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Negash, Martha; Swinnen, Johan

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Biofuels and Food Security: Micro-evidence from Ethiopia

Martha Negash and Jo Swinnen

Katholieke Universiteit Leuven

LICOS Centre for Institutions and Economic Performance
Waaistraat 6 – mailbox 3511
3000 Leuven

BELGIUM

TEL:+32-(0)16 32 65 98
FAX:+32-(0)16 32 65 99
http://www.econ.kuleuven.be/licos

Biofuels and Food Security:

Micro-evidence from Ethiopia

Martha Negash [1] and Johan Swinnen [1,2]

[1] LICOS Centre for Institutions and Economic Performance
& Department of Economics
Katholieke Universiteit Leuven

[2] Centre for Food Security and the Environment (FSE)
Stanford University

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Abstract

This paper provides microeconomic evidence on food security impacts of privately organized biofuel outgrower schemes in Ethiopia. We conducted a household and community level survey and evaluated the impact of castor bean farming. We use endogenous switching regressions to analyze the impact on food security. Food security (as measured by a "food gap") and food caloric intake is significantly better in households producing castor beans. "Fuel" and "food" are complements rather than substitutes at the micro-level in castor production in Ethiopia.

Keywords: biofuel, castor, food security, Ethiopia

JEL: Q42, Q16, O13, Q12

Corresponding author: Martha Negash, martha.negash@kuleuven.be

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1. Introduction

Biofuel development is a controversial issue, in particular in developing countries. Biofuels are said to cause environmental problems and to worsen food security – reflected in the 'food' versus 'fuel' debate (Cotula et al., 2010; Pimentel et al., 2009; Bindraban et al., 2009; Fargione et al., 2007). Some studies show that biofuel investments provide alternative income through employment, boost economic growth and reduce the incidence of poverty (Arndt et al., 2011; Huang et al., 2012; IIED, 2009). Others suggest that biofuel expansion jeopardizes food security goals (IFPRI, 2008; Mitchell, 2008; FAO, 2008).

So far analyses of the impacts of biofuel development have been based on qualitative case studies or on aggregate economy-wide simulation models or computable general equilibrium (CGE) analyses. The later have focused on impacts on prices (Ajanovic, 2011; Ciaian and Kancs, 2011), on income and GDP (Arndt, 2011; Ewing and Msangi, 2009) or the world economy (Taheripour et al, 2009). There is no quantitative empirical evidence on the actual impact of biofuels on the rural poor and smallholder farmers.

To fill the gap in our understanding, we estimate the effects of production contracts between smallholder farmers and a biofuel company on farmers' food security. We use detailed company and survey data from Ethiopia. Ethiopia is an excellent case to study these effects. On the one hand, Ethiopia is a major energy importer. In fact it is viewed as the number one "energy poor country" in the world (Nussbaumer, et al, 2011)[1]. Developing renewable alternative resources therefore sounds appealing. On the other hand, Ethiopia's agriculture sector is heavily dominated by subsistence smallholder farmers whose food security is vulnerable and who are often food aid recipients (Devereux and Guenther, 2009). It is therefore argued that expansion of biofuels may compete with the existing weak food supply system. While there has been a widespread debate about the benefits and risks,

[1] The authors constructed a Multidimensional Energy Poverty Index (MEPI) – that focuses on the deprivation of access to modern energy services and ranked countries using the scores from the index.

Ethiopia has taken steps to support the emergence of biofuel value chains. Besides a long established state ethanol project, there are now several private biofuel initiatives, both large scale plantations and outgrower schemes (table 1).

There are several ways in which rural households can potentially engage in the biofuel supply chains: (a) through direct employment in large scale plantations, (b) indirectly through leasing land to biofuel producing companies, (c) through contract farming schemes with processors (or feedstock exporter) companies, or (d) through small scale oil extraction schemes. The way biofuel value chains are organized is key to understand both the impact of biofuels on smallholder famers and the commercial viability of biofuel production (Altenburg, 2011).

Outgrower schemes are often argued to be more pro-poor than large scale capital intensive plantations, especially when they result in technology spillovers to other crops such as observed in Mozambique (Arndt, 2010; Ewing and Msangi, 2009). However, some recent studies on large scale investments on agriculture question this. For example, Maertens and Swinnen (2009) and Maertens et al (2011) find that the poorest households are more likely to benefit from employment on large scale farms than as contract farmers, based on their studies of horticultural value chains in Senegal. Moreover, achieving commercial viability in outgrower schemes may be challenging because of large transaction costs associated with managing production from widely dispersed small farms and problems of securing a sufficient supply of biofuel feedstock[2].

The paper is structured as follows. Section 2 reviews biofuel projects in Ethiopia and the outgrower scheme. Section 3 describes the sampling design and the data. Section 4 explains the estimation technique. Section 5 gives the results and interpretation of the results. Section 6 concludes and discusses policy implications.

[2] From our interviews with biofuel companies operating in Ethiopia, we learned that some projects were abandoned because of these reasons.

2. Castor production and food security in Ethiopia

The emerging biofuel feedstock production from private firms in Ethiopia thus far is dominated by two major non-edible crops i.e. castor been and jatropha (see table 1). Castor is a short season (4-5 months average maturity period) crop that gives oil bearing seeds. Castor oil contains a toxic element and thus cannot be used as food or animal feed source. The oil (i.e. biodiesel blended or not) can replace diesel without any engine modification. Besides, it can be used as lubricant in the automotive field, raw material for cosmetics industries and in pharmaceuticals. Castor is believed to be indigenous to Ethiopia and grows both wild and cultivated in the tropical and subtropical countries of the world (Kumar and Sharma, 2011). It has been promoted in Ethiopia as a commercial crop by foreign companies during the recent wave of biofuel investments and is said to provide a good base for acquiring or expanding a profitable position on the world market (Wijnands et al, 2007).

There is an important potential relationship in castor production and food security. The fact that non-edible sources of feedstock such as castor can potentially be cultivated on marginal lands makes it less threatening to local food production. However, at the same time, these marginal areas are often characterized by strong food insecurity.

In Ethiopia policy makers have allocated areas with low agricultural potentials or degraded areas for the production of biofuel crops. These areas are often recognized as food insecure areas. For example, one company planted perennial crop trees for biofuel feedstock on 15,000 ha areas of degraded hills in the Northern region of the country called Kola Temben, an area known with a large population living under extreme poverty and food insecurity.

There are also other potential relationships between castor production and food security, such as the impact of castor production on the productivity of other (food) crops, through rotation or spillovers effects. These effects are likely to depend on the nature of the production systems (Maertens et al, 2012).

Our study focuses on the contract farming system established by a company in the Southern region of Ethiopia, more specifically in the Wolayta and Gomo Gofa districts which are known to be heavily food insecure. Castor production in the Southern region started in 2008 with castor seed distribution to more than 10,000 farm households in Wolayeta and Gamo Gofa. Farmers traditionally recognize that crop rotation with castor enhances soil fertility, but no one was interested to cultivate it because of its low value as cash crop. The company had to undertake extensive promotion activities to introduce the crop as cash crop. It resulted in widespread adoption (close to 33%) in the third year of the operation.

The company offers a contract to its suppliers. The contract resembles most outgrower contract schemes where a group of farmers signs a contract to receive all the necessary inputs such as fertilizer, herbicide, technical assistance. In return they allocate part of their land for castor production and pay in seeds during harvest. The price of castor seeds is set in advance. The firm's extension workers at village level are responsible for training farmers, facilitating group formation, input distribution and the follow up of cultivation and output collection. The promoters of the crop are mainly extension agents hired by the company (83%), but government extension workers have also been involved in disseminating the information.

Land is an important criterion when recruiting farmers; also to make sure that farmers have enough land to grow the crop and keep adequate land for other crops. Farmers have been advised both by the government extension workers and the company supervisors not to allocate more than a quarter of their land to castor. This is also confirmed by our data. The average allocation of land to castor is 15% of total land covered by annual crops. The maximum land that farmers allocate does not exceed 25% of the total land holding (table 2).

During the initial phase of the project in 2008, a land size of 1ha was a requirement to allow farmers to engage in a castor contract. But meeting break-even quantity for export was extremely challenging for the company despite its wide coverage of areas. In the following years (2009 and 2010) the land size for eligibility was reduced to 0.75ha.

3. Data

Four districts (woredas) were chosen as representatives of the Wolayeta and Gamo Gofa administrative zones in the SNNPR region (figure 1). Following a stratified two stage sampling technique, 24 kebeles (equivalent to villages or a few clusters of villages) were randomly drawn from those selected districts. The number of sample villages is proportional to the size of the total number of villages in each district.

All kebeles in each zone that were eligible to grow castor have received castor seeds with varying degrees of intensity. Castor growing areas of all villages within the altitude range of 1040 to 2010 meters above sea level were included in our sampling frame. Our sampling frame has not covered the villages (commonly known as highlands) that are not agroecologically suitable to grow castor. Thus, the study best represents smallholder farmers in castor growing areas of the region. We used three sampling frames: (a) a list of all kebeles and demographic information was obtained from zone statistics office; (b) a list obtained from the company containing information about households who received castor seed and their participation history; (c) a 2010 list of all households who reside in each kebele was collected from each kebele.

18 to 22 households were interviewed in each village and households were stratified as participants and non-participants in the project. Systematic sampling was applied to select households from a list, using a random start and with selection intervals equal to the total number of residents divided by the number of samples to be selected

from the entire list. For the actual analysis of this paper, participants (adopters) are defined as those who participated through receiving castor seeds and inputs in the 2009 - 2010 agricultural year; and non-participants (non-adopters) as those who did not participate in the project regardless of their past participation history. Participants of 2010 count for 30% of our sample. Since participant samples are close to the actual proportion in the population (33%), we only applied weights to correct for differences in the sample proportions.

We conducted the survey in February and March 2011, soon after the main harvest season. A detailed questionnaire was prepared with questions on crop production, revenue, input use, income by type, and food security. Except for general household characteristics, we disaggregated our data enquiry over the two main crop seasons. In most cases, we interviewed the household head but whenever it was possible we asked both the head's and the spouse's opinion. There were no refusals of interview.

4. Descriptive Statistics

The dataset contains 476 households. About 30% of them are "adopters", i.e. households which allocated land to grow castor and received the necessary inputs in the 2010 cropping season. The incidence of adoption over the sample villages is reported in table 3. The 24 villages in our sample vary in terms of proximity to towns, infrastructure and other economic activities besides farming. In some villages (such as Fango Sore) that are far-off from towns and constrained by a limited availability of markets for alternative commodities, the adoption intensity is above the average rate (54%). Participants and non-participants differ in certain household characteristics. Female headed households and widow-headed households are less likely to participate. The proportion of working age group as well as the number of dependents does not differ between the two groups. There is no strong correlation between education and adoption. Overall, schooling is low: 42% of the total sample never attended school. Adopter households have a lower proportion of households with primary education but a higher proportion of households in junior level education. There is no difference in terms of high school education.

Land holding is a key eligibility criteria for participation, and is significantly higher for participants. The eligibility criteria has not been enforced strictly. There are non-participant households who qualify for participation (about 50%) but did not participate. There are also households that participated but did not formally satisfy the eligibility criteria

Participants use much more fertilizer (almost double) than non-participants. This reflects the fact that participants have better fertilizer access through the biofuel contract scheme.

Participants and non-participants do not differ significantly in terms of proximity to extension centers, or contact with government extension agents. On average 27% of participants gets information about markets, prices and agricultural practices primarily through formal media sources such as radio. Only 18% of non-participants make use of the formal media sources.

5. Food security indicators

To assess food security, we use two types of measures. The first is the number of "food gap" months. "Food gap" is defined as the number of months that the household runs out of its own stock of food (mainly grains and other own livestock food sources) and lacks money to purchase food'. The study area is known for its severe seasonal fluctuation in food security. Smoothing intra-year food security at the household level is a prime concern.

Cultivating castor in these areas can be beneficial for food security in many ways. First, farmers typically have to sell food crops at harvest time when prices of food crops decline. By generating cash income during the harvest season from castor contracts, they no longer have to sell food crops and can store them. . Moreover, stocking food would protect them from having to pay higher prices during the lean seasons. Second, castor beans planted can be collected twice a year. They preserve well on the field without easily spoiling like many food crops that need to be harvested immediately. This allows piecemeal collection of beans and sales to village level collection centers whenever farmers are in need of cash. For rural farmers liquidity constraints are vital to food security. For them flexible access to a cash source by being able to harvest and sell whenever necessary, protects them from taking suboptimal strategies on investments and crop use. Third, spillover effects on food crops by better access to fertilizer and improved land quality by rotating castor beans with other crops is another potential channel through which participant households food security may improve with the scheme.

The length of food gap is on average 1.02 months for adopter households, and 1.58 months for non-participants. This means that non-participant households had more than 50% longer food gaps (0.56 months or 17 days) than participants (table 5). Non-participants have a significantly larger proportion of households (21%) that experience more than three months of food gap during the year. Less than 10% of participants experience such long food gap periods.

As a second indicator of food security, we used per capita food consumption. We adopt FAO/WFP (2009) guidelines to convert food consumption (both self-produced and purchased) into energy kilo calorie (kcal) equivalent levels.

Table 4 shows that the average food consumption is 2515 kcal per capita per day in the survey, lower than the national average.[3] Table 6 presents the percentage of households in the categories of different food consumption levels. The data indicate that food security is high across the survey area, but significantly higher among non-participants than among participants. 63% of non-participants are food insecure (defined as having less than 2100 kcal per capita per day) and 42% are chronically food insecure (defined as having less than 1500 kcal per capita per day). While still high, the numbers are lower for participants: 51% are food insecure and 36% are chronically food insecure.

6. Econometric Approach

While these descriptive statistics provide useful information on the extent of food security and the characteristics of participants and non-participants, one cannot draw conclusions on the casual effect of the outgrower schemes on food security. Adoption of the new crop is potentially endogenous. One can try to address such endogeneity by explicitly modeling the simultaneity nature of the equations (Heckman, 1977). However, a pooled data estimation of both participants and non-participants assumes that the list of explanatory variables have the same impact on both groups of farmers and implies that participation has an average effect on the whole sample which may not be necessarily true due to selection problems (Heckman, 1979)[4] .

To account for the differential impact of covariates on the food security of the different groups, a separate function can be specified and estimated simultaneously through an endogenous switching regression (ESR) model (Maddala and Nelson, 1983). Our approach follows recent empirical applications of the model in studying the impact of

[3] Berhane et al, 2011 reported 2742 kcal average food consumption in Ethiopia using a more nationally representative data from Ethiopian CSA (Central Statistics Authority)

[4] Refer Wooldridge (2010) for recent reviews of econometric models for program evaluation; and see Cameron and Trivedi (2010) for their micro empirical applications.

choice decisions allowing for endogeneity, sample selection and interaction between adoption and other covariates that affect the outcome equation (e.g. Alene and Manyong (2006); Asfaw et al. (2012); Di Falco et al. (2011); Rao and Qaim (2011)). The model allows to construct the counterfactual expected outcome of the treatment effect under different regimes (i.e. adopt or not adopt).

Our model follows the specification given by Madalla (1983) and Lee and Trost (1982). The estimation is implemented using the full information maximum likelihood (FIML) technique to generate efficient and consistent estimators (Lokshin and Sajaia, 2004). Let d_i denote a dichotomous variable that equals 1 for households observed in regime 1 (participation in the castor program) and 0 for households in regime 2 (non-participation).

We observe d_i which is determined by a set of observable and unobservable variables such that;

$$d_i = \begin{cases} 1 \ \ if\ \gamma Z_i > u_i \\ 0 \ \ if\ \gamma Z_i \leq u_i \end{cases} \qquad (1)$$

the latent equation for d_i given by $d_i^* = \gamma Z_i + u_i$. The outcome equation is defined for each position as follows:

$$\text{Regime 1:} \quad y_{1i} = \beta_1 X_{1i} + \varepsilon_{1i} \qquad if\ d_i = 1 \qquad (2)$$
$$\text{Regime 2:} \quad y_{2i} = \beta_2 X_{2i} + \varepsilon_{2i} \qquad if\ d_i = 0 \qquad (3)$$

where y_{ji} are the dependent variables in the continuous equation, X_{1i} and X_{2i} are vectors of exogenous variables, β_1, β_2 and γ are parameters to be estimated. ε_{1i} , ε_{2i} and u_i are assumed to have a trivariate normal distribution, with a mean vector zero and a covariance matrix say δ.

Following the FIML estimation results, the associated conditional expected values and the extent of heterogeneity effects are determined using formulas presented in the appendix. The model is identified by construction through non-linearities (Lokshin and

Sajaia, 2004). However, it is strongly suggested to estimate it with an exclusion restriction (i.e. that Z_i in equation (1) contains at least one variable not in X_i) to improve identification. The variable excluded from X_i needs to be strongly correlated with the regime choice (equation 1) but not with the outcome variable (Maddala, 1999; Verbeek, 2012; Wooldridge, 2010).

We tried to follow the approach of Di Falco et al (2011) and Asfaw et al (2012) by using variables related to information sources (e.g. government extension, informal contacts, information from radio and newspapers). However, of these variables only the variable capturing information from radio, TV and newspapers satisfied the tests, as the other were not related to the adaption choice (see table A.1). We therefore constructed another variable, "farmer eligibility", following the approach described in Khandker (2009 p.203). Farmer eligibility is based on a combination of two variables, i.e. (1) the intensity of past program uptake at the village level, and (2) the eligibility criteria of participation used by the company to contract farmers i.e. farmers having a land size of 0.75 ha or more. The first variable village-level intensity of program uptake is measured as the share of the total number of households who received castor seed in the first phase of the program in the village population.[5] The value of the "farmer eligibility" variable is 1 for households who have more than 0.75 hectare of land and who reside in a village where the intensity of past adoption rate is above the sample mean; and 0 otherwise.[6] Table A.1 shows that this variable and the radio, TV and newspaper information variable both satisfy the criteria for valid selection instruments (they are statistically significant drivers of the decision to participate (Model 1), but not of the food security indicators (Model 2a and 2b)). Both are used in the estimations.

[5] This ratio is displayed in the second column of table 1.
[6] Taking sample median instead of sample mean does not change the result

7. Results

7.1 Determinants of the adoption decision

We first run a Probit regression jointly with the food consumption equation to analyze what factors determine incidence of participation. We controlled for a range of variables including household characteristics, land size, livestock assets, the price of maize (at the beginning of the year before planting decisions are made), access to information and district dummies. For consistency checks (and for calculating marginal effects), we also estimated an independent Probit and Tobit model. In the Tobit estimation, the total area each farmer allocates to castor is used as dependent variable. The estimated coefficients have the expected signs and magnitude. The model fits well predicting 70% of the observations correctly.

Land size significantly affects adoption, but at a decreasing rate as the squared term is negative and significant. The combined effect (direct and squared) is positive for the domain up to 0.31 hectares per capita, which is equivalent of 1.9 hectares per household for the average household. This is more than twice the eligibility criteria (0.75 hectares per household) and includes almost all the households since 93% of households are in this domain.

The results further show that a higher price of maize significantly reduces the allocation of land to castor.[7] One birr increase in the price of maize is associated with 0.17 points decline in allocation of land.

The adoption of castor is also correlated with a farmer's access to formal sources of information such as radio, TV, and newspapers. Participants tend to depend more on formal sources of information for their information on agricultural prices and practices

[7] Our price data is the average annual market prices in each village in the preceding crop year. In villages where complete data was absent for some months, we have taken the nearby closest villages price as a proxy.

than non-participants who are more reliant on friends, local markets and informal networks as their primary sources of information.

Like most findings in the literature, the gender of the household head is negatively and significantly associated with adoption, meaning that women-headed households tend to adopt less.

Exposure to government extension services does not seem to be an important factor for adoption. Distance to the extension centers which are often located at the center of each village is also not significant. The dissemination of the crop was widespread, even in remote villages. Distance does not appear to be a barrier to adoption.

7.2 Determinants of food security

We estimate the endogenous switching regression using the FIML method. This model can control for unobservable selection bias under a structural assumption (i.e. the error terms exhibit independent trivariate distribution). The food equation specifies the food security outcome variable on the left hand side and endogenous dummy variable for participation. Control variables include income by type, household characteristics, asset indicators and district dummies. The FIML estimation results for the food gap and food consumption as dependent variables are reported in tables 8 and 9.

The last rows of table 8 and table 9 show the Log likelihood Ratio (LR) test of the independence of equations. At a 90% confidence level, it confirms that it was appropriate to assume that the effects of covariates in the two groups are significantly different. The opposite signs of the correlation coefficient (ρ) of the two groups imply sorting behavior of farm households into which they would be better off i.e. participants have higher returns under adoption while non-participants are better off not participating. The correlation coefficient of the non-participant outcome equation under the participation equation is positive and significant, suggesting that individuals who choose not to participate in the castor program would have had higher food gaps than a random individual from a sample would have, had they participated in the program.

Finally, the suggestions in tables 8 and 9 show that for both participants and non-participants, off-farm job participation of a family member is significantly linked with lower food gaps on equal magnitudes. Literacy of the household head is associated with lower food gaps in both groups, but it is only significant for non-participant households. Borrowing of more cash during the year, is correlated with higher level of food gaps in both groups. Households that are food insecure may tend to borrow more during the year. Estimates of the remaining coefficients, strongly suggests the presence of heterogeneous effects between the two groups. For example, family size is significantly associated with lower level of food gaps for participants but not for non-participants. Livestock holding reduce food gaps significantly for non-participants not for participants.

The implication of some of the determinant variables differ between the food gap equation and the food consumption equation. Agricultural income determines the level of food consumption strongly and significantly. However, it contributes relatively less on the food gap compared to off-farm income. This is an indication that factors which reduce the food gap may not always be the same as factors that determine total annual food consumption levels.

7.3 Impact of participation

A summary table of impact simulations of participation in Castor outgrower schemes on food consumption and food gaps are presented in table 10. The values across the diagonals (in cell (a) and (d)) represent the expected mean values of participants and non-participants in the sample. The values in cell (b) and (c) are the counterfactual expected values. A positive mean difference of (c) from (a) indicates that participant farmers gain under participation. A negative mean of (d) from (b) on the contrast, implies that non-participant farmers perform better under non-participation.

The results show that participation in castor programs has very substantial effects on food security for the participating households. Participating in castor outgrower schemes caused an increase in food consumption by more than a quarter (27%) for participant households. It reduced the number of length of the households' food gap period on average by almost a quarter (23%, i.e. 0.37 months compared to the average foodgap of 1.58 months) for participant households. Hence, participation in the castor contract provided substantially more food security for adopter households.

In addition, our results also confirm the presence of heterogeneity and sorting based on comparative advantages. The results show that for non-participants food consumption would decline and the number of food gap days would increase had they decided to grow biofuel crop. These households presumably have better alternatives than the castor program and they fare better, at least in terms of food security, by not participating. These findings are in line with other studies' results (e.g. Suri, 2011; Zeitlin, 2010) that farmers with low expected net returns do not adopt a technology and the ones who have higher expected returns do apply them.

8. Conclusions

This paper presents micro- evidence on the impact of the cultivation of a biofuel crop (castor) on food security by presenting survey data and analyzing the effects on poor households in rural Ethiopia. The study is based on data collected in early 2011 from 478 randomly selected households. We use endogenous switching regression with exclusion restriction to control for endogenous selection issues in consumption and adoption decisions. Our choice of the instrument is based on the eligibility criteria used by the contracting company and the pre evaluation period intensity of the program intervention at the village level.

We find that participating in castor production increased households' food security significantly. The effects are substantial and affect both total food consumption and the periods of food shortages (the food gap). Our findings indicate improvements in both indicators (increased food consumption and reduced food gap periods) by approximately a quarter (25%).

Castor production reduces liquidity constraints as they can be harvested at periods of food shortages and can contribute to mitigate seasonal gaps in food availability. In addition, participation in the castor programs improves access to fertilizer for these households, which improves overall crop productivity. This indicates that, in contrast to many of the arguments being raised, that there is complementarity (instead of competition) between "fuel" and "food" at the micro-level in castor production in Ethiopia.

Our analysis also suggests that, not surprisingly, the impact is heterogeneous across households. We find rational sorting based on comparative advantage from the technology/crop where participants gain significantly from adopting which they may not otherwise. Households who do not adapt, appear to do this because they would not benefit. This is in line with findings of other studies.

There are also important findings on adoption of new crops/technologies. We find that land and non-land assets are key determinants of castor adoption, while physical accessibility such as distance from village centers appears not significant for adoption. These findings are interesting from the perspective of improving the dissemination of new technologies in poor rural areas. The castor study suggests that this type of privately promoted technologies appear to be quite efficient in overcoming distance barriers – unlike some other (government-promoted) technologies. This may be an important insight about the efficiency and the potential role of supply chains in technology dissemination in the future.

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Table 1 Private biodiesel projects in Ethiopia

Type of business model	No of project	Type of feedstock specialized	Total area (ha)	
			Total alloted/or leased (‘000 ha)	Under cultivation (‘000 ha)
Large scale plantations*	3	Jatropha, Pongamia, Castor	66.7	8
Outgrowers	1	Castor	NA	NA
PPP	1	Jatropha, Candlenut, Croton	15	7
Mixed outgrower with plantation	2	Castor	3	.08

Source: own survey 2010
*****all are foreign firms

Table 2: Mean land size allocated (ha) to major annual crops and Castor

Season	Long (Sila)		Short (Gaba)	
	Land size in ha	Cumulatieve %	Land size in ha	Cumulatieve %
Teff	0.26	27.07	0.15	15.51
Maize	0.27	55.11	0.40	55.87
Harricot beans	0.18	73.83	0.16	72.41
Sweetpotato	0.12	85.92	0.14	86.36
Castor	0.13	98.97	0.12	98.71
Other	0.01	100.00	0.01	100.00
Total	0.97		0.99	

Table 3: Characteristics of sampled villages and castor seed distribution

Village name	Adopters (% in the population) 2008 (ave.20%)	2010 (ave. 33%)	Distance to the nearest town (km)	Land size per capita (ha) (ave. .14)	Fixed telephone network availability (Yes=1)	Mobile Network availability (Yes=1)	Access to Electricity	Other dominant cash source
Ade Dewa Mundeja	0.11	0.37	16	0.12	✓	✓	✗	Cereal retail
Anka Duguna	0.24	0.50	42	0.11	✓	✓	✗	Limitted
Degaga Lenda	0.19	0.36	12	0.12	✗	✓	✗	Cereal retail
Fango Sore	0.52	0.54	90[a]	0.14	✗	✗	✗	Limitted
Sura Koyo	0.13	0.55	14	0.12	✓	✓	✗	Cereal retail
Tura Sedbo	0.19	0.63	35	0.18	✗	✓	✗	Limitted
Mundeja Sake	0.17	0.49	42	0.09	✓	✓	✗	Cereal retail
Olaba	0.01	0.13	25[a]	0.10	✗	✗	✗	Cereal retail
Mayo Kote	0.31	0.41	16	0.09	✓	✓	✗	Cereal retail
Hanaze	0.26	0.36	61	0.10	✗	✓	✗	Avocado
Tulicha	0.07	0.32	73[a]	0.13	✗	✓	✗	Ginger
Sorto	0.14	0.30	69	0.13	✗	✓	✗	Fruit trees
Bade Weyde	0.10	0.31	70	0.11	✗	✗	✗	Fruit trees
Bola Gofa	0.48	0.28	9	0.10	✓	✓	✓	Dairy
Sezga	0.08	0.28	4	0.20	✗	✓	✗	Pottery
Uba Pizgo	0.17	0.30	17[b]	0.18	✓	✓	✗	Limitted
Zenga Zelgo	0.54	0.28	18	0.14	✓	✓	✗	Limitted
Suka	0.09	0.29	3	0.16	✓	✓	✗	Dairy
Tsela Tsamba	0.05	0.12	7[b]	0.13	✗	✓	✗	Dairy
Lotte Zadha Solle	0.17	0.33	15[a]	0.17	✓	✓	✗	Retail
Gurade	0.08	0.20	11	0.17	✗	✓	✓	Dairy
Bala	0.07	0.41	65	0.22	✓	✓	✗	Live animal
Shalla Tsito	0.04	0.31	80	0.22	✓	✓	✗	Live animal
Zaba	0.17	0.35	68	0.18	✓	✓	✗	Live animal

[a]all weather road but portion of it inaccessible during heavy rain
[b]only dry season road

Table 4: Descriptive summary of selected variables

Variables	All samples	Participants	Non-participants	t-stat (diff)
Outcome Variables				
Crop income ('000 Birr)	4.621	5.141	4.491	1.33* (14%)
Log crop income	8.05	8.22	7.98	2.36*** (23%)
Food gap (months)	1.40	1.02	1.58	-0.56**(17 days)
Per capita food consumption (kcal/person/day)	2515	2772	2407	1.43*(15%)
Household characteristics				
Age of the head (years)	41.811	42.707	41.550	0.75
Gender of the household head (1=female)	0.120	0.058	0.137	2.89***
No schooling (1=yes)	0.42	0.41	0.43	0.28
Elementary education (1=yes)	0.23	0.17	0.26	2.42*
Junior education (1=yes)	0.23	0.28	0.21	1.70*
High school education (1=yes)	0.11	0.13	0.10	1.11
Proportion of labour force (productive age group) in the family	0.505	0.486	0.510	0.99
Proportion of dependents in the family	0.495	0.514	0.490	0.99
Family in polygamy (1=yes)	0.090	0.084	0.074	0.10
Family with a widow member (1=yes)	0.080	0.031	0.114	3.25***
Household wealth variables				
Owned land size (in ha)	0.80	0.95	0.74	4.00***
Per capita owned land size (in ha)	0.14	0.15	0.13	1.00
Family have member who have non agricultural income source	0.509	0.436	0.530	1.20
Owned number of Enset trees (Number)	26.710	31.221	25.444	0.86
Own pair of ploughing oxen (1=yes)	0.231	0.31	0.21	1.62**
Own donkey for transport (1=yes)	0.168	0.216	0.154	1.40*
Access related variables				
Access to fertilizer (1=yes)	0.553	0.683	0.517	2.23***
Total fertilizer use during the year (kg)	20.794	30.124	18.174	1.71***
Borrowed money during the year (1=yes)	0.372	0.424	0.357	1.14
Amount of birr borrowed (birr)	446.619	571.587	411.520	1.20
Distance from extension center (Minutes)	27.738	27.532	27.796	0.10
Contact with extension agent (Number)	11.680	12.816	11.365	0.98
Access to media (1=yes)	0.21	0.27	0.18	1.73***
Access to Telephone	0.260	0.249	0.263	0.34

Note: t-statistics are in absolute terms *significance at 0.1, ** significance at 0.05 *** significance at 0.01; summary statistics variables are weighted stats.

Table 5: Food gaps by participation (%)

	Non-participants	Participants	Pearson chi2
No food gap	47.45	52.11	5.82***
Less than one month	13.51	19.01	0.82
One to three months	18.32	19.01	1.35
More than three months	20.72	9.86	1.24**
Total	100	100	

Table 6: Food consumption by participation (%)

Food security level (kcal/day/per)	Non-participants	Participants	Pearson chi2
Food secure (>2100)	37.43	49.30	8.14***
Marginally food insecure (1,800 -2,100)	9.88	7.75	0.18
Moderately food insecure (1,500 -1,800)	10.78	7.04	2.55**
Chronically food insecure (<1,500)	41.92	35.92	5.90**
Total	100	100	

Table 7: Determinants of household decisions to plant castor seeds

	Jointly estimated probit		Marginal effects (dy/dx)			
	Participation in castor (yes=1)[a]		Probit		Tobit	
Land per capita (ha)	6.570**	(2.618)	1.649**	(0.705)	1.801***	(0.679)
Land per capita squared	-10.337**	(5.002)	-2.776*	(1.472)	-2.772*	(1.502)
Pr of maize before planting is made (birr)	-0.366**	(0.178)	-0.139**	(0.058)	-0.165***	(0.056)
Pre program asset indicator	0.629**	(0.262)	0.094**	(0.046)	0.048*	(0.025)
Farmers choice indicator	0.066	(0.172)	0.063	(0.061)	0.099*	(0.059)
Main info source (1=formal media)	0.320**	(0.157)	0.086	(0.055)	0.084*	(0.051)
Log of number of extension visits	0.022	(0.063)	-0.007	(0.020)	-0.006	(0.018)
Log of distance to extension service	-0.075	(0.088)	-0.011	(0.027)	-0.014	(0.028)
Log of number of Enset trees	0.023	(0.040)	0.006	(0.013)	0.005	(0.012)
Gender of household head	-0.450**	(0.228)	-0.141**	(0.057)	-0.132**	(0.061)
Household attended schooling (yes=1)	0.25	(0.153)	0.063	(0.048)	0.081*	(0.044)
Age of the head	0.03	(0.028)	0.017*	(0.010)	0.017**	(0.009)
Age squared	0.000	(0.000)	-0.000*	(0.000)	-0.000*	(0.000)
At least one family member works off-farm (yes=1)	-0.229*	(0.137)	-0.054	(0.043)	-0.066	(0.041)
Access to own pair of oxen(yes=1)	0.217	(0.192)	-0.002	(0.057)	0.032	(0.057)
Distance to the furthest plot from home	0.003	(0.003)	0.001	(0.001)	0.000	(0.001)
Constant	-0.578	(0.968)	1.649**	(0.705)	1.801***	(0.679)
District dummy	Yes		Yes		Yes	
Wald chi2	160.71		61.99		85.29	
N					476	

* p<0.1, ** p<0.05, *** p<0.01; bootstrap standard errors in parentheses

[a] This is selection equation is jointly estimated with the regime equation shown in the next table 8.

Table 8: Full information maximum likelihood estimates of the Switching regression model (Dependent variable=Log of food gap months)

	Participant		Non-participants	
Land per capita (ha)	-2.799**	(1.392)	-0.221	(0.637)
Land per capita squared	2.066	(2.550)	-0.177	(0.757)
Log of agricultural income per capita	-0.063	(0.057)	-0.074*	(0.039)
Log of non-agricultural income per capita	-0.013	(0.019)	-0.014	(0.017)
Age of the head	0.004	(0.003)	-0.002	(0.002)
Gender of household head	0.128	(0.126)	-0.034	(0.083)
Household attended schooling (yes=1)	-0.030	(0.064)	-0.140**	(0.059)
Family size	-0.053***	(0.019)	-0.014	(0.015)
At least one family member works off-farm (yes=1)	-0.109*	(0.062)	-0.113**	(0.055)
Family in polygamy (yes=1)	0.412***	(0.135)	0.177	(0.113)
Log of number of extension visits	0.025	(0.027)	0.029	(0.023)
Log of distance to extension service	-0.033	(0.037)	-0.003	(0.033)
Own livestock (TLU) per capita	-0.092	(0.066)	-0.165**	(0.073)
Log of number of Enset trees per capita	-0.015	(0.032)	0.011	(0.027)
Borrowed cash during the year (yes=1)	0.212***	(0.063)	0.100*	(0.055)
Constant	1.438***	(0.431)	2.030***	(0.273)
District dummy	Yes		Yes	
Sigma (δ)	-1.09***		-0.77***	
ρ	-0.22*		0.40**	
N				476
Likelihood ratio test of independent equations (X^2)				2.98*

Table 9: Full information maximum likelihood estimates of the Switching regression model (Dependent variables: Log food consumption kcal/capita/day)

	Participants		Non-participants	
Land per capita(ha)	0.384	(2.289)	2.030*	(1.042)
Land per capita squared	-1.090	(3.984)	2.780**	(1.255)
Log of agricultural income per capita	0.334***	(0.083)	0.186***	(0.067)
Log of non-agricultural income per capita	0.036	(0.030)	0.037	(0.029)
Age of the head	0.005	(0.004)	0.001	(0.004)
Gender of household head	-0.272	(0.188)	0.356**	(0.142)
Household attended schooling (yes=1)	0.010	(0.092)	-0.052	(0.100)
Family size	-0.150***	(0.034)	-0.162***	(0.025)
At least one family member works off-farm (yes=1)	0.246***	(0.093)	0.266***	(0.093)
Family in polygamy (yes=1)	0.150	(0.199)	-0.330*	(0.193)
Log of number of extension visits	0.094**	(0.039)	0.100**	(0.040)
Log of distance to extension service	0.005	(0.056)	0.100*	(0.055)
Own livestock (TLU) per capita	0.073	(0.107)	-0.061	(0.124)
Log of number of Enset trees per capita	-0.050	(0.046)	-0.018	(0.046)
Borrowed cash during the year (1=yes)	0.145	(0.092)	0.172*	(0.094)
Constant	5.432***	(0.802)	5.987***	(0.512)
District dummy	Yes		Yes	
Sigma (δ)	-0.71***		-0.18***	
ρ	0.23*		-0.34***	
N				476
Likelihood ratio test of independent equations (X^2)				5.28**

Table 10: Simulated net impact of participation in biofuel crop contract

Sub-sample	Decisions stage: To participate	Decisions stage: Not to participate	Treatment Effect
Log of food gap (months)			
Households who participated	(a) 0.84	(c) 1.20	(treated) -0.37***
Households who did not participate	(b) 1.04	(d) 0.98	(untreated) 0.06***
Log per capita annual food consumption (kcal/capita/day)			
Households who participated	(a) 7.86	(c) 7.59	(treated) 0.27***
Households who did not participate	(b) 7.23	(d) 7.41	(untreated) -0.18***

*significance at 0.1, ** significance at 0.05 *** significance at 0.01 level

Figure 1: Sampled villages in SNNP (South Nations and Nationalities) region, the dots indicate the villages surveyed

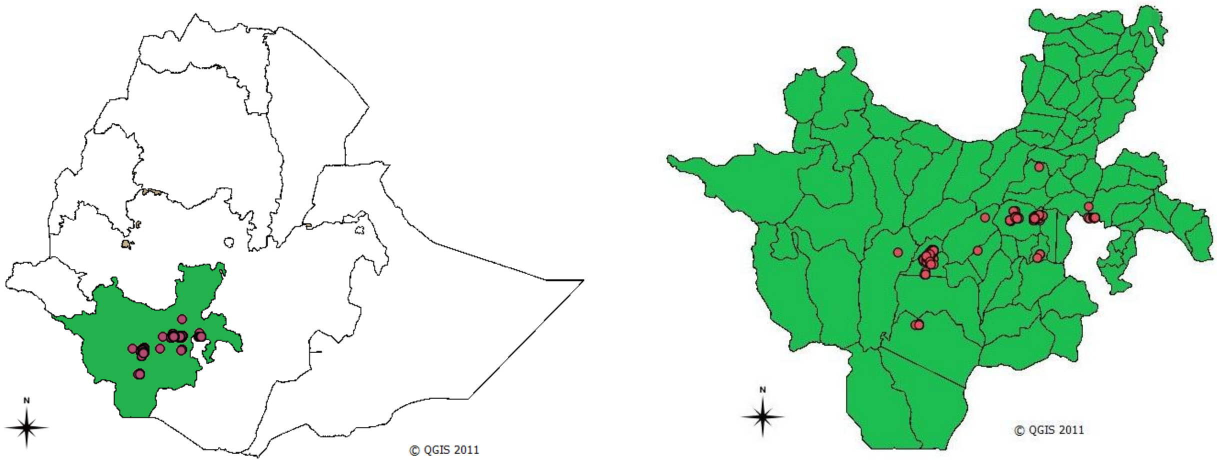
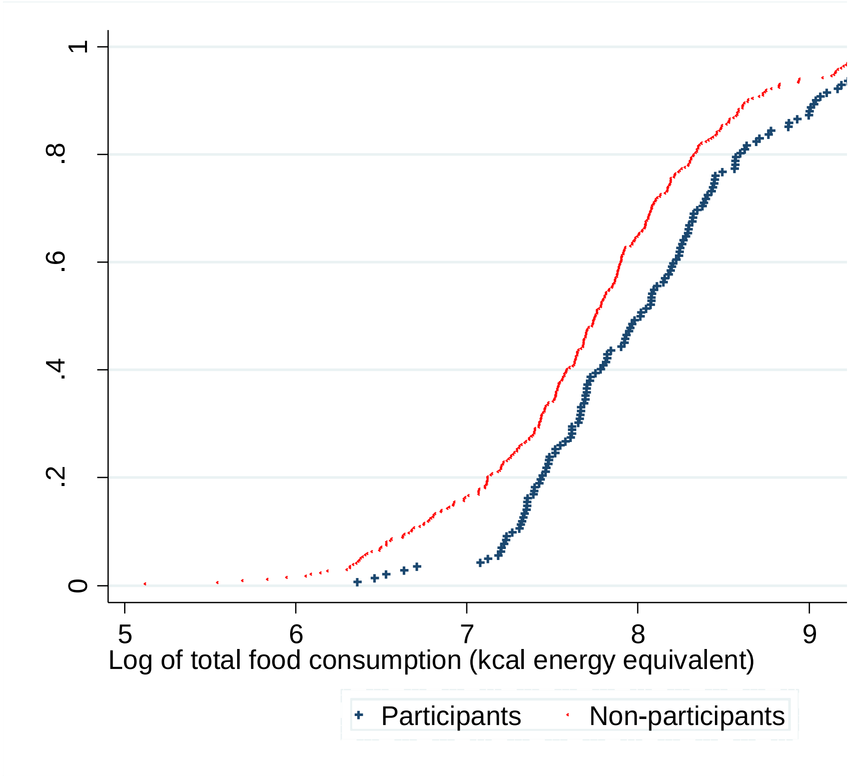


Figure 2: Distribution of per capita food consumption



Appendix 1 :

Table A1: Test on the acceptability of the selected instruments

Variable	(Model 1) Participation in castor (yes=1)		(Model 2) (a) Food gap months by farm households that did not adapt		(b) Food consumption (kcal/capita/day) by farm households that did not adapt	
Farmers choice	0.104*	(0.086)	0.010	(0.054)	-0.298	(0.384)
Formal media (radio and newspaper) information	0.395**	(0.180)	-0.211	(0.350)	0.079	(0.106)
Government extension information	-0.154	(0.132)	-0.019	(0.043)	-0.073	(0.074)
Informal contacts information	0.235	(0.217)	0.079	(0.074)	0.124	(0.116)
Distance from the extension center	-0.040	(0.076)	0.018	(0.026)	0.081	(0.142)
Constant	-0.925***	(0.328)	1.191***	(0.120)	6.710***	(0.192)
N	476		142		142	
Wald test (chi2)/F-STAT	31.63***		3.71		5.63	

Robust standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.01. Parameters for all the other variables are not reported.