \beta^D X_i + \gamma^D P_i + \eta_i \qquad (2)$$

where η_i is an error term. We assume that the errors in the two equations are independently, identically and normally distributed error terms with zero means.

In an imperfect seed system, productivity will not only be a function of farm and socio-economic characteristics, but also which source(s) the household accesses seeds from. The impact of different seed sources on value of total yield per ha is explored using the following relationship (equation (3)):

$$Y_i = \beta^Y X_i + \lambda P_i + \psi S_i > 0, \qquad (3)$$

where Y_i is total yield and S_i stands for the different seed sources

Equation (3) is estimated using OLS[11]. However, because the endogenous variables appear as regressors in equations (1) and (2), the two equations could be considered as a mixed simultaneous system of equations, which contains continuous and discrete endogenous dependent variables. An equation-by-equation estimation approach to a system of equations involving endogenous variables results in biased and inconsistent estimates of the parameters of endogenous terms. Inconsistency arises from correlation of the endogenous variables with the disturbances (Greene, 2000). Heckman (1978) suggested a two-stage estimation procedure where the structural parameters are consistently estimated in two stages. An alternative estimator was suggested by Amemiya (1978). Unlike Heckman's estimator, which uses the reduced form parameters indirectly to get the structural estimates, Amemiya's procedure enables recovering the structural parameter estimates from the reduced form parameters in a direct way. This estimator, although computationally involving, is shown by Lee (1981) to be the most efficient of

[11] It should be noted that there are no reasons to believe a priori that productivity affects participation in CSB or diversity directly. Thus, the productivity equation which assesses the productivity impact of CSB participation is not part of the simultaneity.

the class of mixed simultaneous equation estimators (Zepeda, 1994). The procedure involves four stages where in the first stage the reduced form parameters are estimated using OLS and maximum likelihood. The second stage recovers the starting value structural parameter estimates. The third stage obtains the asymptotic covariance matrix from estimates in the first and second stages. The Generalized Probit GLS estimates are obtained in the last stage using the starting value structural parameters and the variance covariance matrices. Details on the GPGLS estimation are found in Amemiya (1978), Zepeda (1994) and Dies and Hill (1998).

We follow the procedure used in Dies and Hill (1998) to evaluate the performance of the GLS estimator. The first procedure involves bootstrapping the original sample from which the bootstrap coefficient estimates, bootstrap t-values and empirical distribution of the t-values are obtained. The latter are used for computing the t-critical values against which Amemiya's GLS estimates are evaluated. Using bootstrap critical values instead of boostrap standard errors is in line with Horowitz's (1997) argument that although the bootstrap technique has traditionally been used to obtain the standard errors of estimation, it is preferable to use the bootstrap to obtain critical values for the t-statistics that are used as a basis for hypothesis testing. The reason is that the bootstrap standard errors converge to the true standard errors as the sample size gets larger, but the bootstrapped critical values do so at an even faster rate.

In the second procedure, each of the bootstrap samples are bootstrapped to obtain the empirical distribution of the t-values corresponding to the bootstrap estimates. The t-critical values corresponding to the bootstrap coefficients are computed as the t-values at the 90^{th} percentile of the distribution.

5. Results

In table 2, we present the results of the first structural equation in which the left hand side variable is participation in the CSB. The first part of the table shows the results from Amemiya's GLS estimator and in the second, the results based on the 100[12] bootstrap samples are reported. Comparison of the bootstrap and GPGLS results is given in the third part of the table.

In the GLS results based on the standard critical values, wealth and gender of the household head turn out to be significant socioeconomic determinants of participation. The only scheme feature in our study, location of the CSB, also has a significantly negative impact on the likelihood of participation The amount of improved seeds purchased on credit and total fertilizer used[13] have a significantly negative impact on participation. The impact of diversity, representing knowledge and experience, is also positive and significant.

However, most coefficients become insignificant once the bootstrap critical value is used as a benchmark. The amount of improved seeds comes out as the only significant variable across estimations and across critical values. This indicates substitutability between CSB varieties and those from the commercial seed system. Due to its perceived productivity advantages, there is and there will continue to be a push for increased adoption of the modern input package from the government's side. Given the negative

---

[13] In the current agricultural extension system, credit for fertilizer and improved seeds come as a package.

relationship, the continued push for adoption of improved varieties would lead to improvement in access to commercial seeds. In turn, this would lead to reduction in participation in the CSB.

A comparison of the asymptotic and bootstrapping results is presented in the last part of table 2. The comparison is made using percentage differences in each of the statistics where percentage differences are calculated as the ratio of (bootstrap) statistics - (asymptotic) statistics to the absolute value of the asymptotic statistic (Dies and Hill, 1998). Generally the percentage changes in the coefficient estimates are relatively smaller than the percentage changes in the t-statistics. Since the t-statistics is calculated as the ratio of the coefficient estimates to the respective standard deviations, smaller coefficient biases imply larger biases in the standard errors. Furthermore, the upward biases we observe in the t-statistics confirm deflated standard errors. Thus, even in our reasonably large sample, the tendency that asymptotic estimators inflate standard errors remains valid. The 'bias t-statistics' is calculated as the ratio of coefficient (asymptotic)- coefficient (bootstrap) to standard error (bootstrap)/ 10, and measures the statistical significance of an estimated coefficient's bias.

A further look into the biases in the coefficient estimates shows that all the asymptotic coefficient estimates except the coefficients for sex, radio and slope dummies suffered statistically significant biases. In addition to biases in magnitude, the coefficients for age, slope, plot fertility and the constant assumed inconsistent signs across estimates. Thus, the concern over the validity of asymptotic estimates in finite samples should not only spring from the tendency to deflate standard errors and commit type I error over inference, but also the tendency of asymptotic estimates to bias coefficient estimates.

Table 2: Comparison of simultaneous equations with and without bootstrap of the participation function

Variable	Amemiya's GLS simultaneous equation estimation			Bootstrapping Amemiya's GLS estimator			Comparison of Amemiya's and Bootstrap estimates		
	AGLS	T-STAT	t- crit[14] (α=0.10)	BGLS	BT-STAT	Bt- crit[15] (α=0.10)	%Δ in BETA	%Δ in T	BIAS-T
Training	0.144	0.267	1.857	0.466	0.784	2.700	4.482	3.112	-8.984 [ab]
Wealth	-0.263[a]	2.697	4.207	-0.173	1.143	5.269	0.792	-1.066	-6.837 [ab]
Age	-0.0004	0.019	3.244	0.013	0.533	2.767	125.072	45.599	-8.694 [ab]
Female	-2.860 [a]	2.376	5.674	-3.298	1.024	4.653	0.182	-1.157	-0.831
Radio	0.747[b]	1.595	1.287	0.751	1.431	3.698	0.076	0.149	-1.297
Formal education	-0.161	0.202	1.728	-0.002	0.002	2.729	-3.379	-4.083	4.799 [ab]
Religious education	-0.020	0.041	1.507	-0.136	0.267	2.375	-13.431	-15.101	5.362 [ab]
Location of CSB	-0.165 [a]	1.860	2.092	-0.138	1.154	4.412	0.651	-1.163	-5.641 [ab]
Improved seed	-0.019 [ab]	2.828	3.327	-0.019 [ab]	2.192	1.611	0.626	-1.139	-6.619 [ab]
Farm size	0.006 [a]	1.766	2.874	0.002	0.342	2.685	-0.853	-0.947	5.412 [ab]
Medium slope	-0.047	0.061	21.472	-0.052	0.069	2.525	-3.380	-1.258	0.124
Steep slope	-0.607	0.935	4.815	-0.334	0.414	2.417	-1.039	-1.440	2.100 [a]
Moderately fertile	-0.662	0.911	4.976	-1.158	1.236	3.427	-1.956	-1.663	4.001 [ab]
Infertile	0.202	0.375	1.469	0.406	0.685	3.045	0.117	-0.146	-0.335
Fertilizer	-6.614 [a]	2.736	7.657	-4.376	0.987	2.918	0.579	-1.091	-3.441 [ab]
Seed source	-0.004 [a]	2.706	4.298	-0.002	1.153	6.870	0.805	-1.061	-6.866 [a]
Constant	-0.234	0.278	3.763	0.497	0.367	5.104	8.232	1.178	-6.893 [ab]
Shanon	9.581 [a]	2.730	4.979	6.280	1.116	5.551	-0.915	-0.974	7.587 [ab]

[14] The critical values are obtained from the empirical distribution of the bootstrap t-values where each t value corresponds to a bootstrap replication (following Dies and Hill, 1998). We used 100 bootstrap replications for the results.
[15] The bootstrap t-critical values are obtained from bootstrapping the bootstrapped samples. The bootstrap replications in the second bootstrap are 10.
[a] Significant at 10% level, using the standard critical value (i.e. t=1.64)

Table 3 presents results from Amemiya's and bootstrap simultaneous equation estimates for the diversity equation and a comparison between the two estimates.

Like in the participation equation. many of the GLS coefficient estimates based on the standard critical values turned out to be significant. However. evaluation of the estimates against the bootstrap critical values shows that socio-economic and physical farm characteristics were found to be weak in explaining the level of diversity maintained by households. The only socio-economic factor significant in explaining diversity is wealth which has a positive impact. Similar effect of wealth was observed by Benin et al. (2003) in their study of the determinants of cereal diversity in the Ethiopian Highlands. They attributed the impact of wealth on diversity to the ability of less poor households to better use diverse set of resources.

The village level dummies also had insignificant impact on the level of diversity. This could be for two reasons. One is the condensed nature of our sampling. We sampled villages close to where the community seed bank is located which means that the villages are close to each other. That naturally dampens the agro-ecological and infrastructure variation. Furthermore. there can be counteracting effects of the village dummies. For example. villages with agro ecological conditions favouring monocropping could be diversifying because of unfavourable market access.

We found diversity to be increasing with the amount of fertilizer applied. This result might appear counter intuitive given that fertilizer application is associated with use of improved seeds and reduced level of diversity. Smale et al (1994). however. observed that. at very low (but not at high) levels of fertilizer use. it pays to diversify as with moderate fertilizer application. local varieties might perform better than improved varieties. This indicates there could be a threshold to the effect of fertilizer use on the level of diversity where our case is likely to be below the threshold (where fertilizer use enhances diversity).

The impact of CSB participation on diversity is positive and consistently significant across estimates. This indicates the effectiveness of CSB scheme in enhancing diversity. As we argued earlier. the modern seed system has a negative impact on participation. Thus. given present constraints to accessing modern varieties. the impact of CSB scheme as an effective instrument would be primarily deterred by a push for expanding the commercial seed system.

With CSB as an effective conservation scheme. this further implies reduction in the effectiveness of CSB as an effective conservation mechanism with improvement in the existing seed system particularly in the provision of and access to improved varieties.

Unlike the participation equation. the percentage change in the coefficient estimates between the asymptotic and bootstrapping estimators is relatively bigger for the diversity equation. However. the bias t statistic is less significant for the diversity equation. Again. the bias–t statistic is significant at least for some coefficients indicating significant bias in the coefficients estimated using Amemyia's GLS.

Table 3: Comparison of simultaneous equations with and without bootstrap of the diversity function

Variable	Amemiya's GLS simultaneous equation estimation			Bootstrapping Amemiya's GLS estimator			Comparison of Amemiya's and Bootstrap estimates		
	AGLS	T-STAT	T-crit (α=0.10)	BGLS	T-STAT	BT-crit (α=0.10)	%Δ in BETA	%Δ in T	Bias_T
Wealth	0.029[ab]	2.906	2.481	0.026[a]	2.294	3.436	-0.223	-0.211	4.443[ab]
Oxen	0.004	0.186	3.097	0.009	0.258	2.556	9.348	0.383	-7.012[ab]
Age	0.001	0.208	4.594	0.000	0.091	2.632	-16.212	-1.440	9.181[ab]
Female	0.283[a]	2.195	5.345	0.326	1.104	4.007	-0.184	-0.497	0.813
Radio	-0.072	1.493	2.001	-0.078	1.293	2.843	0.043	0.134	-0.531
Formal education	0.007	0.087	2.500	-0.007	0.066	2.561	10.433	-1.762	-5.895[ab]
Religious education	-0.004	0.089	2.273	0.000	0.004	2.428	2.557	0.960	-1.455
Improved seed	0.016[a]	1.752	4.784	0.020[a]	1.829	3.774	0.907	0.044	-4.686[ab]
Farm size	-0.001[ab]	2.108	1.751	0.001	1.259	2.844	0.293	0.403	6.238[ab]
Medium slope	-0.103	1.175	6.252	-0.120	0.986	3.090	-0.450	0.161	5.270[ab]
Steep slope	0.011	0.149	20.845	0.035	0.463	2.528	-2.390	2.109	-0.416
Moderately fertile	0.092	1.405	7.948	0.085	1.017	2.750	5.002	-0.276	-5.416[ab]
Infertile	0.108	1.573	5.682	0.149	1.422	3.262	3.015	-0.096	-3.717[ab]
Goro	-0.170[a]	2.000	2.282	-0.209	0.619	3.743	1.263	0.690	-0.904
Addadi Gole	-0.131	1.539	2.564	-0.171	0.509	3.589	0.054	0.669	5.685[ab]
Buae Tengego	-0.097	1.076	2.022	-0.125	0.379	3.050	-0.588	0.647	-1.505
Kersa	-0.154	1.515	2.348	-0.180	0.530	3.296	0.182	0.650	1.937[a]
Menjikso	-0.004	0.047	5.301	0.341	0.337	7487	152.799	8.107	-5.304[a]
Fertilizer	0.004[ab]	5.015	2.170	0.001[a]	3.136	5.394	0.0423	-0.375	-1.580
Constant	0.948[a]	6.032	4.333	0.955[a]	2.215	3.783	0.180	-0.633	-2.889[a]
Participation	0.106[ab]	5.830	2.147	0.095[ab]	4.231	2.664	-0.108	-0.274	5.017[a]

[a] Significant at 10% level, using the standard critical value (i.e. t=1.64)

[b] Significant at 10% level, using the critical values derived from the empirical distribution of bootstrap t values.

Table (4) presents the results from the OLS estimates of the productivity equation. The productivity equation relates productivity per ha to the different seed sources. socio-economic. physical farm and agroecological characteristics.

The socio-economic factors. namely gender and wealth of the household head. have turned out to be insignificant in explaining productivity. However. productivity is found to significantly decline with age. The number of oxen. measuring access to traction power. is an insignificant determinant of productivity. The coefficient for total area is negative. lending support the inverse farm size-productivity relationship. Productivity was shown not to significantly vary with the proportions of hillside and infertile plots. The impact of fertilizer application is positive and significant.

The impact of own seed on productivity is significant. The positive impact of own seeds on productivity is intuitive since own storage indicates the ability to save a portion of previous harvest and reduces the cost of accessing seeds from other sources. Access to informal seed sources. particularly borrowing from fellow farmers has significant positive impact on productivity. This indicates the importance and the role of informal links in reducing transaction costs in accessing seeds. Access to the commercial seed varieties does not have significant impact on productivity. This might appear counter intuitive since the commercial varieties are tipped to be of superior productive quality. However. since their productivity is. to a large extent. dependent on fertilizer as complement. the effect of improved seeds use on productivity might get insignificant once fertilizer use is controlled for. Borrowing from CSB has significant impact on productivity indicating that CSB as a seed source improves the working of the existing seed system.

Table 4: Estimation results for the determinants of Productivity

Variable	Average yield value	Standard error
Own seed	3.321	0.929***
CSB seed	4.936	1.817**
Borrowed seed	3.801	1.835**
Exchanged seed	-0.892	3.256
Extension seed	0.194	1.008
Female	-0.082	1.888
Age	-0.083	0.029**
Formal Education	-0.372	1.246
Religious Education	-1.874	0.712
Oxen	0.354	0.333
Wealth	0.120	0.149
Farm size	-1.206	0.148***
Fertilizer	0.003	0.001**
Medium slope	-2.795	2.642
Steep slope	-8.031	11.693
Moderately fertile	-2.420	2.083
Infertile	0.873	1.856
Goro	-2.619	1.305**
Addadi Gole	-2.818	1.324**
Buae Tengego	-2.618	0.406**
Kersa	-3.507	0.563**
Menjikso	-0.700	1.321
Source	-0.191	0.645
Constant	15.217	5.035***
Adjusted R- squared	0.26	

Note: *** stands for significance at 1% level and ** stands for significance at 5% level.

6. Conclusions

Biodiversity conservation initiatives in large monocropped farms have been associated with monetary compensation to 'conservator' farmers who choose to engage in the particular program (see for e.g. Wossink and Wenum. 2003). However. in small multicropping farming systems with imperfections in the seed system. expanding the provision of local seeds sources might improve seed access and enhance farm level diversity.

In line with this. the study examines a scheme called Community Seed Banking (CSB) which aims at increasing biodiversity of individual farms through improving the local seed supply system. The particular objectives of the study have been to assess the potential of the CSB in enhancing diversity and in improving access to local seeds.

We hypothesized that participation in CSB leads to enhancement of agrobiodiversity. We also argued that provision of local varieties in the CSB alleviates the problem of seed access and thus CSB participation would improve productivity. In addition. we proposed that the existing level of biodiversity would have a positively enforcing impact on participation in CSB. The relationships we proposed implied endogeniety of diversity and CSB participation measures. To assess the possible simultaneity. we employed the Generalized Probit GLS estimator. which was developed by Amemiya (1978) to handle simultaneous equations with mixed endogenous variables. The performance of the GLS estimator is also examined using the bootstrapping technique.

Our results confirm a significant impact of participation in CSB on farm level biodiversity. Furthermore. CSB participation was shown to significantly increase the productivity of participant farmers. The implication is that agrobiodiversity conservation could be enhanced through provision of desirable local varieties. On the other hand. the level of diversity did not have a significant impact on participation implying that participation is not necessarily conditioned by previous knowledge and experience with respect to maintaining diversity. The number of seed sources farmers access seeds from did not significantly explain participation. However. access to improved varieties. which comprise the modern seed system. was shown to reduce the likelihood of participation in the CSB. This implies that given the current working of the seed system. CSB could work as a conservation instrument for seed-poor farmers who have less access to the commercial seed system. On the other hand. with improvement in the working of the commercial seed system. overall participation in the CSB would reduce. This further leads to reduction in the potential of CSB as a mechanism enhancing conservation. Instruments which explicitly reward 'conservator' farmers should be in place for sustainable agrobiodiversity conservation in light of improved access to the modern seed system. therefore.

Our investigation of the performance of the GLS estimator vis-à-vis the bootstrap yielded the result that the asymptotic results were significantly different from the bootstrapped results. This is in line with previous studies which analysed asymptotic and bootstrapping estimates although our sample size is considerably large. The implication is that asymptotic estimators might not be reliable even when sample sizes appear to be reasonably large. As a result. sufficiently large sample sizes or techniques like bootstrapping should be used to get accurate estimations when asymptotic estimators are employed.

References

Amemiya. T. (1978). The Estimation of a Simultaneous Equation Generalized Probit Model. *Econometrica. 46*(5). 1193-1205.

Benin. S.. B. Gebremedhin. M. Smale. J. Pender. S. Ehui. (2003). *Determinants of Cereal Diversity in Communities and on Household Farms of the Northern Ethiopian Highlands*. Washington D.C.: International Food Policy Research Institute.

Brush. S.. Bellon. M.. & Taylor. J. (1992). Technology Adoption and Biological Diversity in Andean Potato Agriculture. *Journal of Development Economics. 39*(2). 365-387.

Demissie. A.. & Tanto. T. (2000). *Dynamic Participatory Approach to the use of Plant Genetic Resources*. Addis Ababa: Institute of Biodiversity Conservation and Research.

Dies. D. R.. & Hill. C. R. (1998). An Application of the Bootstrap Method to the Simultaneous Equations Model of the Demand and Supply of Audit Services. *Contemporary Accounting Research. 15*(1). 83-99.

European. E. A. (2005). *Information for Improving Europe's Environment*

Freedman. D. A.. & Peters. S. C. (1984). Bootstrapping an Econometric Model: Some Emprical Results. *Journal of Business and Economic Statistics. 2*(2). 150-158.

Greene. W. (2000). *Econometric Analysis* (4th ed.). New Jersey: Printce Hall Inc.

Heal. G. (2004). Economics of Biodiversity: An Introduction. *Resource and Energy Economics. 26*(2). 105-114.

Heal. G.. Walker. B.. Levin. S.. Arrow. K.. Dasgupta. P.. Daily. G.. et al. (2004). Genetic diversity and interdependent crop choices in agriculture. *Resource & Energy Economics. 26*(2). 175.

Heckman. J. J. (1978). Dummy Endogenous Variables in a Simultaneous Equation System. *Econometrica. 46*(4). 931-959.

Herath. H.. Hardaker. J.. & Anderson. J. (1982). Choice of Varieties by Sri Lanka Rice Farmers: Comparing Alternative Decision Models. *American Journal of Agricultural Economics. 64*(1). 87-93.

Holden. S.. Lofgren. H.. & Shiferaw. B. (2003). *Economic Reforms and Soil Degradation in the Ethiopian Highlands: A Micro CGE model with Transaction Costs*.Unpublished manuscript.

Horowitz. L. J. (1997). Bootstrap Methods in Econometrics. In D. M. K. a. K. F. Wallis (Ed.). *Advances in Economics and Econometrics: theory and applications. Seventh World Congress* (Vol. Volume III. pp. 189-221): Cambridge University Press.

Jeong. J.. & Maddala. G. S. (1993). A Perspective on Application of Bootstrap Methods in Econometrics. In G. S. Maddala. C. R. Rao & H. D. Vinod (Eds.). *Handbook of Statistics* (Vol. 11. pp. 574-610). North Holland: Ellsevier Science Publishers.

Lewis. V.. & Mulvany. P. (1997). A Typology if Community Seed Banks. *Natural Resources Institute.University of Greenwich*. Kent: Natural Resources Institute. University of Greenwich.

Meng. E.. Taylor. J.. & Brush. S. (Eds.). (1998). *Implications for the Conservation of Wheat Landraces in Turkey from a Household Model of Varietal Choice*. Boston; Dordrecht and London: Kluwer Academic.

Moser. C. a. C. B. (2003). The Complex Dynamics of Smallholder Technology Adoption: The Case of SRI in Madagascar. *Cornell University Applied Economics and Management Working Paper No. 2003-20*.

Oltmer. K.. Nijkamp. P.. & Florax. R. (2000). A meta analysis of Environmental Impacts of Agri Environmental Policies in the European Union. *Tinbergen Institute Discussion Paper. TI 2000-083/3*.

Roberts. R. D. (1987). Financing Public Goods. *Journal of Political Economy. 95*(2). 420.

Secretariat. o. C. o. B. D. (2001). Article2: Convention on Biological Diversity: United Nations Environmental Programme.

Smale. M.. Bellon. M.. G. A.. & Alfonso. J. (2001). Maize Diversity. Variety Attributes. and Farmers' Choices in Southeastern Guanajuato. Mexico. *Economic Development and Cultural Change. 50*(1). 201-225.

Smale. M.. Just. R.. & Leathers. H. (1994). Land Allocation in HYV Adoption Models: An Investigation of Alternative Explanations. *American Journal of Agricultural Economics. 76*(3). 535-546.

Wale. E.. & Virchow. D. (2003). Crop diversity as the derived outcome of farmers' 'survival first' motives in Ethiopia:

what role for on-farm conservation of sorghum genetic resources? *The 25th International Conference of IAAE: Reshaping Agriculture's Contribution to Society*. Durban. South Africa.

van der Meulen. H.. de Snoo. G.. & Wossink. G. (1996). Farmers' Perception of Unsprayed Crop Edges in the Netherlands. *Journal of Environmental Management. 47*(3). 241.

van Dusen. M. E. (2000.). In-situ conservation of crop genetic resources in the Mexican Milpa System. *Ph.D. diss.. University of California. Berkley.*

Vanslembrouck. I.. Van Huylenbroeck. G.. & Verbeke. W. (2002). Determinants of the Willingness of Belgian Farmers to Participate in Agri-environmental Measures. *Journal of Agricultural Economics. vol. 53*(no. 3). 489-511(423).

Wilson. G. A. (1997). Factors Influencing Farmer Participation in the Environmentally Sensitive Areas Scheme. *Journal of Environmental Management. 50*(1). 67-93.

Wossink. G. A. A.. & van Wenum. J. H. (2003). Biodiversity conservation by farmers: analysis of actual and contingent participation. *European Review of Agricultural Economics. 30*(4). 461-485.

Zepeda. L. (1994). Simultaneity of Technology Adoption and Productivity. *Journla of Agricultural and Resource Economics. 19*(1). 46-57.