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Household level spillover effects from biofuels: Evidence from Ethiopia

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The indirect effects of biofuels are mostly considered negative. In this paper, we argue that there may be a positive indirect effect of biofuels on food security and poverty. Our analysis shows that the introduction of castor production for biofuel in a poor country as Ethiopia can significantly improve food productivity of rural households who produce raw material for biofuel production. This spillover seems particularly linked to enhanced access to inputs and technical assistance which were provided as part of biofuel feedstock production contracts. Our results thus help nuancing the view that biofuels necessarily harm smallholders' food security.

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1. Introduction

Biofuels are an increasingly controversial issue, in particular in developing countries. On one hand, the proponents of the use of biofuels in developing countries point out that three quarters of the world's poor consume only 10% of the global energy supply (Bazilian et al., 2010).[1] Because energy poverty constrains poverty reduction efforts (Lee & Chang, 2008; Odhiambo, 2009; Kebede et al., 2010), diversification of energy resources, including biofuels, is viewed as a way to improve energy access and security – and thereby development. Sovacool (2012), for example, argues that decentralized production and distribution of biofuel energy in poor countries is a 'low hanging fruit' to expand energy access to energy deprived population in low-income countries. On the other hand, those opponents of biofuels argue that biofuels cause environmental problems and worsen food security. This is reflected in the 'food' versus 'fuel' debate (Bindraban et al., 2009; Cotula et al., 2008; Pimentel et al., 2009; FAO, 2008).

Empirically, the research on the relationship between food security and biofuels reaches conflicting conclusions. Some studies on the impact of biofuels suggest that biofuel investments provide alternative income through employment, boost economic growth, and thereby reduce the incidence of poverty and improve food security (Arndt et al., 2011; Huang et al., 2012; Negash & Swinnen, 2013). Others show that biofuel expansion reduces the availability of food and increases food prices, thereby jeopardizing food security for the poor (FAO, 2008; von Braun et al. 2008; Mitchell, 2008; Zhang et al. 2013).

The debate on the costs and benefits of biofuels has been dramatically changed by two studies (Searchinger et al., 2008; Fargione et al., 2008) highlighting the so-called indirect land use change effect (ILUC) which should be taken into account when evaluating the welfare effect of biofuels. These authors pointed out to the unintended consequences of releasing more carbon emissions due to land-use changes induced by the expansion of cropland for ethanol and biodiesel in response to the increased demand for biofuels. These arguments were reinforced by the 2008 food crisis which brought the link to food prices, food security and biofuel production to the forefront. For both environmental and food security reasons, the indirect effects of biofuels are considered negative.

[1] The majority of those energy poor households live in the net oil importing Sub-Saharan Africa. They often depend on direct burning of solid biomass as a prime source of energy with undesirable effects on health and agricultural productivity (Duflo et al., 2008).

In this paper we argue that there may be another indirect effect of biofuels which may be particularly important for smallholder feedstock production in poor countries. Using micro-survey evidence from Ethiopia and a matched plot pair design through which we control for the effect of plot and farmer characteristics, we find that food crop productivity improved on plots intercropped with biofuel feedstock (castor) due to enhanced access to inputs and technical assistance which were provided as part of the feedstock production contracts. Our estimates are in line with studies which have identified similar spillover effects of cash crop production on food crop productivity (Maertens, 2009; Minten et al., 2007; Barrett et al., 2012).

Our paper is the first to identify these indirect effects of biofuels on food crop productivity and to provide an estimate of the potential size. There is only limited information so far on the importance and the nature of contract farming in biofuel supply chains. Yet available studies suggest that it is present in several developing countries. Contract farming in biofuel chains is documented in Jatropha production in Zambia (German et al., 2011) and Tanzania (Portale, 2012), in soybean in Brazil (Padula et al., 2012), and in palm oil in Malaysia and Indonesia (Vermeulen & Goad, 2006). Our results may therefore have far reaching implications and may potentially be important for many poor people.

The paper is organized as follows. In section 2, we describe the biofuel policies and castor production in Ethiopia, together with their link with food security. In section 3, we present the setup of the castor outgrower scheme in the study area and explain our empirical methodology. Section 4 contains descriptive statistics on the farmers and plots producing the biofuel feedstock and a description of our measure of productivity. Productivity differences and econometric results are presented in section 5. Section 6 discusses and concludes.

2. Biofuels in Ethiopia

Ethiopia is a relevant case to study the micro-level effects of biofuels in developing countries. On the one hand, Ethiopia is a major energy importer. In fact it is considered as the number one "energy poor country" in Africa (Nussbaumer et al., 2012).[2] Developing renewable alternative resources therefore sounds appealing. On the other hand, Ethiopia's agriculture

[2] 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.

sector is heavily dominated by subsistence smallholders whose food security is vulnerable and who are often food aid recipients (Devereux & Guenther, 2009).

2.1 Biofuel policies

Enrouraged by the various commonly portrayed opportunities lying ahead of the development of biofuels (such as energy source diversification, foreign currency saving, rural poverty alleviation and technology transfers), in 2007 the Ethiopian government launched an extensive biofuels expansion strategy and an ad hoc investment promotion program for two biodiesel crops: castor and jatropha. At the same time, the government established a 10% blending requirement of ethanol with petrol, and biodiesel with diesel. While the ethanol target was successfully reached in 2012 in major cities, progress regarding the biodiesel target is meager. The government manages a vertically coordinated ethanol production system while biodiesel is left largely to private operators.

The availability of land, especially in under-developed regions makes Ethiopia attractive for the potential production of biofuel. According to government reports, 23.3 million hectares (20% of the total country area) are available for the production of both castor and jatropha (MoME, 2007). Even taking the more modest estimate by the World Bank (2011) of 7 million hectares of non-cultivated and non-protected land together with the high dependency of the country on oil imports, the development of a biofuel industry presents a notable opportunity to improve energy access and substitute fuel import for small-scale rural use, if not for the transport or industrial sector.

From 2007 onwards, the Government of Ethiopia has specifically supported the economic attractiveness of biofuel production and the expansion of investments in the sector by providing incentives to investors which include tax holidays, low-cost land leases, and long term credit facilities, among others. The government's interest in biofuels was later reemphasized in the Growth and Transformation Plan (GTP). Over a five year period (2010-2015), Ethiopia's GTP foresees increasing the production of ethanol to 194.9 million liters, biodiesel to 1.6 million liters, and an increase in blending facilities to 8 for ethanol and to 72 for biodiesel. As outlined, the main objectives for promoting biofuels are to create clean energy source diversity, serve as substitute for petroleum import and create jobs for local people. The document also recognizes the important contribution of involving the private sector and smallholders into the development of biofuel.

However, after a few years of enthusiasm, Ethiopia substantially downsized most of the incentives that were in place to promote the production of biofuels. The key reason behind this policy shift away from biofuel was an increasing concern over competition between food and biofuel crops and over bad management of land investments. This issue was raised by both the international and local communities and led to a substantive narrowing of land being allocated to investors for the production of biofuel feedstock. Now, only what is categorized as marginal land can be used for biofuel production (Negash & Riera, 2014).

2.2 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 beans and jatropha (Table 1). Both have been identified by the government of Ethiopia as priority crops for biodiesel feedstock because of their numerous attractive properties. First, castor, a non-edible crop that gives oil bearing seeds, has seen its global demand and production rise in recent years and it is believed to have strong market potential (Wijnands et al. 2007). The oil (i.e. biodiesel blended or not) can replace diesel without any engine modification. In addition, it can be used as automotive lubricant, as raw material for the cosmetic industry and in pharmaceuticals. Second, the oil contains a toxic element and hence does not compete directly with food or animal feed. Third, it can grow on marginal soils and is said to combat desertification (Reubens et al., 2011; Wani et al. 2012). These last two characteristics make castor production less threatening to local food production. However, at the same time, these marginal areas where castor production is allowed are areas with low agricultural potential and/or degraded areas and are often characterized by strong food insecurity.

>> insert Table 1 here <<

There are also other potential links between castor production and food security, such as the impact of castor production on the productivity of other (food) crops, through rotation or spillover effects. This is an issue which has received little attention in the biofuel literature but has been widely studied in the literature on cash crops and export agriculture (e.g. Minten et al., 2007). In the rest of this paper, we analyze these spillover effects from biofuel crops and we study how they affect food production, and thus food security, at the household level.

3. Data and methodology

3.1 Data

A farmers' survey was organized in February-March 2011 soon after the main harvest season in the South Nations and Nationalities (SNNP) region of Ethiopia. The objective was to evaluate the castor contract farming system established by a company in the Gomo Gofa and Wolayta districts which are known to be heavily food insecure (CSA, 2011).

Castor production started in the region in 2008 with castor seeds being distributed to more than 10,000 farmers in the two districts. However, due to the low value of castor as cash crop, initial uptake was very low and the company had to undertake extensive promotion campaigns to encourage farmers to grow castor. After three years of operation, adoption of castor had substantially increased.

The contract offered by the company to its suppliers is standard to most outgrowers contract schemes. Farmers receive all the necessary inputs such as fertilizer, herbicide, and 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 the village level are responsible for training farmers, facilitating group formation, input distribution and for following up the 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. Anecdotal evidence from company supervisors suggests that contract enforcement problems common to food supply chains are limited in this case.[3]

[3] This can be explained by the low competition in the area. For a review on contract enforcement problems in global supply chains, see Swinnen & Vandeplas (2010).

Regarding data collection, four districts (woredas) representatives of the Wolaita and Gamo Gofa administrative zones in the SNNPR region were chosen. We followed a stratified two-stage sampling technique through which 24 villages (kebeles)[4] were randomly drawn from the selected four districts (a map of the sampled villages is shown in Figure A1 in Appendix). The number of sampled villages in each district was chosen proportional to the size of the total number of villages per district. All villages in areas agro-ecologically suitable to grow castor (i.e. within the altitude range of 1040 to 2010 meters above sea level, outside of what is commonly known as highlands) have been targeted and received castor seeds from the company. These villages were all included in the sampling frame. Three main sources were used: (i) a list of all villages per district, together with demographic data, obtained from the zone statistical office (ii) a list of all households residing in each village, obtained from the village administration and (iii) a list of all households who received castor seeds, obtained from the company.

In each village, households were stratified as participants and non-participants and to 18 to 22 households were interviewed. Households were selected systematically from the list of households residing in the village, 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. Our sample thus represents smallholder farmers in the castor growing areas of the region. . It contains information about 478 farmers in 24 villages of which 113 grow castor. Among them, 107 (94%) own more than one plot and 83 (75%) intercrop castor on one of their plot.

3.2 Empirical strategy

Evaluating the effect of technology adoption on productivity faces numerous challenges. Observable and unobservable farmers' and land characteristics are correlated with farm productivity measures because they influence technology and crop adoption decisions, input application choices and observed outcomes. Farmers and farms heterogeneity will lead to a selection bias if not properly accounted for. For example, more skilled and/or better educated farmers can be more inclined to adopt the new technology. If this is the case, comparing outcomes of adopters and non-adopters to analyze the impact of a given technology will suffer from a self-selection problem and yield inconsistent and biased results. Hence, it is important to control for farmer differences when comparing outcomes across types of farmers. But a

[4] Kebeles are the lower administrative unit in Ethiopia, they are equivalent to a village or a cluster of a few villages.

second challenge lies in the fact that farmers can implement the technology on their best plots or at least on plots having favorable characteristics and offering a higher productivity for the technology being adopted. Differences across plots should also be accounted for when comparing outcomes across plots.

To overcome these methodological challenges, we follow the method proposed by Barrett et al. (2004) and used in Chen & Yen (2006) and Minten et al. (2007). Using data from adopting farmers only and detailed information on plots both under the new and old technology, we are able to isolate the productivity effect of adopting the technology, i.e. in our case castor production. We use panel data methods applied to a situation where instead of the 'time' dimension, we have different plot observations. The vast majority of farmers who adopted castor have more than one plot and at least one is intercropped with castor. Because farmers simultaneously use both technologies, i.e. at least one plot is intercropped with castor and one plot is not, we will randomly select one plot intercropped with castor and one plot without castor production. Using a sample of paired plots cultivated by the same farmer in the same season and using detailed information on plot characteristics to control for differences, we are able to measure the spillover effect from adopting castor and hence resolve the unobserved heterogeneity problem.

Following the specification from Barrett et al. (2004) and Minten et al. (2007), the technologies on each of the two plots, the castor intercropped plot and the plot without castor, can be represented by:

$$y_{ic} = f_{ic}(x, z)$$

$$y_{nic} = f_{nic}(x, z)$$

Where y_{ic} is a measure of productivity of castor intercropped plots, y_{nic} a measure of productivity on plots without castor, x is a t dimensional vector representing production inputs under the control of the farmer and z is a s dimensional vector including exogenous plot characteristics.

Taking a standard logarithmic Cobb-Douglas function,

$$\log y_{ic} = \alpha_{ic\,0} + \sum_{j=1}^{t} \beta_{ic\,j} \log x_{ic\,j} + \sum_{j=1}^{s} \delta_{ic\,j} \log z_{ic\,j} \quad (1)$$

$$\log y_{nic} = \alpha_{nic\,0} + \sum_{j=1}^{t} \beta_{nic\,j} \log x_{nic\,j} + \sum_{j=1}^{s} \delta_{nic\,j} \log z_{nic\,j} \quad (2)$$

Differencing equations (1) and (2), we get the differential production function:

$$d\ \log y = \alpha_0 + \sum_{j=1}^{t} \beta_j\, d\ log\, x_j + \sum_{j=1}^{s} \delta_j d\ log\, z_j + d\ \varepsilon \qquad (3)$$

Where $d \log y$ is the difference in productivity, $d \log x$ the difference in input application rates on the two plots, $d \log z$ reflects the exogenous differences in the plots and $d\ \varepsilon$ is a mean zero independent error term. All farmer-specific characteristics that are plot invariant, whether observed (e.g. education, gender, household size, rainfall) or unobserved (e.g. ability, social connections) are differenced away. Direct estimation of Equation (3) and particularly the parameter α_0 gives consistent and unbiased estimates of plot productivity differences attributable to castor production.

4. Descriptive statistics and food productivity indicators

4.1 Farm and farmers characteristics

The predominant farming system of the study area is a mixed crop-livestock system. The most important food crops which farmers cultivate include diverse types of cereals and root crops and enset (commonly called "false banana") [5]. Some farmers produce some local cash crops such as fruit, ginger, coffee, and cotton. Crop production entirely depends on rainfall, which is often erratic and unpredictable and which leaves many vulnerable to food insecurity. Almost half (47%) of the families in these regions face 2 to 3 months of food shortages, according to CSA (2011).

Descriptive statistics of farmers growing castor are shown in Table 2. 89% of the households in our sample are headed by a men. The average head has about 45 years old and 3 years of education. On average, households have 7 members of which 4 are in the labor force (productive age group). The large majority of households participate in activities benefiting the community and less than 10% of them had a mobile phone at the time of interview. Looking at an indicator of food insecurity, 33% of adopters have failed to get adequate food at some point during the last season and only 19% of the sample has had troubles fulfilling his family's food need during at least 2 months, which is considerably smaller than the regional average of 47%

[5] Enset is a perennial and relatively drought-resistant plant, maturing at around four years and grows up to seven years, serves as a food store for most households.

(CSA, 2011). Smallholders have on average 1ha of land but there is a wide dispersion. The land they cultivate is divided into 3 plots, of which 1 is intercropped with castor. The average area allocated to castor is 0.13 ha and the variation among farmers is small. On average, respondents had been contracted to the company for one and a half years.

>> insert Table 2 here <<

Table 3 provides details on the extent of intercropping with castor. The number of crops castor is intercropped with varies from 1 to 11, with the proportion of plots where 2, 3 or 4 or more crops are cultivated in total being fairly equal in the sample (Table 3a). It can also be seen that there is a large diversity in terms of the crops that are cultivated together with castor. The most frequent crop is maize, closely followed by haricot beans and then coffee, sweet potato and mango (Table 3b).

>> insert Table 3 here <<

Qualitative indicators (Table 4) show that 67% of the households are happy with the assistance they received from the company and 53% would recommend other farmers to join the program. Slightly less than half of the sample is satisfied with the contract itself. To understand farmers' motivation, we asked them about their perceived benefits associated with growing castor. 87% of participant farmers responded that they planted castor in the expectation of higher income. Interestingly, only 10% of them stated it was mainly to benefit from higher soil productivity associated with planting castor. This suggests that a small share of farmers were aware of the soil improvement benefit of castor, especially when used in intercropping.

Analyzing possible improvements and problems, 70% of the farmers state that the company should increase the price paid for the castor beans. During interviews, several farmers indeed complained that castor was not profitable given the current market prices of other food crops. 22% of the farmers mention that assistance and technical support should be improved and 19% mention the need for additional inputs (fertilizers, seeds and pesticides).

>> insert Table 4 here <<

4.2 Food productivity indicators

To measure plot level food crop productivity we use data on crop production and compute two different indicators: a measure of income and a measure of calories produced, each of which are standard practices in the literature (Govereh & Jayne, 2003; Holden, et al., 2001; Kassie, et al., 2011).[6,7] First, we converted all plot level production into monetary values. We computed the food crop value aggregates using average prices from the entire sample that can be considered as a proxy for the regional market price levels. Second, we converted plot level food crop production to calorie equivalent and computed food productivity in terms of the calorie content. Using FAO and WFP guidelines, we used standard food caloric conversion rates to convert food production into energy kilo calorie (kcal) equivalent levels (FAO, 2003; FAO/WFP, 2009).

To be able to compare plot productivity between plots that are intercropped with castor and plots that are not intercropped with castor, we compute a measure of income and calories produced on each plot per hectare without castor production.

5. Spillovers of biofuel production on productivity

5.1 Unconditional productivity differences between castor plots and non-castor plots

Unconditional productivity differences using the indicators described in section 4.2 for the two plots that were selected in the matched sampling design are presented in Table 5.[8] At the farm level, we compare a plot intercropped with castor with one plot without castor randomly selected among the plots without castor of the farm. Descriptive statistics at the plot level indicate that food crop income per hectare without castor is 79% higher on plots intercropped with castor. Food crop income increases from 2,221 Ethiopian Birr (ETB) to 3,982 ETB and the difference is significant at the 10% level.[9]

An even larger and significant difference appears when comparing food production in calories per hectare without castor across plots that are intercropped with castor and the ones that are not. Total calories produced on plots with castor is on average 112% higher.

To understand where the differences in productivity come from, it is interesting to analyzing input differences. The data in Table 5 indicate that labor input (measured as the

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[6] Because of data unavailability, we are not able to calculate the Land Equivalent Ratio, a commonly used index of intercropping benefits defined as the relative land area required as sole crop to produce the same yields as inter-cropping (Vandermeer, 1992).
[7] Information on crop cultivation was elicited by the household survey. For each plot and each crop, we asked farmers to provide information on the quantity harvested. For the purpose of aggregating, the different units of measurement used have been transformed into kilograms.
[8] Since our empirical strategy involves matching one plot intercropped with castor with one plot without castor at the farm level, we lose some observations due to incomplete data. Some farmers only cultivate one crop in the main agricultural season, some others cultivate more than one plot but castor is cultivated on all of them. These cases were excluded from our analysis.
[9] At the time of the survey (2011), the US$-ETB exchange rate was around 17.

number of man-days worked on the plot) is similar between the two types of plots but that the quantity of fertilizer applied on plots with castor is double. This reflects the fact that not only do participants receive better access to fertilizers through the contract scheme but also that they use it where they are supposed to, on the plots where castor is grown. The differences do not appear to be due to differences in irrigation because plots without castor seem to be even less irrigated than plots with castor. However, the difference should be interpreted with caution given the small number of plots with an irrigation system.

Comparing the characteristics of the plots, we see that the size of the plots where castor is grown is larger but the difference disappears if we compare the area of land cultivated excluding the land allocated to castor. On average, farmers cultivate 2 to 3 different crops on the same plot. When castor is grown, it is added as an extra crop to the plot but does not seem to reduce the number of other crops on the plot. Table 5 also presents physical characteristics of the two plots that were selected in the matched sample. The descriptive variables indicate that the plots seem to be fairly similar in several aspects such as ownership, soil type, slope and quality 5 years ago. One interesting difference emerges when we look at reported quality. The share of plots with castor considered as fertile by the farmers is smaller than the share of plots without castor that are said to be fertile. This is similar to the irrigation differences, and suggests that farmers did not decide to grow castor seeds on their more fertile plots.

>> insert Table 5 here <<

To get a better understanding of the differences between the plot intercropped with castor and the plots without castor, table 6 presents the results from a simple selection (logit) model at the plot level where the dependent variable equals 1 if the plot was intercropped with castor and 0 if it was not. None of the coefficients is significantly different from zero. This further confirms that on average the plots with and without castor are of similar quality.[10]

>> insert Table 6 here <<

[10] In Appendix C, we evaluate whether the lack of significant results in the logit model is a result of high standard errors because of multicollinearity between the explanatory variables. We propose two indicators: partial correlations and variance inflation factors, and neither of these suggests that severe multicollinearity is at hand. Subsequent results from regression models which include the same explanatory variables can thus be interpreted with confidence.

5.2 Econometric results

We now turn to the econometric analysis and implement the empirical analysis described in section 3.2 to evaluate and explain the productivity differences between plots where castor is grown and plots where it is not. We ran a differential productivity regression on a sample of paired randomly selected plots, plots intercropped with castor and plots without castor, each pair cultivated by the same farmer. Results are presented in Table 7. Potential sources of bias have been removed since observed and unobserved farmer and community-specific variables have been differenced away.

Results confirm that the physical characteristics of the plots do not contribute much to explain the productivity differences between the plots. Only a black soil type leads to significant higher productivity, both when measured by the calories and income indicator. Analyzing the main variable of interest, it can be seen that the intercept is large and significant. The increase in productivity measured in terms of food calories produced ranges between 528,820 and 796,507 calories per hectare without castor, which represents an increase of 35%-52% (columns (1) – (2)). The effect decreases when controlling for the quantity of fertilizer applied on the plot but remains significant. The increase in productivity measured in terms of food income is of similar magnitude. Productivity increases by 46% (or equivalently 1,030 ETB/ha) on plots intercropped with castor (column (3)). Controlling for fertilizer use, the positive effect on productivity measured by income decreases to 25% and becomes insignificant. This confirms the fact that spillovers from castor production for biofuels are partly attributable to better access to fertilizers and inputs.

As robustness tests, we ran several alternative econometric specifications (including Random Effects and Pooled OLS models). The results of these additional analysis are presented in Appendix B (Tables B1 and B2). All the results are qualitatively and quantitatively similar to the ones presented here, lending support to the robustness of our results.

>> insert Table 7 here <<

With relevant explanatory variables and a matched plot pair design we have done our best to account for observables and unobservable characteristics both at the farmer and the plot level. While we cannot be certain that we have not omitted any relevant explanatory variable, we are confident that the resulting bias would be smaller than the productivity enhancing effect from the cultivation of castor and access to fertilizers.

In summary, our analysis shows that the introduction of castor production for biofuel in a poor country as Ethiopia can significantly improve food productivity of rural households who produce raw material for biofuel production. Indeed, farmers allocated around 30% of one of their plots (13% of their total land) to castor production but as this paper shows, it does not mean that 13% less food is being produced since the increase in plot productivity on the remaining of the land increased by at least 35%. Spillovers of castor production cause strong increase in food productivity, thereby offsetting the impact of reduced land used for food crops.

6. Conclusion

The effects of biofuels on smallholders in developing countries are still lively debated. We contribute to the discussion presenting micro-evidence on the indirect impact of cultivation of a biofuel feedstock crop, castor, for poor farm households in Ethiopia. Using survey data collected in early 2011 in the SNNP region about farmers engaged in a feedstock production contract with a company, we show that large spillover effects exist. Using a matched plot design to pair plots where castor is grown and intercropped with plots where no castor is grown at the farmer level, and using two measures of productivity (i) food crop income and (ii) food calories produced, we show that productivity is between 35% and 52% higher on plots intercropped with castor.

This increase in productivity seems particularly linked to enhanced access to inputs and in particular fertilizer which were provided as part of the biofuel feedstock production contract. The effect is large but not that surprising since fertilizer use is very constrained in the region surveyed and marginal effects can be very significant in such circumstances. We show that farmers apply the inputs received on the plots where castor is grown.

Significant spillover effects of contract farming for food crops on non-contracted food crops have been shown in the literature. These have been shown to result from access to improved technologies, better management practices, better input use and improved land quality due to rotation and intercropping (Minten et al. 2007; Swinnen & Maertens, 2007; Masakure & Henson, 2005). In this paper, we show that such positive spillover effects through which participants in contract schemes improve food productivity may also occur in the case of biofuel feedstock. This paper thus help nuancing the view that biofuels necessarily harm smallholders’ food security.

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Tables

Table 1. Private biodiesel projects in Ethiopia

Type of business model	# of projects	Type of feedstock specialized	Total area (ha)	
			Total allotted/or leased ('000 ha)	**Under cultivation ('000 ha)**
Large scale plantations[a]	3	Castor, Jatropha, Pongamia	66.7	8
Outgrowers[b]	1	Castor	NA	1.5-3
Mixed outgrower with plantation	2	Castor	3	3
PPP[c]	1	Castor, Jatropha, Candlenut, Croton	15	7

Source: data collected from the authors' own survey

[a] All are foreign firms

[b] Cultivation is integrated with farmers' own plots which makes it difficult to estimate the exact land allocation under this scheme. From Negash & Swinnen (2013), 10-20 thousand households cultivate on average 0.15 ha each. This approximately gives a total of 1500-3000 hectares of land allocated to castor under this scheme

[c] In some cases, farmers are encouraged to plant jatropha as fences and collect the seeds.

Table 2. Farmers' and farms characteristics

Variable	Mean	SD	Min	Max
# of observations	83			
Head of household				
% of male	90			
Age	43.9	13.3	18	95
Years of education	3.3	4.2	0	15
Household characteristics				
Household size	6.8	2.6	1	18
% of hh members in labor force	59			
% with at least one member working off-farm	41			
% that own a mobile phone	8			
% involved in any communal activity	89			
% that failed to get adequate food during last season	33			
% that failed to get adequate food for at least 2 months during the last season	19			
Livestock units owned (TLU)	2.800	3.180	0	17.40
Total land owned (ha)	1.030	0.640	0.250	4.750
# of plots owned	2.990	1.100	1	6
Average distance between plots and home (min)	10.87	10.54	0.700	46.50
Castor contract				
Years since start of contract	1.570	0.680	1	3
Land allocated to castor (ha)	0.130	0.087	0.025	0.417
# of plots intercropped with castor	1.036	0.188	1	2
# of extension agents' visits in the last year	8.660	11.03	0	48
% that are satisfied with the assistance from the company	67			
% that would recommend others to join the program	53			
% that are satisfied with the contract with the company	48			

Source: own survey

Table 3. Details of intercropping

a. # of crops intercropped with castor

	%
1	33
2	34
3	13
4 or more	20

Source: own survey

b. Main crops intercropped with castor

	%
Maize	39
Haricot beans	35
Coffee	23
Sweet Potato	22
Mango	20
Cassava	18
Moringa	17
Teff	16
Banana	16
Avocado	11
Enset	10

Source: own survey

Table 4. Quality and motivation to grow castor

	% of farmers
Satisfaction	
Farmers satisfied with the assistance from the company	67
Farmers that would recommend others to join the program	53
Farmers are satisfied with the contract with the company	48
Reasons to grow castor[a]	
Higher income	87
Higher soil productivity	10
Guaranteed market	1
Other	1
Areas of improvement[b]	
Price of castor is too low	70
Technical assistance should be strengthened	22
Input supply should increase and be better timed	19

[a] Only one response was allowed.
[b] The sum exceeds 100% because more than one response was allowed.
Source: own survey

Table 5. Plot level characteristics (main agricultural season)

Variable	Plots without castor	Plots with castor	Difference	T-statistic
# of observations	72	72		
Productivity				
Food crop income (ETB)	753	974	220	-0.99 *
Food crop income per hectare (ETB)	2,221	2,520	299	-0.51
Food crop income per hectare without castor (ETB)	2,221	3,982	1,761	-1.69 *
Food production (calories)	529,208	797,438	268,230	-1.37
Food production (calories) per hectare	1,521,031	2,003,377	482,346	-0.94
Food production (calories) per hectare without castor	1,521,031	3,224,338	1,703,306	-1.77 *
Plot inputs				
Plot labor input per hectare (adult equivalent)	375	361	-14.12	0.13
Plot fertilizer use per hectare (kg)	14.9	30.36	15.46	-2.31 **
Plot irrigated (dummy)	0.07	0.00	-0.07	2.30 **
Plot characteristics				
Plot size (ha)	0.34	0.42	0.08	-1.66 *
Land cultivated with castor	-	0.13	-	-
Number of intercropped crops	2.74	3.50	0.76	-2.57 **
Years since plot was last left fallow	0.24	0.10	-0.14	1.31
Distance between plot and home (min)	16	19	3.13	-0.72
Plot physical characteristics				
Plot soil type: black	44%	28%	-16%	2.1 **
Plot soil type: mixed	31%	38%	7%	-0.88
Plot soil type: red	21%	31%	10%	-1.33
Plot soil type: other	4%	3%	-1%	0.45
Plot ownership: owned	90%	94%	4%	-0.94
Plot ownership: rented	4%	3%	-1%	0.45
Plot ownership: sharecropped	0%	1%	1%	-1
Plot quality: fertile	58%	42%	-16%	2.01 **
Plot quality: average	32%	42%	10%	-1.21
Plot quality: poor	8%	14%	6%	-1.06
Plot quality 5y ago: better	57%	58%	1%	-0.17
Plot quality 5y ago: same	29%	28%	-1%	0.18
Plot quality 5y ago: worse	8%	10%	2%	-0.29
Plot slope: flat	72%	65%	-7%	0.9
Plot slope: gentle	18%	28%	10%	-1.39

Plot slope: steep	10%	7%	-3%	0.6
Plot with terraces	19%	21%	2%	-0.21

*p<0.10, **p<0.05, ***p<0.01
At the time of the survey (2011), the US$-Ethiopia Birr (ETB) was around 17.
Source: own survey

Table 6. Selection equation, plots intercropped with castor (=1) versus plots without castor

	Coefficient	z-value
Plot size (ha)	1.99	(1.75)
Plot soil type: black	-0.56	(0.36)
Plot soil type: red	-0.30	(0.44)
Plot quality: fertile	-0.31	(0.30)
Plot quality: poor	0.04	(0.39)
Plot slope: gentle	0.52	(0.53)
Plot with terraces	-0.09	(0.44)
Years since plot was last left fallow	-0.47	(0.47)
Plot ownership: owned	-0.01	(0.61)
Distance between plot and home (min)	-0.01	(0.01)
Plot slope: steep	-0.19	(0.62)
Plot quality 5y ago: better	-0.01	(0.28)
Plot quality 5y ago: worse	0.12	(0.40)
Constant	-0.23	(0.58)
# of observations	142	
Log likelihood	-92.29	
Wald test	33.88	
Prob>Chi2	0.005	

Cluster robust standard errors in parentheses

Table 7. Differential productivity regression on plots intercropped with castor and plots without castor

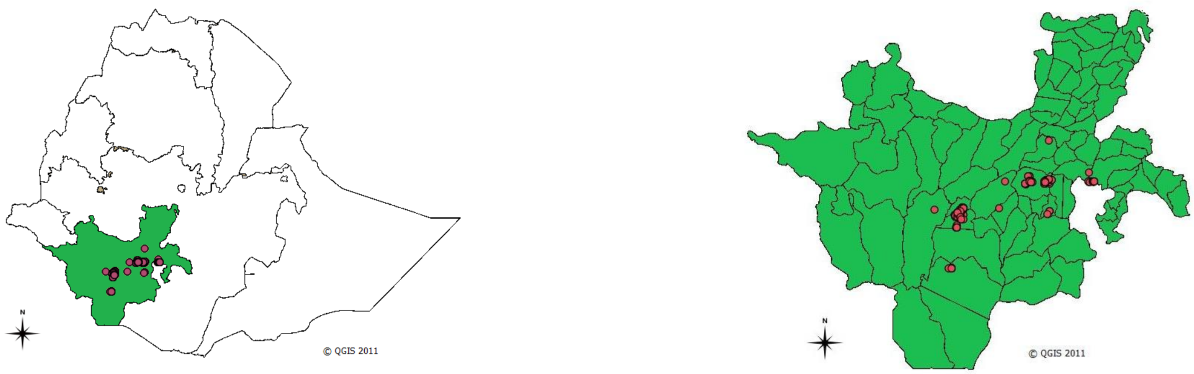
	Food calories per ha w/o castor		Food income per ha w/o castor	
	(1)	(2)	(3)	(4)
Intercept	796,507***	528,820*	1,030***	550
	(227,951)	(275,115)	(268)	(402)
D.Plot fertilizer use per ha (kg)		15,766**		26***
		(6,784)		(8)
D.Plot labor input per ha (adult equivalent)	442	250	0.159	0.001
	(328)	(268)	(0.480)	(0.382)
D.Plot soil type: black	883,969*	923,836*	1,960**	1,510**
	(484,731)	(526,822)	(876)	(631)
D.Plot soil type: red	611,496	267,350	906	418
	(504,917)	(464,374)	(664)	(704)
D.Plot quality: fertile	545,683	350,773	52	374
	(660,959)	(657,900)	(1309)	(938)
D.Plot quality: poor	757,983	172,095	617	-99
	(884,978)	(617,994)	(860)	(644)
D.Number of intercropped crops	106,911	58,423	-85	-178
	(147,929)	(125,428)	(163)	(164)
D.Plot with terraces	403,837	620,168	1,916	1,932
	(1,249,553)	(1,199,524)	(1,415)	(1,353)
D.Plot ownership: owned	-550,624	92,937	188	820
	(1,133,259)	(1,119,450)	(1,475)	(1,514)
D.Distance between plot and home (min)	2,2125*	13,115	18	7
	(11,251)	(12,755)	(13)	(13)
Observations	68	68	68	68
R-squared	0.138	0.225	0.145	0.273

Cluster robust standard errors in parentheses
District dummies included but not reported
* p<0.10, ** p<0.05, *** p<0.01

Appendix

A. Map of sampled villages

Figure A1: Sampled villages in SNNP (South Nations and Nationalities) region



B. Robustness tests

Table B1. Productivity effects on plots intercropped with castor – Random effect model

	Food calories per ha w/o castor		Food income per ha w/o castor	
	(1)	(2)	(3)	(4)
Plot intercropped with castor	705,205***	519,300*	558*	247
	(251,986)	(285,095)	(331)	(405)
Plot fertilizer use per ha (kg)		10,620*		23**
		(6394)		(10)
Plot ownership: owned	332,236	387,795	458	575
	(348,535)	(322,920)	(510)	(461)
Distance between plot and home (min)	9,481	7,458	7	5
	(5,792)	(6,343)	(6)	(7)
Plot labor input per ha (adult equivalent)	61	22	0.130	0.026
	(157)	(155)	(0.248)	(0.237)
Plot soil type: black	450,846	410,154	590	364
	(475,335)	(462,906)	(765)	(607)
Plot soil type: red	616,533***	538,125***	592*	470
	(184,366)	(197,743)	(334)	(327)
Plot quality: fertile	-80,507	53,717	-166	234
	(387,901)	(398,618)	(694)	(557)
Plot quality: poor	-822,899***	-722,573***	-1129***	-883***
	(260,591)	(249,070)	(387)	(334)
Number of intercropped crops	20,399	-10,708	-88	-121
	(74,274)	(59,047)	(74)	(74)
Plot with terraces	371,532	416,758	636	738
	(398,047)	(438,228)	(665)	(737)
Number of plots owned by household	-174,798	-136,601	-386	-287
	(219,901)	(234,175)	(382)	(402)
Household size	-29,176	-22,971	-26	-32
	(65,340)	(62,958)	(103)	(88)
Education of the HH head (years)	33,407	18,604	12	-0.666
	(28,598)	(25,420)	(54)	(45)
Gender of HH head	374,575	403,420	865	843
	(414,905)	(391,039)	(624)	(552)
Observations	140	140	140	140

Cluster robust standard errors in parentheses
District dummies included but not reported
* p<0.10, ** p<0.05, *** p<0.01

Table B2. Productivity effects on plots intercropped with castor – Pooled OLS model

	Food calories per ha w/o castor		Food income per ha w/o castor	
	(1)	(2)	(3)	(4)
Plot intercropped with castor	701,571**	521,224*	561*	248
	(252,908)	(289,666)	(342)	(417)
Plot fertilizer use per ha sila (kg)		10,176		22*
		(6,394)		(11)
Plot ownership: owned	366,848	424,431	544	632
	(324,139)	(292,749)	(466)	(427)
Distance between plot and home (min)	8,905	6,811	6	4
	(5,651)	(6,081)	(6)	(7)
Plot labor input per ha (adult equivalent)	50		0.119	0.010
	(160)	(162)	(0.253)	(0.252)
Plot soil type: black	434,678	379,201	497	252
	(471,066)	(459,594)	(751)	(609)
Plot soil type: red	624,458***	553,846**	586*	479
	(185,020)	(200,059)	(335)	(341)
Plot quality: fertile	-105,714	20,784	-208	179
	(388,171)	(402,951)	(651)	(553)
Plot quality: poor	-874,359***	-788,933***	-1288***	-1029***
	(271,358)	(267,452)	(397)	(364)
Number of intercropped crops	17,494	-12,584	-90	-121*
	(71,935)	(57,094)	(71)	(69)
Plot with terraces	372,650	420,800	577	701
	(398,055)	(438,449)	(667)	(748)
Number of plots owned by household	-180,011	-145,225	-401	-304
	(220,220)	(233,717)	(383)	(403)
Household size	-29,070	-23,228	-27	-33
	(64,086)	(61,498)	(101)	(86)
Education of the HH head (years)	32,844	18,774	12	0.115
	(28,446)	(25,681)	(53)	(45)
Gender of HH head	369,993	394,464	843	815
	(409367)	(384,467)	(606)	(533)
Observations	140	140	140	140
R-squared	0.187	0.219	0.139	0.227

Cluster robust standard errors in parentheses
District dummies included but not reported
* p<0.10, ** p<0.05, *** p<0.01

C. Checking for multicollinearity

Table C1. presents the correlation matrix of all independent variables used in the selection equation (Table 6). We see that the correlations between most of the variables are low. The variables that are the most correlated are soil typesblack and red and quality-fertile but the magnitude of these correlations are still very much acceptable (0.46). However, because the test of multicollinearity with partial correlation has been criticized as being incomplete (Gujarati, 2004), we propose a second method. Table C2. presents the R^2 coefficient and the Variance Inflation Factor (VIF) from the selection equation (Table 6). The R^2 results from the regression of all other variables on each variable. The VIF is computed as $1/(1-R^2)$ and gives an indicator of how much of the inflation of the standard error could be caused by collinearity. If all variables would be orthogonal to each other, the VIF would take a value of 1 while it could get very large in the opposite case. As a rule of thumb, VIFs greater than 10 are considered as indications of severe multicollinearity (Cameron & Trivedi, 2005). With all VIFs being smaller than 2, we conclude that concerns about multicollinearity can be dismissed. Because these variables are also used in the main regression model, we are confident about the interpretation and robustness of our results.

Table C1. Pairwise correlation matrix of independent variables, selection equation

	Plot size (ha)	Plot soil type: black	Plot soil type: red	Plot quality: fertile	Plot quality: poor	Plot slope: steep	Plot slope: gentle	Plot with terraces	Plot quality 5y ago: better	Plot quality 5y ago: worse	Years plot left fallow	Plot owned
Plot size (ha)	1											
Plot soil type: black	-0.02	1										
Plot soil type: red	0.06	-0.46	1									
Plot quality: fertile	0.07	0.40	0.05	1								
Plot quality: poor	0.02	-0.14	0.06	-0.34	1							
Plot slope: steep	0.00	-0.17	-0.02	-0.05	0.07	1						
Plot slope: gentle	-0.24	0.05	0.03	-0.16	-0.01	-0.17	1					
Plot with terraces	-0.09	-0.04	-0.05	-0.02	0.07	0.35	0.30	1				
Plot quality 5y ago: better	-0.03	0.19	-0.08	0.10	-0.21	-0.21	0.15	-0.11	1			
Plot quality 5y ago: worse	-0.11	-0.13	0.24	-0.03	0.14	0.34	0.06	0.26	-0.38	1		
Years plot left fallow	-0.01	-0.14	0.14	-0.08	0.10	0.07	-0.10	-0.09	-0.20	-0.05	1	
Plot owned	0.01	-0.01	-0.05	0.00	-0.12	0.07	0.13	0.12	0.17	0.08	-0.05	1
Distance b/w plot and home	0.36	-0.06	0.06	0.03	-0.08	-0.08	-0.26	-0.17	0.08	-0.13	0.08	-0.09

Table C2. Multicollinearity test, selection equation

Variable	Variance Inflation Factor	R^2
Plot size (ha)	1.23	0.19
Plot soil type: black	1.82	0.45
Plot soil type: red	1.62	0.38
Plot quality: fertile	1.57	0.36
Plot quality: poor	1.22	0.18
Plot slope: steep	1.44	0.31
Plot slope: gentle	1.46	0.32
Plot with terraces	1.41	0.29
Plot quality 5y ago: better	1.42	0.30
Plot quality 5y ago: worse	1.54	0.35
Years since plot was last left fallow	1.13	0.12
Plot ownership: owned	1.12	0.11
Distance between plot and home (min)	1.27	0.21