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

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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. We employed 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 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.

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1. Introduction

The focus of sustainable agricultural development has for a long time been the management and utilization of abiotic resources. The subsequent neglect of biological resources in agriculture and their appropriate utilization has led to tremendous agrobiodiversity losses with noticeable consequences.[1]

The loss in agrobiodiversity initially triggered the establishment of *ex-situ* germ plasm banks where genetic materials are collected from localities and stored in the banks. This approach was criticized by evolutionary biologists and many others since the genetic materials conserved therein are 'frozen' against the course of evolution (Smale et al., 2001). However, genetic materials conserved *in-situ*[2] evolve against natural and man-made stresses which makes them more valuable compared to *ex-situ* conserved materials**.**

Despite its potential merits, ensuring an appropriate level of *in-situ* conservation constitutes a major challenge to policy makers and development practitioners. This is mainly due to concerns that favoring diversification at a farm level might compromise the productivity benefits of specializing in a few crops. Enhancing farm level conservation without foregoing productivity, thus, calls for interventions that provide the appropriate (extra) incentives. Community Seed Banking (CSB) is one such scheme aimed at providing a secure local seed system (as an additional productivity incentive) and enhancing farm level agrobiodiversity (Lewis and Mulvany, 1997; Demissie and Tanto, 2000). The scheme involves multiplication, storage and distribution of varieties that are either currently planted by some farmers but that others do not have access to; or varieties that are not currently planted by farmers in the locality but are either available in other localities or in central Gene Banks. 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 imperfection in the already existing seed system, provision of seed varieties would ease constraints to seed access, improve overall resource allocation and increase productivity. [3]

In line with this, the study aims at assessing the effectiveness of participation in CSB in enhancing agrobiodiversity and increasing farm-level productivity. In an attempt to properly assess the impact of CSB participation on farm level diversity, we consider the knowledge and experience that farm households have in managing local varieties and in conservation as potential determinants of participation. Since experience is directly associated with the level of conservation, assessing the effectiveness of such schemes without taking into account the impact of previous knowledge and experience would be inaccurate due to the problem of endogeneity bias.

In order to assess potential endogeneity, we estimate a simultaneous equation with participation and current farm level biodiversity (representing experience) as endogenous variables. Due to the mixed nature of the simultaneous equations, we employ Amemiya's GLS estimator, which is believed to be efficient in handling such equations (Lee, 1981). To further assess its reliability, we use the method pioneered by Dies and Hill (1998) in which the estimates from the asymptotic estimator are evaluated against bootstrap results.

The rest of the paper is organized as follows. In Section 2, we present the hypotheses we attempt to test followed by a description of the setting and sampling procedure in section 3. Section 4 presents the econometric model and estimation techniques. The results and discussion are presented in Section 5. Section 6 concludes.

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[1] The extent of agrobiodiversity loss and its implications are reviewed in Thrupp (2000) and Heal et al. (2004).

[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 improved allocation of resources.

2. Conceptual framework and hypotheses

Biodiversity loss is associated with large farms and massive adoption of improved varieties, which are vulnerable to environmental stresses. On the other hand, biodiversity in small farms, whose crop portfolio is dominated by local varieties, is perceived to be intact. The problem of biodiversity loss in such small farms has, as a result, been disregarded. This is particularly attributed to observations that the level of diversity maintained by farmers increases with market imperfections and risk aversion: risk-averse households and households with low market integration tend to be more diverse (Van Dusen, 2000). Wale and Virchow (2003) also argue that the 'survival first' motive could give additional motives to increase diversity beyond the level that is triggered by market imperfections and transaction costs. Heal et al. (2004), however, show that from the society's point of view, biodiversity will always be under-invested at the farm level. Thus, the observation that small farms might be more diverse than standard profit optimisation would predict does not guarantee a level of diversity (at a farm level) that would match the socially optimal level as long as diversity brings about external benefits to society. Ensuring a socially optimal level of diversity calls for interventions that are primarily effective in enhancing diversity. Moreover, given the gap between the individually optimal level of biodiversity and that of the socially optimal level, the interventions should confer additional benefits to individual farmers for them to be adopted.

CSB is one such intervention aiming at increasing biodiversity at the individual farm level through providing local seeds that are not locally available or not well distributed across farmers. Thus, we set out to assess the effectiveness of CSB in enhancing diversity and productivity.

While adoption of improved varieties generally leads to a reduction of diversity (Brush et al., 1992), there are reasons to believe that landrace farming is associated with diversity, holding other things constant. Within-farm heterogeneity with respect to physical farm characteristics is one reason. Meng et al., (1998) found that households managing farms with diverse characteristics tend to grow more landrace varieties. Transaction costs associated with accessing varieties with particular qualities form another reason. 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. 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. Following this, we expect adoption of CSB varieties, which are local, to lead to increased diversity. We also expect farm level diversity to vary with socio-economic and physical farm characteristics of the household.

Provision of CSB seeds is also expected to increase productivity given the imperfections in the already existing seed system. In the case we are studying, the seed system is comprised of two sources. The primary source of seeds 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) and also depend on one's ability to save from previous harvest. 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 the provision of a relatively easily accessible source. In line with this we hypothesize CSB to be a seed source which improves the already existing seed system thereby enhancing productivity. Socioeconomic, physical farm and agroecological characteristics as well as other seed sources are also expected to affect productivity.

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 the Unsprayed Crop Edges Program in the Netherlands, Van der Muleun (2001) found that perceptions regarding the environment significantly differ between participants and non-participants. In the case of an intervention like CSB, participation will also be a function of the household's access to other seed sources (and the impact of other seed sources on participation depends on whether the CSB and other seeds are substitutes or complements). In addition, since 'farmer' and 'other behavioural' factors would condition previous knowledge and experience in managing biodiversity; we expect farmer knowledge and experience to be important determinants of participation in CSB.

On the other hand, 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 in the respective equations. The hypothesized relationships above imply simultaneity[4], and 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.

While asymptotic estimators[5] 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[6] 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, which is reasonably large compared to previously tested samples.[7]

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 named Chefedonsa, a woreda[8] with 30 kebeles, located in

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

[5] Asymptotic estimators are estimators with known properties that apply to large samples and whose finite sample behaviour is approximated by what is known about their large sample properties (Greene, 2000).

[6] 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).

[6] 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).

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

the Eastern Oromiya Zone of the Oromiya National Regional State. The specific study site is a center of origin and diversity for many wheat and pulse varieties. Due to this, one of the eleven community seed banks across the country is located in the woreda. Agroecologically, the study area is of good agricultural potential and is located in a plateau as high as 2800m above sea level, which makes it frost prone. Main produces include durum and bread wheat, *teff* and pulses.

The main source of CSB varieties is the central Gene Bank of the Institute of Biodiversity Conservation and Research. Varieties from the gene bank are multiplied on rented farmer plots and stored in the CSB storehouse. Another source of CSB seeds is the required 10 kg deposit by CSB participants. In return, they can borrow local seeds of available type and amount. Participants are also entitled to interest on deposited seeds although collecting the interest is not practiced yet. 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 be currently 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 in our diversity and participation equations, we base our productivity analysis on both total yield and on wheat yield values.

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 main crops. An average of 4.6 varieties are grown per household, with 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. Training and radio ownership were included as measures of access to information. We consider plot slope and fertility as measures of physical farm characteristics. 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 agroecological 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

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[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 (representing richness and relative abundance) However, since the results were similar, we opted to report the results based on the Shannon's index.

characteristics. The categories of physical farm and agroecological variables included in the diversity equation are also 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**	73.744	36.920
LOCATION OF CSB	Location of the bank (measured in terms of distance from homestead to the bank (minutes)	26.824	84.226
PHYSICAL FARM	**VARIBLES**	2.115	2.316
	Farm size (ha)	0.761	0.326
FARM SIZE	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
MODERATELY FERTILE	Proportion of land with good fertility	0.217	0.306
INFERTILE	Proportion of land with moderate fertility	0.243	0.298
	Proportion of infertile land		
AGROECOLOGICAL		0.239	0.456
GORO	**VARIABLES**	0.294	0.427
ADDADI GOLE	Kebele dummy (1=Goro)	0.123	0.329
BUAE TENGEGO	Kebele dummy (1=Addadi Gole)	0.083	0.278
KERSA	Kebele dummy (1=Buae Tengego)	0.605	0.128
MENJIKSO	Kebele dummy (1=Kersa)	0.160	0.367
KOREMTA	Kebele dummy (1=Menjikso)		
SEED SYSTEM	Kebele dummy (1=Koremta)	26.82	84.126
IMPROVED SEED	**VARIABLES**		
	Amount of improved seeds borrowed in 2003	217	291
FERTILIZER	Amount of modern fertilizer borrowed in 2003 (kg)	1.342	0.543
SEED SOURCE	Number of sources a household has secured seeds from (all traditional and modern)	.214	0.387
OWN SEED	Proportion seeds from own storage in the total farm	.074	0.199
CSB SEED	Proportion seeds from CSB in the total farm	.039	0.179
BORROWED SEED	Proportion seeds borrowed from fellow		
EXCHANGED SEED	farmers Proportion seeds exchanged with	0.016	0.111
EXTENSION SEED	fellow farmers	0.224	0.362
MARKET SEED	Proportion seeds from the extension system	0.424	0.438
	Proportion seeds from the market		
DEPENDENT			
	VARIABLES	0.271	0.445
PARTICIPATION		1.251	0.464
SHANON	Participation in CSB (1=yes;0=otherwise)	5574	6316
YIELDV	Richness measured in terms of Shannon's index		
	Total (wheat) yield per ha (Br/ha)		

4. 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:

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

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:

$$D_i = \beta^D X_i + \gamma^D P_i + \eta_i , \tag{2}$$

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 :

$$Y_i = \beta^Y X_i + \lambda P_i + \psi S_i > 0, \tag{3}$$

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

Our other measure of productivity, value of wheat yield per ha unit of plot, is expressed as in equation (4) where W_i is the value of wheat yield and S_i stands for the different seed sources.

$$W_i = \begin{cases} W_i^* \text{ if } W_i^* = \beta^Y X_i + \lambda P_i + \psi S_i > 0, \\ 0 \; if \;\; W_i^* \leq 0 \end{cases} \tag{4}$$

Equation (3) is estimated with standard OLS and equation (4) is estimated with a Tobit model. Estimation of equations (1) and (2) is more problematic. 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 the recovery of 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 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 procedure involves bootstrapping the original samples to obtain empirical distribution of the t-values from which critical values are computed. This 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. We also use the bootstrapped samples to compute the bootstrap coefficients and their corresponding standard errors. To compute the t-critical values corresponding to the bootstrap coefficients, we bootstrap from each bootstrap replication and repeat the procedure we used to obtain the critical values for the original estimates.[10]

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 bootstrap samples are reported. Comparison of the bootstrap and GPGLS results is given in the third part of the table.[11]

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 amounts of improved seeds purchased on credit and total fertilizer used[12] 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 relationship, continued push for the adoption of improved varieties will lead to improvement in the working of the existing seed system. In turn, this will 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 ('bias t-statistics'). Since the t-statistics is calculated as the ratio of the coefficient estimates to the respective standard deviations, smaller coefficient estimate biases imply larger biases in the standard errors. Furthermore, the upward biases we observe in the t-statistics confirm deflated standard errors. Thus,

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[10] The software package LIMDEP 8.0 was used to estimate both the asymptotic and bootstrap statistics.

[11] For consistency reasons, we discuss the different results in the order they appear in the tables. However, our focus of discussion is the results based on bootstrap critical values.

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

even in our reasonably large sample, the tendency that asymptotic estimators inflate standard errors remains valid. The ‘bias t-statistics’ calculated as the ratio of coefficient (asymptotic)- coefficient (bootstrap) to standard error (bootstrap)/10, 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[13] (α=0.10)	BGLS	BT-STAT	Bt- crit[14] (α=0.10)	%Δ in BETA	%Δ in T	BIAS-T
Training	0,144	0,267	1,819	0,466	0,784	1,253	2,239	1,933 [a]	-5,418 [ab]
Wealth	-0,263[a]	-2,697	4,664	-0,173	-1,143	2,956	0,341	0,576	-5,910 [ab]
Age	-0,0004	-0,019	2,546	0,013	0,533	1,991	37,824	29,790	-5,473 [ab]
Female	-2,860 [a]	-2,376	6,661	-3,298	-1,024	1,413	-0,153	0,569	1,361
Radio	0,747	1,595	1,897	0,751	1,431	2,212	0,005	-0,103	-0,077
Formal education	-0,161	-0,202	2,144	-0,002	-0,002	2,043	0,989	0,991	-1,664
Religious education	-0,020	-0,041	2,010	-0,136	-0,267	2,045	-5,833	-5,540 [ab]	2,281 [ab]
Location of CSB	-0,165 [a]	-1,860	2,393	-0,138	-1,154	3,350	0,162	0,379	-2,231
Improved seed	-0,019 [ab]	-2,828	2,170	-0,019 [ab]	-2,192	2,180	-0,021	0,225	0,446
Farm size	0,006 [a]	1,766	3,119	0,002	0,342	2,415	-0,667	-0,806	6,860 [ab]
Medium slope	-0,047	-0,061	22,884	-0,052	-0,069	2,678	-0,090	-0,125	0,057
Steep slope	-0,607	-0,935	4,326	-0,334	-0,414	1,708	0,450	0,558	-3,388 [ab]
Moderately fertile	-0,662	-0,911	4,360	-1,158	-1,236	2,264	-0,749	-0,357	5,295 [ab]
Infertile	0,202	0,375	2,456	0,406	0,685	2,299	1,006	0,828	-3,435 [ab]
Fertilizer	-6,614 [a]	-2,736	7,903	-4,376	-0,987	3,878	0,338	0,639	-5,047 [ab]
Seed source	-0,004 [a]	-2,706	5,088	-0,002	-1,153	4,081	0,294	0,574	-4,796 [ab]
Constant	-0,234	-0,278	3,571	0,497	0,367	3,984	3,126	2,321 [a]	-5,397 [ab]
Shanon	9,581 [a]	2,730	5,201	6,280	1,116	6,422	-0,345	-0,591	5,867

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[13] 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.

[14] The bootstrap t-critical values are obtained from bootstrapping the bootstrapped samples. The bootstrap replications in the second bootstrap are 10.

[a] Significant at the 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, an evaluation of the estimates against the bootstrap critical values shows that socio-economic and physical farm characteristics were 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. A 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 sets of resources.

The village level dummies also had insignificant impacts on the level of diversity. This could be due to 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 agroecological 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 the 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 local varieties might perform better than improved varieties. This indicates that 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 the 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 a 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	2,188	0,026[ab]	2,294	2,252	-0,097	-0,211	2,474[ab]
Oxen	0,004	0,186	2,694	0,009	0,258	1,709	1,106	0,383	-1,352
Age	0,000	0,208	2,715	0,000	-0,091	2,871	-1,600	-1,440	2,436[a]
Female	0,283[a]	2,195	7,118	0,326	1,104	2,014	0,152	-0,497	-1,459
Radio	-0,072	-1,493	2,398	-0,078	-1,293	1,835	-0,082	0,134	0,977
Formal education	0,007	0,087	3,162	-0,007	-0,066	2,562	-2,018	-1,762	1,307
Religious education	-0,004	-0,089	2,596	0,000	-0,004	2,004	0,950	0,960	-0,684
Improved seed	0,016[a]	1,752	4,467	0,020[a]	1,829	2,512	0,223	0,044	-3,338[ab]
Farm size	-0,001[a]	-2,108	2,381	0,000	-1,259	1,631	0,293	0,403	-5,210[ab]
Medium slope	-0,103	-1,175	4,500	-0,120	-0,986	2,027	-0,162	0,161	1,375
Steep slope	0,011	0,149	21,174	0,035	0,463	1,930	2,144	2,109	-3,157[ab]
Moderately fertile	0,092	1,405	5,220	0,085	1,017	2,190	-0,082	-0,276	0,910
Infertile	0,108	1,573	5,658	0,149	1,422	2,198	0,380	-0,096	-3,914[ab]
Goro	-0,170[a]	-2,000	2,504	-0,209	-0,619	4,131	-0,228	0,690	1,151
Addadi Gole	-0,131	-1,539	3,091	-0,171	-0,509	3,745	-0,300	0,669	1,176
Buae Tengego	-0,097	-1,076	2,269	-0,125	-0,379	4,404	-0,287	0,647	0,847
Kersa	-0,154	-1,515	2,536	-0,180	-0,530	3,909	-0,167	0,650	0,758
Menjikso	-0,004	-0,047	6,308	0,341	0,337	36,050	83,139	8,107	-3,415[a]
Fertilizer	0,0004[ab]	5,015	3,365	0,000[ab]	3,136	2,043	0,009	-0,375	-0,276
Constant	0,948[a]	6,032	6,398	0,955[a]	2,215	2,205	0,008	-0,633	-0,172
Participation	0,106[ab]	5,830	3,384	0,095[ab]	4,231	3,843	-0,100	-0,274	4,711[ab]

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

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

Table (4) presents the results from the OLS and tobit estimates of the productivity equations. The productivity equations relate productivity per ha to the different seed sources, socio-economic, physical farm and agroecological characteristics. The signs and significance as well as magnitudes of the coefficients in the two equations are similar except for some. Thus, our discussion of the results is based on the results from both equations.

The socio-economic factors, namely gender, age and wealth of the household head, have turned out to be insignificant in both equations. The number of oxen, measuring access to traction power, is also insignificant. As would be expected, the proportions of hillside and infertile plots have significantly negative impact on productivity. Also, the impact of fertilizer application is positive and significant.

The impact of own seed on productivity is insignificant in the wheat yield equation. In the total yield equation, however, an increased proportion of seeds accessed from own storage is shown to lead to significant productivity improvements. 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 a 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 in either equation. At a glance 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 a complement, the effect of improved seeds use on productivity might become insignificant once fertilizer use is controlled for. This shows that farmers are individually rational in adopting diversity increasing CSB varieties since the varieties confer productivity benefits.

Table 4: Estimation results for the determinants of productivity

Variable	Total yieldv	Wheat yieldv
Own seed	16.579	4.590
	(2.07)**	(0.79)
CSB seed	4.367	19.178
	(0.30)	(1.83)*
Borrowed seed	-20.094	23.133
	(1.11)	(1.84)*
Exchanged seed	-2.341	-7.068
	(0.08)	(0.35)
Extension seed	5.243	-0.015
	(0.62)	(0.00)
Female	-1.336	-13.576
	(0.08)	(1.12)
Age	-0.393	-0.095
	(1.63)	(0.55)
Oxen	2.757	1.502
	(0.98)	(0.73)
Wealth	-1.047	-0.087
	(0.80)	(0.09)
Farm size	-8.775	-9.429
	(6.45)***	(10.28)***
Fertilizer	0.009	0.016
	(0.87)	(2.28)**
Medium slope	11.726	3.518
	(0.81)	(0.35)
Steep slope	-27.681	-16.060
	(2.45)**	(2.01)**
Moderately fertile	-4.245	-7.288
	(0.42)	(1.01)
Infertile	9.275	-1.970
	(0.90)	(0.26)
Goro	-22.115	-15.226
	(2.12)**	(2.01)**
Addadi Gole	-7.127	-6.030
	(0.68)	(0.78)
Buae Tengego	-11.100	-13.541
	(0.91)	(1.52)
Kersa	-24.696	-18.531
	(1.86)	(1.92)
Menjikso	-7.469	-4.870
	(0.66)	(0.59)
Constant	87.208	108.183
	(3.69)**	(6.26)**
Prob > chi2		0.0000
R- squared	0.31	

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 effectiveness 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 the provision of local varieties in the CSB alleviates the problem of seed access and, thus that 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 effected through a 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, were shown to reduce the likelihood of participation in the CSB. This implies that given the current working of the seed system, CSB works as an effective 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 fall. This further leads to a reduction in the effectiveness 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 our 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.

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