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Contract farming and the adoption of sustainable farm practices: Empirical evidence from cashew farmers in Ghana

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Abstract

Contract farming has been shown to increase agricultural productivity and thus welfare of farmers in developing countries. However, studies that look at the potential environmental effects of contract farming remain quite scanty. This is however crucial, since contract farming may contribute to intensification in cultivation of the contracted crops, in terms of area and the intensity of inputs used. This study investigates the impact of participation in contract farming on sustainable farm practices, using a marginal treatment effects (MTEs) approach to account for potential selection bias and heterogeneity across households. The empirical results show significant heterogeneity in the effects of contract farming on the intensity of sustainable farm practice use. In particular, farmers with high propensity to participate in contract farming tend to have low probabilities of using sustainable farm practices. The findings of this study not only provide new insights into the heterogeneous effects of contract farming, but also entry points for further research to address the dual challenge of agriculture to produce sufficient food, while reducing the adverse impact on the environment.

KEYWORDS
contract farming, marginal treatment effects, sustainable farm practices

JEL CLASSIFICATION
O13, Q15, Q27, Q51

Several studies have shown that participation in contract farming constitutes an important vehicle in the transition to modern agriculture and significantly improves the living conditions of many smallholder farmers worldwide. It does not only enable smallholder farmers to overcome market and production barriers, and to sell their products on international markets, but also leads to higher yields, higher incomes, and to improved food security (Dubbert, 2019; Dubbert & Abdulai, 2021; Maertens & Velde, 2017; Minot & Sawyer, 2016; Ton et al., 2018; Wang et al., 2014).

Despite this voluminous literature on the economic impacts of contract farming, very few studies have examined its effects on the environment and sustainable farm practices generally (Ibanez & Blackman, 2016; Kleemann & Abdulai, 2013; Kleemann et al., 2014). This question is crucial because market-driven transformations such as contract farming can lead to the expansion of cropland area geared at increasing the productivity of the contracted crop (Evans et al., 2015; Vanderhaegen et al., 2018). The associated intensified use of chemicals, which are commonly provided within contract arrangements, the intensified use of land, and the spread of monocultures pose a great threat to ecosystems. They affect rural landscape dynamics, pollute water resources, and lead to a loss of organic soil mater and biodiversity (Foley et al., 2011; Laurance et al., 2014; Schrama et al., 2018). According to the Food and Agricultural Organization (FAO), about 33% of global soils are already degraded as a result of unsustainable farming practices (FAO, 2015).

While land capacities in developed countries are increasingly exhausted due to the ongoing intensification, the greatest expansion of agriculture will almost certainly take place in developing regions of Asia, South America, and Sub-Saharan Africa, which have large land areas with unexploited agricultural potential (Bruinsma, 2009). All three regions are expected to be severely affected by climate change (Serdeczny et al., 2017). Climate change already has negative impacts on many developing and emerging economies (Issahaku & Abdulai, 2020; Shahzad & Abdulai, 2020). In particular, the effects of global warming are destroying crop harvests and undermining food security. The Intergovernmental Panel on Climate Change (IPCC) considers Africa as the region that is expected to be strongly affected by the negative consequences of climate change, because of the region's heavy reliance on rainfalls (IPCC, 2020). Together with the potentially unsustainable impacts of contract farming, this appears to be a threat to the realization of the second goal of the sustainable development goals (SDGs), which aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture (UN, 2015). Therefore, modern agricultural systems such as contract farming need to achieve both goals of increasing agricultural productivity to ensure food security and increase smallholder farmers' welfare, as well as protecting natural resources and preventing further environmental degradation (Jianping et al., 2014; Knickel et al., 2017; Schrama et al., 2018).

The present study contributes to this gap in the empirical literature by analyzing the effects of contract farming on the adoption of sustainable farming practices, using recently collected farm-level data of 391 Ghanaian cashew farmers. Contracts in our sample are not linked to any sustainable cultivation methods or certification schemes. To capture sustainable farm practice use, we construct an index variable that consists of different farm practices used in cashew farming and weigh them depending on their individual impacts on sustainability. These practices include application of fertilizers, pest and weed control, intercropping, and soil and water conservation practices. This provides a more comprehensive insight than looking at the practices individually as done in some related studies (Blackman & Naranjo, 2012; Elder et al., 2013).

Given that participation in contract farming is nonrandom, we employ a two-stage procedure that accounts for selection bias and estimates marginal treatment effects (MTEs) (Cornelissen et al., 2018; Heckman & Vytlacil, 2005). The MTE estimation takes into account the heterogeneity in both observed and unobserved characteristics that may influence sustainable farm practices among farmers. To the extent that farmers may differ in their farm practices (including sustainable farm practices), implies failure to account for this heterogeneity can result in confusion in the interpretation of the impact of participation in contract farming (Heckman et al., 2018). The MTE estimation further allows the identification of different treatment parameters such as average treatment effects (ATE), average treatment effects on the treated (ATT), as well as on the untreated (ATUT).

Cashew is explicitly suited to study the effect because it is an important cash crop and livelihood source for thousands of smallholder farmers in Ghana (African Cashew Initiative, 2010). Over the last decade, cashew nuts have become popular in international markets, resulting in an increase in export potential, with contract farming strengthening production-marketing-processing linkages. However, the increasing demand for cashew nuts in recent years has also led to an increase in monoculture farming, and thus to problems with pests and diseases, which in turn, can lead to more chemical use and unsustainable farm practices (Monteiro et al., 2017; O'Farrell et al., 2010).

The remainder of this paper is structured as follows: The next section presents the relationship between contract farming and sustainable farm practice use, while Context and Data section provides background information on cashew cultivation in Ghana and a description of the data used in the analysis. The Empirical Specification section outlines the conceptual framework and empirical specifications employed in the analysis, while Empirical Results section discusses the results of the study. Conclusions and policy implications are provided in the final section.

CONTRACT FARMING AND SUSTAINABLE FARM PRACTICES

Contract farming is increasingly used in developing countries to link smallholder farmers in developing countries to export markets. Contracting companies usually provide farmers with production inputs such as fertilizer and pesticides in order to grow the contract crop under predefined conditions for export. However, in contrast to certification schemes such as organic or fair-trade that meet specific environmental and social performance criteria (Ibanez & Blackman, 2016; Kleemann et al., 2014), contract farmers are not required to meet any specific criteria. They rather aim to achieve higher output levels and maximize profits, and there is a broad agreement that crops produced for exports are heavily treated with pesticides to ensure higher productivity and specific quality standards (Kleemann & Abdulai, 2013; Popp et al., 2013).

Notwithstanding this potential relationship between contract farming and environmental conditions, the impact of contract farming on the environment has received very little attention in the empirical literature so far (Minten et al., 2007; Vanderhaegen et al., 2018). For example, Mishra et al. (2018) show in their study on smallholder onion farmers in India that farmers with access to irrigation were more likely to participate in contract farming. The associated intensified use of land and water potentially leads to degradation and loss of biodiversity. This is discussed in studies such as in Singh (2002), Bijman (2008), and Vicol (2017), who all raise concerns about environmental degradation and overexploitation of resources due to contract farming, suggesting that contract farming could have negative impacts on sustainable land management.

However, it is possible that participation in contract farming could have positive impacts on sustainable farm practice use by farmers. For example, Minten et al. (2007) find spillover effects on land fertility of vegetable contract farmers from Madagascar due to the application of fertilizer and compost, which farmers did not use prior to the contracts. Furthermore, because sustainable farm practices usually involve higher implementation costs resulting from higher input, information, and labor requirements, the higher incomes of contract farmers can lead to reinvesting incomes in sustainable farm practices (Dedehouanou et al., 2013; Kathage et al., 2015; Wollni et al., 2010). The higher incomes of contract farmers can also lead to farmers learning to optimize production processes (Dedehouanou et al., 2013). Beside these demand-side factors, the adoption of sustainable farm practices also depends on supply-side factors and are embedded in social norms. According to Ton et al. (2018) and Wollni et al. (2010), remoteness to population centers, property rights, access to credit, and extension services are equally important in influencing farmers' decision making. Authors like Mzoughi (2011) and Carlsson et al. (2008) even argue that the decision to use sustainable farm practices is embedded in social norms and moral concerns.

By analyzing the impact of contract farming on sustainable farm practices, we attempt to provide an entry point to address the effects on ecological sustainability, which encompasses the use of environmental and natural resources to the extent that those regenerate and thus can be used by future generations of farmers (World Bank, 2008).

CONTEXT AND DATA

Context

Agriculture is the main backbone for economic growth, poverty reduction, and food security in Sub-Saharan Africa. Especially West Africa has a remarkable potential to increase agricultural production due to its highly diverse agro-climatic conditions and its large unexploited land areas (Monteiro et al., 2017). In recent years, cultivation of nontraditional crops experienced significant growth. One such crop is cashew nuts. Among the main cashew production areas, West Africa is the most recent and dynamic in the world, accounting for 45% of the worldwide production (FAOSTAT, 2018).

Cashew cultivation in Ghana started in the 1960s, initially aimed at helping to reduce soil erosion and to enhance afforestation. It is only since the late 1990s that cashew was identified as one of the major nontraditional crops to be developed as part of Ghana's efforts to diversify the country's export base. Nowadays, cashew is the second main cash crop in terms of export value behind cocoa in Ghana (African Cashew Initiative, 2010).

These developments have led to cashew trees being planted more and more intensively, replacing traditional food crops such as sorghum, rice, or groundnuts (Evans et al., 2015). At the same time, Ghana's cashew sector remains a relatively small player and less advanced in realizing its potential. The country accounts for only about 3.1% of the world's cashew production (Ricau, 2019). The relatively limited productivity can be attributed to a limited understanding concerning vegetative propagation methods and sustainable farm practices. Pests and diseases are among the factors that significantly hinder cashew production, making the widely propagated monocultures vulnerable, and in need of guidelines for a more sustainable cultivation of the trees (Monteiro et al., 2017).

Data

The data used in the present study come from a recent survey that was conducted from August to October 2017 in Ghana. A multistage random sampling procedure was employed for the selection of observation units. First, Brong-Ahafo region and Northern region were purposively selected based on the national intensity of cashew production. In a second stage, four districts where cashew is intensively cultivated were chosen. These include Nkoranza, Techiman, and Wenchi districts in Brong-Ahafo region, as well as Bole district in the Northern region. Third, four communities per district (in Bole eight communities) were randomly selected using information provided by cashew buyers and community chiefs. Finally, contract farmers and noncontract farmers were randomly selected per community, resulting in a total sample of 391 cashew farming households consisting of 177 contract and 214 noncontract farming households.

The survey used a detailed questionnaire to solicit information on farmer and household characteristics, such as age, education, access to credit, and extension services, as well as farm characteristics such as production inputs, output, farm size, and tenure arrangements. As indicated before, in contrast to certification schemes such as organic or fair-trade that involve meeting specific environmental and social performance criteria, contracts in our sample are not specifically linked to any sustainable cultivation methods or certification schemes.

Sustainable farm practices

In view of the increasing globalization and threats of climate change, a commercial and sustainable agriculture is of decisive importance for further development of developing countries such as Ghana (Jianping et al., 2014). To examine the impact of contract farming on sustainable farm practices, we employ the framework proposed by Rigby et al. (2001) in developing our indicator of sustainable agriculture practice. In line with this framework, we identify practices most commonly used in cashew cultivation and allocate scores according to whether the particular practice improves or diminishes farm sustainability. These practices and their impacts were derived from the empirical literature (Dendena & Corsi, 2014; Opoku-Ameyaw et al., 2011). First, we consider land preparation. Soil and water conservation practice is a critical step for establishing a cashew plantation as the young cashew tree is very sensitive to competition with weeds. Practices such as leveling the terrain and mulching prevent soil erosion and also contribute to weed control, retention of soil moisture, and modulation of soil temperature (Monteiro et al., 2017). Cashew trees are generally rain fed cultivated. In rain fed regimes, techniques such as catch pits and reverse terraces were found to significantly enhance plant growth and nut yield by reducing runoff and nutrient leaching, as well as increasing soil moisture on hilly land, thus opening up the opportunity to grow cashew on marginal land (Dendena & Corsi, 2014).

Moreover, larger tree spacing is essential to promote the growth of a uniform canopy, to avoid overcrowding, but also to apply intercropping. Agricultural extension officers, therefore, advise farmers to plant cashew trees at a 10 by 10 meter distance to allow enough light and for space (Dendena & Corsi, 2014). Intercropping has a long tradition in cashew cultivation. It involves growing food crops in the area between the trees and can be extensively applied, particularly in the establishment phase of the trees. The practice not only optimizes the use of available land, but also preserves the fertility of soils, reduces the dependency on fertilizers, and helps to spread workload consistently throughout the year. Therefore, intercropping reduces risks, increases crop output, provides additional revenues, and thereby enhances food security of growers by varying their diets (Opoku-Ameyaw et al., 2011).

Second, we discuss the methods used by farmers to control weeds and pests. Because weeds can prevent seedlings from developing, weeding is essential around the tree trunks up to a radius of about 2 meters until the canopy shade out the weeds. For a long time, manual slashing was the most widespread method, but was turned down by many farmers due to the higher labor demand in favor of the use of chemical herbicides (Dendena & Corsi, 2014). Among the factors significantly hindering cashew production are pests and diseases. Pests include bugs, caterpillars, beetles, aphids, scales, and mites. They cause considerable damage to foliage and fruits by determining the death of the floral-flushing shoots and the early abortion of young nuts, thus resulting in considerable loss of output (Monteiro et al., 2017). Chemicals such as herbicides, pesticides, and insecticides can effectively prevent those pre-harvest losses. Problematic, however, is that those chemicals are often not applied properly either in high amounts or at inappropriate times (e.g., directly before rainfalls). The misuse not only damages useful insects and microorganisms through run-off into the soil, but also contaminates drinking water for the surrounding population (Sheahan et al., 2016). While chemical control is the most commonly used method, practices such as pruning, which involves the manual removal of infected branches of the tree, can prevent the spread of diseases without the use of pesticides (Monteiro et al., 2017).

The third farming practice we consider is the application of fertilizers to improve soil nutrients. Although cashew trees are robust and can grow in nutrient-poor soils, balanced plant nutrition is essential to achieve economic yields, especially in the establishment phase of the young cashew tree (Dendena & Corsi, 2014). Nitrogen fertilizer application enhances yields, whereas phosphorus and sulfur positively affect plant growth. However, experimental evidence shows that nitrogen causes environmental degradation through soil acidification and off-site contamination (O'Farrell et al., 2010). Research also shows that when fertilized with inorganic sources and organic fertilizers, cashew plants respond better to organic fertilizer in the form of manure from cows or poultry. These types of manure contain other macro-and micronutrients like calcium and magnesium, which are not available from inorganic sources. Moreover, manure slowly releases nitrogen, thus limiting leaching and acidification and improves soil structure and water content (Dendena & Corsi, 2014; Monteiro et al., 2017).

Following Rigby et al. (2001), we weigh each practice from -3 (strongly negative impact) to $+3$ (strongly positive impact) according to how sustainable its impact is on habitat, soil quality, and groundwater quality. The individual weights for each practice are then added up to a total weight. To construct the outcome variable, we add up the total weights of the different practices.[1] Index values calculated this way range between −18 and +25. For a better interpretation, we use linear transformation so that the index scores lie between 0 and 1 (Rigby et al., 2001). Table A2 in Appendix S1 further illustrates the intensity of farm practices by quantiles. For example, it shows that solely farmers in the higher quantiles use soil and water conservation methods and organic fertilizers, while farmers in the lower quantiles use more chemical pest and weed control measures.

In addition, the calculation of the index variable enables us to consider the fact that many farmers in developing countries practice organic-by-default. This means that they abstain from chemical inputs because they are too expensive. This, however, does not necessarily mean that they adopt alternative sustainable farm practices (Kleemann & Abdulai, 2013). Thus, the way the index variable is constructed ensures that farmers who practice organic-by-default are not automatically classified as more sustainable than others.

Table 1 presents a summary of the above described farm practices and their mean values differentiated between contract and noncontract farmers. The mean values represent the share of the respective practices in proportion to the total cashew land size. First of all, neither contract nor noncontract farmers appear to use inorganic fertilizers. This is surprising, because a balanced plant nutrition is important in improving productivity. As indicated before, the nonusage could be attributed to nonavailability, which is also shown in the comparatively low productivity of Ghana's cashew nut sector (Ricau, 2019). Furthermore, several studies have shown the generally very low levels of inorganic fertilizer use in Sub-Saharan Africa (Abdulai & Goetz, 2014; Takahashi et al., 2020).

The use of organic fertilizers is very low as well, but contract farmers use significantly less organic fertilizers than noncontract farmers. A reason for this difference could be the age differences of the cashew trees. In particular, cashew trees of contract farmers in our sample are

TABLE 1 Scoring and descriptive statistics of sustainable cashew cultivation practices. This table shows the individual farm practices and their weights included in the index. The total weight (Column 4) was determined from the individual weights presented in Table A1 in the Appendix S1 and was calculated, following the framework of Rigby et al. (2001)

		(1)	(2)	(3)	(4)
		Contract farmers	Noncontract farmers		
Activities	Practices	Mean	Mean	Mean diff.	Total weight
Land preparation	Soil and water conservation	0.118 (0.324)	0.168 (0.378)	−0.050	+7
	Tree distance >10 m	0.274 (0.430)	0.243 (0.414)	0.031	+3
	Intercropping	0.460 (0.426)	0.471 (0.417)	−0.012	+6
Weed control	Manually	0.233 (0.387)	0.336 (0.446)	−0.102**	+7
	Chemically	0.161 (0.360)	0.094 (0.279)	0.068**	−9
Pest control	Manually	0.543(0.439)	0.541 (0.450)	0.002	+2
	Chemically	0.675 (0.424)	0.628 (0.441)	0.047	−9
Fertilization	Organic	0.039 (0.423)	0.080 (0.370)	−0.040*	+4
	Inorganic	0	0	0	−3

Note: Figures refer to cropping season 2016/2017; the coefficients represent the share in relation to the total cashew cultivation area. Standard errors are in parentheses. Significance level at ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

significantly older than those of noncontract farmers. However, it is the young trees that actually need more fertilizer for growth.

Another reason might be that contract farmers' livestock ownership per acre is less, compared to noncontract farmers (see Table 2 in the next section). As argued by Ali et al. (2012), livestock ownership allows farmers to use manure from the animals for their farms. In areas with manure markets, farmers can normally sell and purchase manure from the market. However, in the absence of manure markets, the only source is from livestock ownership. Hence, the lesser number of livestock a farmer has, given the farm size, the lesser the quantity of organic manure that will be available for use on the farm.

Further, we observe that contract farmers tend to use significantly more pesticides and apply significantly less manual weeding than noncontract farmers do. This underscores our thesis that contract farmers have easier access to chemical inputs, particularly pesticides in the present study, and therefore, tend to employ less sustainable farm practices. Contract farmers also tend to use less intercropping and water and soil conservation measures, although the differences are not statistically significant.

Descriptive statistics

Table 2 presents definitions and descriptive statistics of the outcome and control variables used in the analysis. Sample means of the variables are presented for contract and noncontract farmers. As indicated before, our index variable reflects the intensity of sustainable farm practice use in cashew cultivation, and ranges between zero (fully unsustainable) and one (fully sustainable). It shows that contract farmers have a significantly lower value than noncontract farmers, indicating that on average, contract farmers tend to use less sustainable farm practices, compared to noncontract farmers. This is also shown in Figure 1, which displays kernel density estimates of the intensity of sustainable farm practice use for the two categories of farmers. The estimates show considerable heterogeneity within and across contract and noncontract farmers. However, the intensity of sustainable farm practice use appears to be lower for contract farmers than that of their noncontract farming counterparts. The figures in Table 2 also reveal significant differences in age, gender, farm size, property rights, and hired labor between contract and noncontract farmers.

In summary, the differences in mean suggest that farmers who participate in contracts and those who sell via the spot market are systematically different across observable characteristics and outcome variables. However, the simple comparison of mean differences across contract farmers and noncontract farmers does not account for confounding factors that lead to these differences. We, therefore, employ econometric analysis to disentangle the bias driven by selection into contract farming and to examine its impact on sustainable farm practice use.

EMPIRICAL SPECIFICATION

Identification strategy

In this section, we present the empirical framework employed in the estimations to examine the impact of participation in contract farming on the use of sustainable farm practices. In the absence of data before participation, we rely on cross-sectional comparisons of participants and

TABLE 2 Descriptive statistics of variables included in the estimation

	Description	Contract farmers	Noncontract farmers	Mean diff.
Outcome variable				
Sustainability index	Intensity of sustainable farm practices applied in cashew cultivation (0 [highly unsustainable] to 1 [highly sustainable])	0.413	0.465	−0.052**
Control variables				
Age	Age of household head (years)	54.864	52.177	2.687***
Female household head	1 if household head is female, 0 otherwise	0.198	0.313	−0.115*
Education	Education of household head (years)	4.972	4.481	0.490
Farm size	Total size of cashew farmland (acre)	10.929	8.839	2.091**
Farm age	Age of the cashew farm (reference year is 2017)	12.707	11.048	1.659***
Property rights	1 if farmer owns farm land, 0 otherwise	0.933	0.880	0.053*
FBO	1 if farmer is member in a farmer-based organization, 0 otherwise	0.300	0.257	0.042
Hired labor	Number of hired workers (per ha)	7.431	5.903	1.529*
Native	1 if farmer is native in community, 0 otherwise	0.802	0.766	0.036
Access to credit	1 if farmer asked for and received credit (last 3 years), 0 otherwise	0.401	0.373	0.027
Extension service	1 if farmer received extension services (last 3 years), 0 otherwise	0.542	0.519	0.024
SEC	Soil and ecological conditions	0.029	−0.014	0.033
Nkoranza	1 if farmer is located in Nkoranza district, 0 otherwise	0.231	0.177	0.054
Wenchi	1 if farmer is located in Wenchi district, 0 otherwise	0.192	0.214	−0.023
Techiman	1 if farmer is located in Techiman district, 0 otherwise	0.192	0.210	−0.018
Bole	1 if farmer is located in Bole district, 0 otherwise	0.384	0.397	−0.013
Tree age	Age of cashew trees (years)	9.884	9.054	0.830*
Livestock	Livestock ownership (Number of livestock per acre)	2.757	3.096	−0.619
Instrument variable				
Farm radius	Number of cashew farmers living in a 3 km radius around farmhouse	15.469	12.431	3.037***

Note: All outcome variables exclusively relate to costs and incomes from cashew production; all figures refer to cropping season 2016/2017. Significance levels at $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

Abbreviations: FBO, farmer-based organization; SEC, soil and ecological condition.

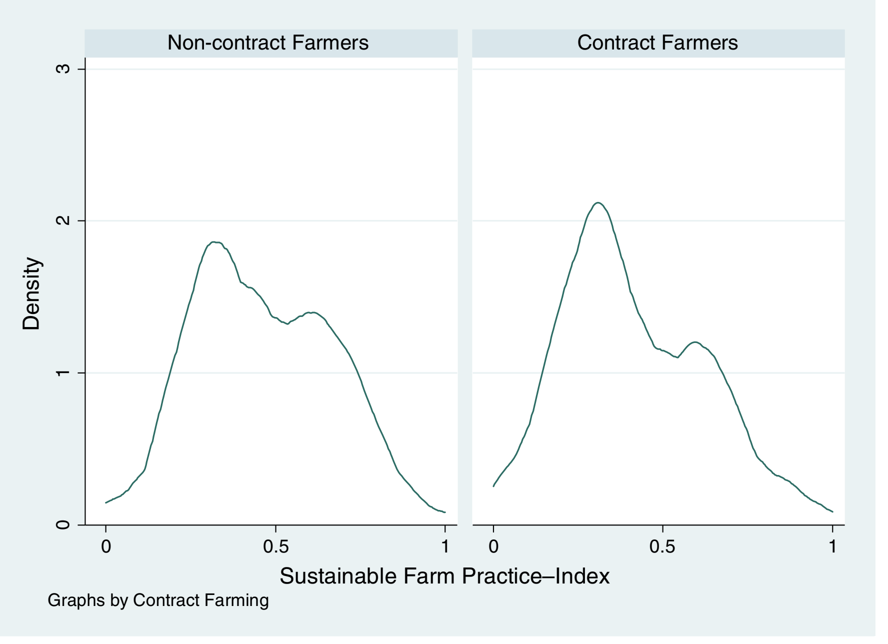

FIGURE 1 Intensity of sustainable farm practice use and contract farming. This figure shows the kernel density estimates of sustainable farm practice use for noncontract farmers and contract farmers, respectively

nonparticipants. As with most studies using observational data, selection bias poses the main empirical challenge in the analysis. This is because the decision to participate in contract farming and to use sustainable farm practices could be influenced by some similar characteristics. For example, factors like farm size, education level, and property rights could be influencing self-selection into contract farming and the outcome of interest. In this case, the cross-sectional data we use in the present study requires stronger identification assumptions than experimental or panel data. In view of these potential biases, some extra care is needed in the empirical analysis. We employ the MTE model to account for both selection bias and heterogeneity among farmers.

The conceptual framework employed in this study assumes that treatment (participation in contract farming) of a farm household i is a binary variable denoted by D_i. We assume that a farmer chooses a strategy that results in maximum expected net benefits (D_i^*). However, D_i^* cannot be directly observed, but can be expressed as a function of observable and unobservable elements in the following latent variable model:

$$D_i^* = \beta_D(Z) - V_i, \tag{1}$$

with $D_i = 1$ if $D_i^* \geq 0$ and $D_i = 0$ otherwise,

where D_i is a binary indicator that equals 1 if a farm household participates in contract farming, and zero if otherwise; $Z = \left(X_i, \widetilde{Z}_i\right)$ represents a vector of observable covariates (i.e., household and farm characteristics X_i) that influence the outcomes (i.e., sustainable farm practices) equation and an instrument for identification $\widetilde{Z}_i$ excluded from the outcome equation, β_D is a vector of parameters to be estimated, and V_i is the unobserved resistance to treatment or participation (i.e., the error term).

Because the error term enters the selection equation with a negative sign, it represents the unobserved characteristics that could make an individual farmer less likely to participate in contract farming. Hence, it is often referred to in the MTE literature as the "unobserved resistance" to treatment. As such, farmers with high values of V are less likely to participate (high resistance to participate) in contract farming, compared to farmers with low V values who are more likely to participate (low resistance to participate) in contract farming. Assuming that a farmer participates in contract farming when $D_i^* \geq 0$, then Equation (1) can be specified as: $\beta_D(Z) \geq V_i$. We transform this inequality by applying a c.d.f. to both sides, where $\Phi(V_i) \equiv U_D$ represents quantiles of the distribution of unobserved resistance to participation V and $\Phi(\beta_D(Z)) \equiv P(Z)$ represents the propensity score for participation. The propensity score is the probability that farmer i with observed characteristics Z will participate in contract farming. Following this, a farm household will participate in contract farming if the propensity score of participation is greater than the unobserved resistance to participation $(P(Z)) \geq (U_D)$.

Impact of participation in contract farming on sustainable farm practice use

Let us represent T_{1i} as farmer i's sustainable farm practice use under the hypothetical scenario that the farmer is treated, that is, participates in contract farming, and T_{0i} under the hypothetical scenario that the individual is not treated, and does not participate in contract farming and sells on the spot market. We model the relationship between sustainable farm practice use T_{ji} and participation as follows:

$$T_{ji} = \beta_j X_i + U_{ji} j = 0,1, \tag{2}$$

where X_i represents again a vector of observed household and farm characteristics as in Equation (1) with β_j being the associated vector of parameters to be estimated. The instrument $\widetilde{Z}_i$ from Equation (1) is excluded from the outcome equation. U_{ji} is the error term representing unobserved characteristics that affect sustainable farm practices. The subscript j denotes the participation status, where $= 1$ represents contract farmers, and $j = 0$ represents noncontract farmers.

We are interested in the individual treatment effect, which is the difference in sustainable farm practice use between contract and noncontract farmers, given by $T_{1i} - T_{0i} = X_i(\beta_1 - \beta_0) + U_{1i} - U_{0i}$. Treatment effect heterogeneity thus results from observed $X_i(\beta_1 - \beta_0)$ and unobserved $(U_{1i} - U_{0i})$ characteristics. The key feature of the MTE approach is that it allows the unobserved gains from treatment $(U_{1i} - U_{0i})$ to be correlated with unobserved characteristics that affect selection (V_i). Therefore, the MTE for an individual farmer with observed characteristics $X = x$ who is in the u_D-th quantile of the V distribution will have a propensity score $P(Z) = U_D$. Following Cornelissen et al. (2018), we further assume that the MTE is additively separable into observed and unobserved components:

$$\text{MTE}(\text{x}, u_D) = \text{E}(T_1 - T_0 | X_i = \text{x}, U_D = u_D).$$

Heterogeneity in observables.

Heterogeneity in unobservables.

$$= x(\beta_1 - \beta_0) + \mathrm{E}(U_1 - U_0 | U_D = u_D). \tag{3}$$

The estimation of the treatment effects requires a first stage in which the instrument $\widetilde{Z}_i$ in Equation (1) causes variation in the probability of participation, conditional on the observed characteristics. Thus, the instrument must be independent of the error term in Equation (2), given the observed controls. We use the variable farm radius as an instrument for participation in contract farming. It measures the number of neighboring cashew farmers in a 3 km radius around the farmhouse. We argue that participation in contract farming is influenced by the extent to which farmers are clustered in a given location. When the level of clustering is high, companies will be more likely to engage farmers (Michelson, 2013). This is because it enhances access to farmers and aggregation of output at relatively lower cost, compared to locations where cashew farmers are less populated and companies have to invest more time and resources in locating farmers (Barrett et al., 2012; Saenger et al., 2013).

This is, however, not expected to affect our outcome variable, sustainable farm practice use, directly. Of course, one can be critical of the fact that a high density of farmers may result in exchange of experience and knowledge, which then could have an impact on their individual farm practices. To account for this issue, we include the variable membership in farmer-based organization (FBO) to control for exchange of information (Elder et al., 2013). Another critical issue is the fact that farmers living in the same area/cluster may have the same soil conditions, which in turn, could affect individual farm practices. In order to alleviate these effects, we control for soil and ecological conditions (SEC) in the specification. To do this, we use principal component analysis to construct a latent indicator variable of SEC. SEC includes soil fertility, soil erosion, shape of land, and region and is presented in Table A3 in Appendix S1. SEC is expected to control for the possibility of the instrument picking up the effects of SEC. To further check the validity of the instrument, we employ the approach used in Di Falco et al. (2011) and perform a falsification test. If a variable is a valid instrument, it will affect the participation decision, but will not affect sustainable farm practice use among farm households that do not participate in contract farming. Table A4 in Appendix S1 shows that the identifying instrument significantly affects participation in contract farming, but does not appear to influence sustainable farm practices of noncontract farmers. These results suggest that the variable farm radius appears to fulfill the criteria for instrument validity and can be used as an identifying instrument. Nevertheless, it should be stressed that the falsification test can only indirectly support the validity of the instrument.

For the estimation of the MTE, we model the expected value of sustainable farm practice use (T_i) conditional on the observed characteristics (X_i) and the propensity score $P(Z)$:

$$\mathrm{E}(T_i | X_i = \mathrm{x}, P(Z) = p) = X_i\beta_0 + X_i(\beta_1 - \beta_0)p + K(p), \tag{4}$$

where $X_i\beta_0$ is the effects of the observed characteristics in the nonparticipation state, $X_i(\beta_1 - \beta_0)$ is the treatment effects due to observed characteristics, p is the propensity score, and $K(p) = p\mathrm{E}(U_1 - U_0 | U_D \leq p)$ is a nonlinear function of the propensity score.

However, farmers potentially may differ in their levels of resistance to participate in contract farming due to unobserved characteristics, leading to selection on unobservable gains. Previous studies in the literature analyzing farmers' contract participation often failed to account for this heterogeneity (e.g., Dubbert, 2019; Maertens & Velde, 2017), which could potentially lead to underestimation of the treatment effects (Heckman et al., 2018). The MTE accounts for this heterogeneity in the estimation of the treatment effects. An important identification feature when estimating the MTE is the nonlinear functional form assumption made on $K(p)$. The nonlinearity assumption enables a test to be conducted to ascertain whether the MTE is constant or varies over varying levels of unobserved resistance to treatment U_D, which is important for empirical identification (Andresen, 2018; Carneiro et al., 2011).[2]

From Equation (4), the MTE is obtained by taking a derivative with respect to p (Cornelissen et al., 2018; Heckman & Vytlacil, 2005) as follows;

$$\text{MTE}\,(X_i = \text{x}, U_D = p) = \frac{\partial \text{E}(T_i\,|X_i = x, P(Z) = p)}{\partial \text{p}} = x\,(\beta_1 - \beta_0) + \frac{\partial \text{K(p)}}{\partial \text{p}}. \tag{5}$$

We implement the approach based on the exclusion restriction, by estimating a first-stage probit of Equation (1) to obtain estimates of the propensity score $P(Z)$ as $\widehat{p}$. By modeling the $K(\widehat{p})$ as a second-order polynomial (i.e., $k = 2$) of $\widehat{p}$, we estimate the MTE in the second-stage, using the local instrumental variable (IV) estimator, as expressed in Equation (4). We let $(K(\widehat{p}) = \alpha\widehat{p} + \varepsilon)$ and re-specify Equation (4) as follows;

$$T_i = \beta_0 X_i + X_i\,(\beta_1 - \beta_0)\widehat{p} + \sum\nolimits_{k=1}^{k} \alpha_k \widehat{p}^k + \varepsilon_i, \tag{6}$$

where $K(\widehat{p})$ is a nonlinear function of the predicted propensity score $\widehat{p}$, ε_i is the error term and all other terms remain as earlier defined.

Following Heckman and Vytlacil (2005) and Cornelissen et al. (2018), the MTE can be aggregated over U_D to estimate the ATE, ATT (effect of treatment on the treated), and ATUT (effect of treatment on the untreated) as weighted averages of the MTE.[3]

EMPIRICAL RESULTS

In this section, we present the estimates from the analysis. The first and second parts of this section present the first-stage and second-stage estimates, which reveal the determinants of participation in contract farming and its impact on the intensity of sustainable farm practice use, based on observable characteristics. Whereas the final part presents the estimates of the MTEs, which illustrates whether farmers who are more likely to participate in contract farming based on unobservable characteristics exhibit higher or lower use of sustainable farm practices from participation. We present the MTE curve as well as estimates of the ATE, ATT, and ATUT.

Selection into contract farming

The identification of the MTE depends on the common support of the propensity score, which requires sufficient overlap in the characteristics of contract and noncontract farmers for comparison. Figure 2 shows the common support, which ranges from about 0.1 to 0.9 and indicates that there is considerable overlap between these two groups.

Table 3 presents the determinants of participation in contract farming and its impact on sustainable farm practice use. Column (1) shows the probit estimates of selection into contract

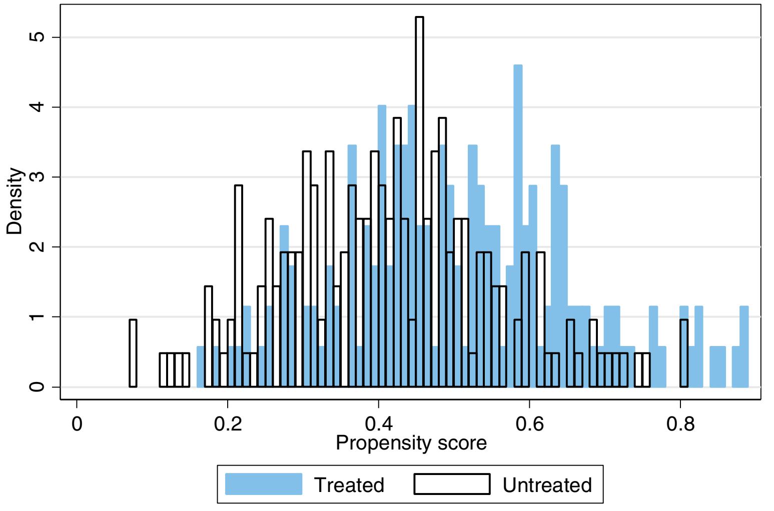

FIGURE 2 Common support of the propensity scores $\boldsymbol{P}(\boldsymbol{X_i}, \boldsymbol{Z_i})$ for $d = 1$ (treated/contract farmers) and $d = 0$ (untreated/noncontract farmers) on sustainable farm practice use

farming. The estimates show that the variable representing female household head is a significant, but negative determinant of participation, suggesting that female famers are less likely to participate in contract farming compared to male household heads. This finding is in line with other studies that document that women are less likely to participate in contract farming at all (Wang et al., 2014).

The variable representing farmer's age tends to be a positive determinant, suggesting that older famers are more likely to participate in contract farming, a result that contrasts with other findings (Wang et al., 2014) that indicate elderly people have less information about contracts, and are, therefore, less likely to participate in contract farming. However, related studies on technology adoption show that older farmers have more farming experience and are, therefore, more likely to adopt new agricultural technologies (Shahzad & Abdulai, 2020).

The variable representing farm size tends to be a positive determinant for participation, indicating that farmers with larger farms are more likely to be involved in contract farming. This is in line with the review results by Wang et al. (2014) and consistent with the notion that farmers with larger farms are more likely to be offered a contract for the transaction cost-saving benefit of the buyer.

The coefficient of the variable representing hired labor is a positive and significant determinant of participation in contract farming, and indicates that farmers who use hired labor are more likely to participate in contract farming, a finding that is consistent with the general view that contracting involves high-value farm commodities that are labor intensive (Narayanan, 2014; Otsuka et al., 2016).

Heterogeneity in treatment effects in observed characteristics

Columns (2) and (3) in Table 3 report the estimates for the effects of contract farming on sustainable farm practice use in the nonparticipation (untreated) (β_0) and participation (treated)

TABLE 3 Selection equation and outcome equations. This table reports the results of the marginal treatment effect model

	(1)		(2)		(3)	
	Selection		β_0		$\beta_1 - \beta_0$	
	Coeff.	**Std. err.**	**Coeff.**	**Std. err.**	**Coeff.**	**Std. err.**
Constant	−2.217**	0.957	0.833*	0.330	0.549	1.016
Female HH head	−0.408**	0.169	−0.288***	0.116	0.472*	0.275
Age	0.009*	0.034	0.010***	0.002	−0.020***	0.005
Education	0.009	0.019	0.007	0.006	−0.011	0.009
Farm size	0.017**	0.008	−0.004	0.007	0.016	0.012
Farm age	0.020*	0.012	0.167	0.112	−0.106	0.261
Property rights	0.376	0.249	−0.157	0.070	0.332	0.155
Native	−0.038	0.172	0.145**	0.091	−0.299**	0.176
FBO	0.130	0.161	0.009*	0.007	−0.015*	0.011
Hired labor	0.022**	0.009	0.021	0.017	−0.031	0.035
SEC	−0.009	0.043	0.012	0.058	−0.083	0.128
Access to credit	0.055	0.147	−0.103	0.073	0.224	0.158
Extension service	−0.122	0.145	−0.288	0.116	0.472	0.275
Bole	0.145	0.228		−0.006	0.039	
Nkoranza	0.317	0.225		0.050	0.036	
Wenchi	−0.058	0.216		−0.065	0.042	
Farm radius	0.019***	0.006				
Test of observable heterogeneity (*p*-value)				0.004		
Test of unobserved heterogeneity (*p*-value)				0.018		

Note: Column 1 reports the estimates of participation in contract farming from the probit selection model. Columns 2 and 3 present the estimates of the sustainable farm practice equation in the non-participation and participation states (the difference between participation and non-participation), respectively. The *p*-values for the test of observed and essential (unobserved) heterogeneity as well as the excluded instrument (farm radius) are presented at the bottom of the table. Significance level at $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Abbreviations: FBO, farmer-based organization; SEC, soil and ecological condition.

stages $(\beta_1 - \beta_0)$, respectively. The estimates indicate the extent to which treatment effects differ, depending on farmers observed characteristics. We interpret the average differences in outcomes directly from β_0, while $\beta_1 - \beta_0$ can be interpreted as the treatment effects (Andresen, 2018).

The estimates reveal that gender of the household head tends to have differential effects on the state of participation and nonparticipation. In the nonparticipation state, the estimates show that the intensity of sustainable farm practices for female-headed households is 29 percentage points lower than that of male-headed households. However, when female-headed households participate in contract farming, their intensity of sustainable farm practices increases by 47 percentage points than male-headed households. With age of the household head, the results show that in the nonparticipation state, the intensity of sustainable farm practices increases with age by one percentage point, while the treatment effects show that when older farmers participate in contract farming their intensity of sustainable farming practices decreases by 2 percentage points.

Being native in the community also tends to have differential effects on contract and noncontract farmers. In the nonparticipation state, the estimates show that the intensity of sustainable farm practices for native farmers is 14.5 percentage points higher than that of nonnative farmers. However, when native farmers participate in contract farming, their intensity of sustainable farm practices decreases by 30 percentage points compared to nonnative farmers. Lastly, the coefficient for FBO membership is statistically significant in both states. The coefficient in the nonparticipation stage is positive, implying that the intensity of sustainable farm practices of an FBO member is 0.9 percentage points higher than that of nonmembers. However, when FBO members participate in contract farming, their use of sustainable farm practice decreases by 1.5 percentage points compared to that of nonmembers.

These findings reveal two interesting effects. First, although older and male farmers tend to be more likely to participate in contract farming, their treatment effects reveal that they become less sustainable in their farming practices compared to their counterparts. Second, we observe that contract farming tends to negatively impact on sustainable practices of farmers who are native and members of an FBO, suggesting that modern agricultural systems, such as contract farming, may undermine traditional agricultural practices (Singh & Singh, 2017). Due to participation in contract farming, the use of these traditional practices that are adapted to specific local environments declines in favor of productivity enhancing inputs.

Variables such as education, access to credit, and extension services are not statistically significant in the model. An explanation for this could be that companies do provide some form of extension service and credit to farmers they have contracts with. Thus, extension services and credit provided by the government may not have substantial effects on the performance of contract farmers. Education is generally considered to be a positive determinant for adopting sustainable farm practices and new technologies (Abdulai & Huffmann, 2014). However, education is probably not significant here because of the low and similar education levels of the farmers in the sample (Guo et al., 2007). A review by Wang et al. (2014) on contract farming also found that the education level of the household head is often not significantly related to participation in contract farming.

Average and marginal treatment effects estimates for unobserved characteristics

An important feature of this study is the analysis on how farmers' participation in contract farming tends to impact on their use of sustainable farm practices, and how this effect varies with their unobserved characteristics. Figure 3 presents the MTE curve, which represents the distribution of marginal returns to treatment over varying levels of unobserved resistance to treatment U_D (in our case, the resistance to participate in contract farming) among the farmers. The figure shows an upward sloping trend, with relatively low treatment effects at the beginning of the U_D distribution and eventually increasing to positive effects at the right end of the distribution, suggesting that the effect of contract farming participation on sustainable farm practices varies with levels of unobserved characteristics.

The ATE lies around −0.31, and the upward sloping pattern implies negative selection on unobservable gains. In effect, given the unobserved characteristics, farm households who are most likely to participate in contract farming, appear to be the least sustainable in their farm

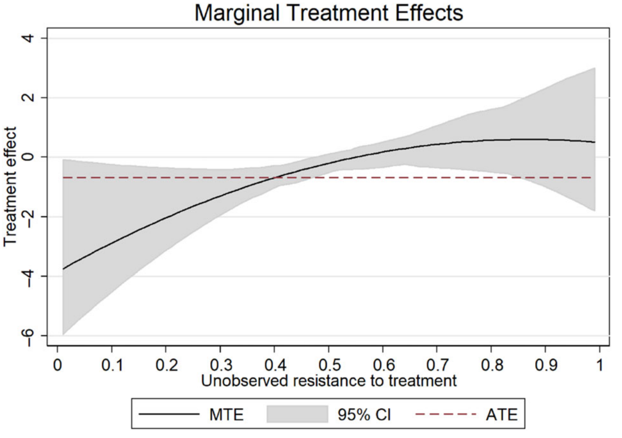

FIGURE 3 Marginal treatment effects. This figure shows the marginal treatment effect (MTE) of sustainable farm practice use estimated at the mean values of *X*

TABLE 4 Estimates of average returns to contract farming participation. This table presents the estimates of different treatment effects parameters

	Sustainable farm practice use
ATE	−0.314** (0.158)
ATT	−1.737*** (0.455)
ATUT	0.828 (0.427)
Test of unobserved heterogeneity (*p*-value)	0.018
Observations	391

Note: Standard errors are in parentheses. Significance levels at ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
Abbreviations: ATE, average treatment effect; ATUT, average treatment effect on the untreated; TT, average treatment effect on the treated.

practices. This pattern of unobserved heterogeneity in returns to participation is statistically significant at the 5% level (see p-values for the test of unobserved heterogeneity at bottom of Table 3). Thus, farmers with low resistance to treatment (high propensity to participate in contract farming) appear to exhibit the lowest sustainable farm practice use. This finding is consistent with the intuition that contract farming lowers sustainable farm practices through more chemical input use as previously indicated in this paper.

Table 4 presents the treatment effects in terms of sustainable farm practice use from participation in contract farming across different categories of farmers. In particular, we derive the standard parameters ATE, ATT, and ATUT, which are weighted averages of the MTE. The results show that participation in contract farming significantly decreases the probability of sustainable farm practice use for the average farmer (ATE). The findings of the ATT, which put more weight on farmers with high propensity scores for participation, suggest that contract farming significantly decreases sustainable farm practice use of the average farmer who participates in contract farming. For the average untreated farmer (ATUT), in contrast, participation in contract farming would increase sustainable farm practice use, although, the effect is not statistically different from zero. Thus, the different treatment effects parameters suggest the

TABLE 5 Test of non-linearity of K(p) in p

Degree of polynomial	2	3	4	5
p-value	0.859	0.908	0.942	0.966

Note: This table shows the p-values of test of non-linear terms of $E(\boldsymbol{T_i} \mid \boldsymbol{X_i} = x, \boldsymbol{P}(\boldsymbol{X_i}, \boldsymbol{Z_i}) = p)$ using models with different orders of polynomial in p. In each case, the null hypothesis of linearity can be rejected.

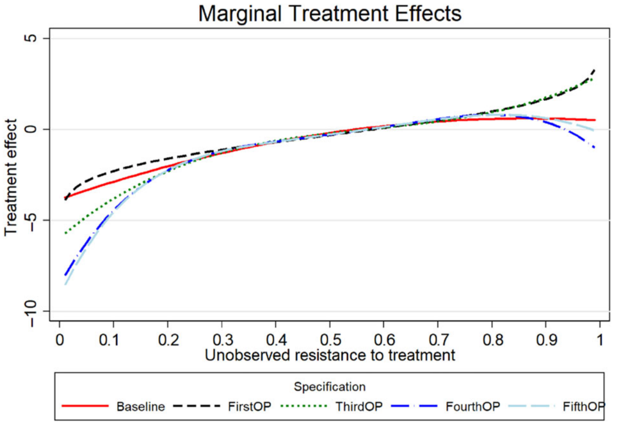

FIGURE 4 Robustness checks of functional forms. This figure depicts the alternative specifications of the marginal treatment effects (MTEs) using different functional forms such as the first-order polynomial (linear), third-order polynomial (cubic), fourth-order polynomial (quartic), and fifth-order polynomial (quantic). The baseline represents the MTE curve of the baseline model, which is the second-order polynomial (quadratic)

following pattern, ATT (−1.74) < ATE (−0.31) < ATUT (0.83), confirming the negative selection on gains as shown by the MTE curve in Figure 3.

Nonlinearity and robustness checks

As indicated previously, an important issue when estimating the MTE is the functional form assumption made on the $K(p)$. Given that selection on unobservable gains is revealed by the nonlinear functional form of $K(p)$ (Andresen, 2018; Carneiro et al., 2011), we follow Carneiro et al. (2011), and test whether the treatment effects vary with the unobserved resistance to treatment (varies with u_D).[4]

To do so, we estimate Equation (6) and specify $K(\widehat{p})$ to be a polynomial in $\widehat{p}$. Thus, we specify a polynomial in $\widehat{p}$ of orders 2–5 and test whether the coefficients on the polynomial terms are equal to zero. If they are equal to zero, this would indicate that $K(\widehat{p})$ is not a nonlinear function of $\widehat{p}$, while a rejection would indicate that $K(\widehat{p})$ is a nonlinear a function (constant in u_D). Table 5 presents the results and shows that the p-values in each polynomial are not equal to zero, thus rejecting the hypothesis of linearity, confirming our assumption of nonlinearity.

As indicated in section 4.2, we also conduct robustness checks to ascertain whether the pattern of selection on gains is robust to different specifications of the $K(\widehat{p})$ functional forms. Specifically, we examine the robustness of our second-order polynomial baseline results to different functional forms such as first (linear), third (cubic), fourth (quartic), and fifth (quantic) order polynomial approach (Cornelissen et al., 2018). Figure 4 presents the estimates of the MTE curves for the different functional forms of $K(\hat{p})$, and generally confirms the pattern obtained in the baseline MTE curve, suggesting that the basic shape of the MTE curve is robust to different functional forms of $K(\hat{p})$.

CONCLUSION

Modern production and marketing channels, such as contract farming, which increase farm productivity and income, are quite crucial for poverty alleviation and food security in developing countries. However, Sub-Saharan Africa is and will continue to be affected by climate change, making farming generally more difficult. Sustainable and resource-conserving cultivation methods that do both, preserve the soil and protect the environment, but also enhance productivity are, therefore, necessary and have become major research and policy issues. In this context, it remains unclear whether contract farming might have negative trade-off effects on the environment, and as such negatively impact on the achievement of the second SDG of the United Nations that aims at eradicating hunger, achieving food security, and improving nutrition, as well as promoting sustainable agriculture.

This study used recent survey data of cashew farming households from Ghana to examine the effects of participation in contract farming on the intensity of sustainable farm practices, and how the use of these farming practices influences farm productivity. We employed the MTE model to account for selection bias, as well as observable and unobservable heterogeneity among farmers.

The empirical results showed significant heterogeneity in the effects of contract farming on the intensity of sustainable farm practice use. In particular, the results on observable characteristics revealed that older and male farmers tend to be more likely to participate in contract farming, but their treatment effects reveal that they become less sustainable in their farming practices compared to noncontract farmers. Moreover, participation in contract farming tends to negatively impact on sustainable practices of farmers who are native in the community and members in a farmer group. The results on unobservable characteristics revealed substantial heterogeneities, indicating that farm households who are most likely to participate in contract farming, appear to be the least sustainable in their farm practices, suggesting that participation in contract farming hinders sustainable farm practice use.

The findings suggest that contracts need to be linked to sustainable farming practices in order to ensure that farmers adhere to environmentally friendly cultivation methods. Because these measures involve long-term investment decisions that ensure soil quality, this may require policies that help in improving farmers' access to financial resources and tenure security that guarantees that farmers benefit from their investments (Abdulai & Goetz, 2014). The finding that women would significantly increase sustainable farm practice use when participating in contract farming, calls for actions that give women better access to contract farming. Furthermore, the government could launch awareness and acceptance campaigns for sustainable farm practices to scale up farmers adoption of these farming methods.

Contracting companies could also commit to provide farmers with more sustainable production inputs as well as to train them in sustainable farming methods. One attempt could be the use of cashew leaf litter and fallen cashew apples that are left unused on the plantations as organic fertilizer. They could be collected and processed into compost, and then used to improve organic material to meet the nutrient requirements of cashew trees. The existing contracts could also be linked to certification schemes that actively promote sustainable farming practices. This will not only ensure cashew cultivation for following generations of farmers, but could also increase the value of Ghanaian cashew nuts in marketing and export.

To the extent that the benefits of sustainable farming practices may be public goods, making it probably difficult for private sector funding, government could provide incentives for companies, in the form of reduced taxes, or encourage them as part of corporate social responsibility, to incorporate sustainable farm practices in their contracts to ensure environmental sustainability. Moreover, nongovernmental organizations that are involved in contract farming arrangement could also be encouraged to incorporate sustainable farm practices in their contracts with farmers, which might influence the scaling up process in the long-run.

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ENDNOTES

[1] Table A1 in Appendix S1 presents the above described weighting of farm practices to construct the index variable.

[2] Please see details on the nonlinearity check of $K(p)$ in Section 0

[3] In the interest of brevity, the equations to calculate the ATE, ATT, and ATUT are given below:

$$\text{ATE} = E[T_1 - T_0] = E[\beta_1(X_i) - \beta_0(X_i)]$$

$$\text{ATT} = E[T_1 - T_0|D_i = 1] = E[\beta_1(X_i) - \beta_0(X_i)|D_i = 1] + E[U_1 - U_0|D_i = 1]$$

$\text{ATUT} = E[T_1 - T_0|D_i = 0] = E[\beta_1(X_i) - \beta_0(X_i)|D_i = 0] + E[U_1 - U_0|D_i = 0]$.

[4] We thank an anonymous reviewer for suggesting this to us.

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SUPPORTING INFORMATION

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