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Ripe for contracts? Estimating the impact of an avocado producer organization contract farming intervention

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Abstract

We evaluate the impact of a producer organization avocado contract farming intervention in Kenya that included (1) an agreement to sell to an avocado exporting company, (2) access to training, and (3) support to gain group-level Global Good Agricultural Practices (*GLOBALG.A.P.*) certification as main activities. Using a (nonexperimental) doubly robust difference-in-differences design with farm-level panel data from 2015 and 2017, we show that farmers began selling to the contracted company, were recently trained and received the *GLOBALG.A.P.* certification. However, the intervention's uptake was less than perfect, especially concerning the procurement aspect of the contract, suggesting widespread side selling. In terms of outcomes, contract farming nevertheless significantly improved sales prices and reported quality, increased direct sales to companies, and led to more planted trees, but also increased total production costs. The effects are driven by the Hass avocado variety, which is in higher demand in export markets and the contracted avocado variety. No significant income and other welfare effects were found.

KEYWORDS

contract farming, doubly-robust difference-in-differences, exporting, farmer organizations, Kenya, smallholder farmers

JEL CLASSIFICATION

O13, Q01, Q13, Q17

1 | INTRODUCTION

Agricultural markets in low-income countries are changing rapidly with high-value, export-oriented supply chains becoming increasingly important in the context of the rapid growth of agricultural trade in the past decades and the need for structural transformation (Barrett et al., 2022; Ogutu et al., 2020). Within these supply chains, vertical coordination beyond spot markets and informal traders (brokers) is often required to ensure a reliable, high-quality supply and to meet the increasing international demand for traceability and sustainability. Contract farming, involving a preharvest agreement between buyer and producers, has been seen as a key vertical integration mechanism, especially in the case of smallholder production of perishable, quality-sensitive crops with no strong economies of scale in production (Minot & Sawyer, 2016).

A large literature has studied the effects of contract farming, generally suggesting positive impacts on farm productivity and household welfare (see Bellemare & Bloem, 2018; Minot & Sawyer, 2016; Ton et al., 2018 for recent surveys), although this is not unambiguously the case everywhere (Meemken & Bellemare, 2019). Many studies have also shown additional benefits for smallholder farmers (Birthal et al., 2005; Glover & Kusterer, 1990; Guo et al., 2005; Little & Watts, 1994; Miyata et al., 2009; Porter & Phillips-Howard, 1997; Singh, 2002; Warning & Key, 2002), including increased employment, price stability, a more reliable income, access to new technologies and credit, and improved export market access. Negative impacts have also been reported, such as environmental degradation, child labor, inequity in access and wealth concentration (for references see Bellemare & Bloem, 2018). Many questions remain insufficiently addressed, however. Welfare has been mostly measured by income, but other aspects of welfare such as subjective well-being, household food security, and stability of income have received much less attention. Few studies have looked at the impact of contract farming on costs looking at benefits instead. Also incomplete contract compliance, especially in the form of side-selling, has received far less attention, although creating a threat to the sustainability of any contract scheme (Alemu et al., 2021; Geng et al., 2023; Gerard et al., 2021). With buyers and producers not randomly entering into contracts, causal identification remains arguably the key challenge for this literature. The literature relies mostly on (observational) cross-sectional data, invoking strong identification assumptions to control for selection on unobservables, except for notable exceptions (Arouna et al., 2021; Michelson, 2013; Ogutu et al., 2020; Sullivan et al., 2022). For this reason, Bellemare and Bloem (2018) argue that future research should focus on conducting randomized controlled trials or adopting a difference-in-differences design to make progress in terms of causal identification.

With this study we aim to make three contributions to the literature. First, we make progress in terms of causal identification by studying the impact of a recent contract farming intervention with farm-household panel data, applying the (doubly robust) difference-in-differences design by Sant'Anna and Zhao (2020). Their method combines inverse probability weighting (as in Abadie, 2005) with outcome regression (as in Heckman et al., 1997) and allows us to control for (time invariant) unobservables by comparing farmers who adopt the contract intervention with a control group of farmers who do not, under the assumption of a common trend. The doubly robust strategy assures that our estimates are consistent if the propensity score model or the outcome regression model is correctly specified, but not necessarily both. Second, we provide evidence on take-up among contracted farmers by looking at the degree to which they indeed sell to the contracted company, attend training, and attain Global Good Agricultural Practices (*GLOBALG.A.P.*) certification.[1] And third, we analyze not only the impacts of contract farming on farm productivity (i.e., quantity sold) and income, but also on investment, various production costs (family and hired labor, transport cost, pesticides and fertilizer), prices and quality, and nonincome aspects of welfare (satisfaction, stability, food security).

The contract farming intervention we are studying was set up by the *Netherlands Trust Fund's Export Sector Competitiveness Program* during 2014–2017 to build employment and enhance the export competitiveness of the avocado sector in Kenya. Kenya is the sixth-largest avocado producer in the world and the largest producer in Africa. Kenya is also the largest net exporter of avocado outside of Latin America and exports 30% of its total avocado production (Food and Agriculture Organization of the United Nations, 2019).

Avocados are grown predominantly by smallholder farmers, who grow them for sale on local and international markets and for their consumption. Most smallholder farmers sell their avocados through middlemen—either government-certified agents or unofficial brokers—especially in the case of exporting. Avocado production for export is still limited by information and market frictions (poor knowledge of market prices and global quality standards, high transportation costs), lack of technology adoption (weak harvest management, no grafting on rot-resistant rootstocks, poor pest and disease management), fixed costs in production (collection centers and refrigeration facilities) and insufficient production of the Hass variety, the preferred variety for exports (Wasilwa et al., 2004).[2] Additionally, the dominant role of middlemen in avocado export markets and the low level of organization among smallholder farmers challenge smallholder farmers to capture the surplus generated from increased international demand for avocados.

The program intervention set up farmer organizations for avocado-farming households in Murang'a County,

[1] *GLOBALG.A.P.* is the world's most widely implemented and independently assessed farm certification scheme for "Good Agricultural Practices" in on-farm production and post-production processes to produce safe and healthy agricultural products, taking into account economic, social and environmental sustainability (Sareen, 2016).

[2] Farmers in Kenya produce three main varieties of avocado: Hass avocados have dark green-brown skin and account for roughly 10% of avocado production, Fuerte avocados have thin bright green skin and account for 20% of production and Kienyeji—the local variety—accounts for the remaining 70% of production (Horticultural Crops Directorate (HCD), 2015). The Hass variety is in high demand in international markets because it is more resistant to pests and diseases, has a higher oil content and conceals bruises (Amare et al., 2019).

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central Kenya, which each signed (similar) contracts with a different avocado exporting company. Although 10 farmers organizations were ultimately linked with companies, four farmer organizations were set up in time for our baseline survey in 2015. The (group-level) contract between farmer organization and exporting company stipulated (1) procurement (prices and quality requirements, and logistical support such as transport from the group's collection center), (2) access to training (on production techniques, orchard management, pest and disease management, and postharvest handling), and (3) support to gain *GLOBALG.A.P.* production quality standard certification (at the group level).[3] This intervention subsequently results in a certain level of uptake of these activities by individual farmers. The uptake of these activities, in turn, results in various improved farm-level outcomes (production, marketing) and impact (welfare). Figure A.1 in Appendix A shows the full Theory of Change from program to impact via intervention, output, uptake, and outcome.[4]

The villages in which the farmer organizations were established were identified by program officers together with the county officials in the study region considering the presence of avocado farming, nonexistence of contract farming, and the willingness of the village to participate. Avocado exporting companies were introduced to these farmer organizations and contracts were signed by both parties. Any avocado farming household—inside or outside the village where the farmer organization was established—could then join the farmer organization, provided they owned at least one mature Hass avocado tree (some farmer organizations required at least two trees) and paid the one-time admission fee (median fee KSh 100 ≈ $1.00) and the annual renewal fees (median fee KSh 200 ≈ $2.00). As a result, nonrandom program placement and farmer self-selection create a challenge for identifying the impact of contract farming on farmers' behavior, production, marketing and welfare outcomes. Specifically, estimators that are unable to fully control for these selection effects likely tend to overestimate impact as companies will prefer to sign contracts with more productive farmer groups and farmers producing more high-quality avocados benefit more from selling to the company rather than middlemen, because middlemen (unlike companies) do not differentiate prices according to quality levels.

We address the selection issue in two ways. First, we leverage the longitudinal aspect of our data to estimate effects through a doubly robust difference-in-differences design (Sant'Anna & Zhao, 2020). We focus on average treatment effects on the treated by comparing adopters with nonadopter households. We perform balancing tests and also test the key identifying common trend assumption of a difference-in-differences design. Second, we exploit the fact that the program to connect farmers to avocado exporting companies creates some exogenous spatial variation in the likelihood that farmers will adopt contract farming. Specifically, with the introduction of the four new farmer organizations, the change in farmer-level distance to the nearest farmer organization has a significant relationship with the probability of adopting contract farming but is uncorrelated with baseline village and farmer characteristics. We also show that a cross-sectional approach gives higher impact estimates than doubly robust difference-in-differences estimates as expected.

We find that the intervention was successful with farmers selling to the contracted companies, receiving training and attaining the *GLOBALG.A.P.* certification. However, uptake was less than perfect and only 36% of the contracted farmers sold any avocado to the contracted company, suggesting widespread side-selling. Contract farmers, however, benefited from significantly improved sales prices, increased direct sales to a company, produced higher quality and increased the number of planted Hass trees. At the same time contract farmers had significantly higher costs of production. No significant income or other welfare effects were found.

Before turning to the analysis, we note that it has been observed recently that the external validity of the findings from the existing literature on contract farming is limited as most studies focus on a single contractual scheme or a small geographical area in one country (Meemken & Bellemare, 2019). This limitation also holds for this study. The literature on contract design reinforces this point, showing diverse impacts of different types of contracts (Debela et al., 2021; Dubbert & Abdulai, 2022; Ruml et al., 2022). The contract we are studying specifically involves four key components, namely farmer organization membership, the ability to sell to an exporting company, the opportunity to receive training, and support to learn working according to *GLOBALG.A.P.* standards with the chance to attain certification. This complex type of contract is rarely studied in the literature and little can be said about the external validity of our findings a priori. Without different treatment arms, we are only able to study the combined impact of the contract farming intervention components, rather than identify the contribution of each component

[3] Here we follow the literature in adopting a broad rather than narrow definition of contract farming as "a preharvest agreement between farmers and buyers" (Meemken & Bellemare, 2019), not only specifying prices, quantity and quality but possibly also resource provision, training and/or management specifications (Eaton & Shepherd, 2001).

[4] Apart from the contract farming intervention targeting smallholders, the program also included interventions targeting trade-supporting institutions and small and medium-sized companies exporting avocados as important other stakeholders in the avocado value chain (Dengerink & van Rijn, 2018). These are indicated in the Theory of Change in grey but not evaluated in this study.

individually. We have therefore situated our study within the contract farming literature to which we can directly contribute, rather than within the distinct literatures on the role of farmer organizations, commercialization, training, and certification for farmer behavior, performance and welfare to which our contribution is indirect.

The remainder of this article is structured as follows. In Section 2 we describe the panel data, including sampling design and participation in the contract farming intervention. Section 3 explains the methodology to estimate the impact of the contract farming intervention and Section 4 presents the results. Section 5 concludes.

2 | DATA

2.1 | Sampling design

We surveyed 453 avocado-farming households through a baseline survey (November–December 2015) and an endline survey (August–September 2017).[5,6] We arrive at our sample by, first, including all 112 households that were, at baseline, registered with the four newly formed farmer organizations according to written lists made available by the program ("registered farmers group"). Potential locations for the new farmer organizations were identified by local program officers from Murang'a County, taking into account criteria such as the presence of avocado farming, the nonexistence of contract farming and the willingness of the village to participate. Second, we identified 27 villages in the Kandara region where no avocado exporting companies were active at baseline and randomly sampled 341 avocado-farming households from these villages ("unregistered farmers group"). The villages were selected to match the targeted villages' characteristics in terms of size, road- and market access, crops produced and socioeconomic- and agroclimatic conditions.[7] All households were included in the surveys after written informed consent was obtained from the designated respondent, usually the household head. Households without mature avocado trees were excluded from the survey.

2.2 | Adoption of and selection into contract farming

The program design specified the location where new farmer organizations would be set up and facilitated collecting information on all 112 avocado-farming households who were the registered members of the new farmer organizations at the time of our baseline survey. However, many of the initially registered farmers would drop out, even before any activity was organized, and not initially registered farmers would join. Because we do not observe the exact time of dropping out or joining, we define farmers as being treated by the intervention and hence adopting contract farming if they were members of the newly formed, contracted, farmer organizations at endline and had not previously engaged in contract farming at baseline. The nonadopters serve as the control group. Figure 1 shows that in our panel data, 124 farmers ultimately adopted the contract farming intervention. Of those, 70 were already registered at baseline and 54 joined later—between the baseline and the endline.[8] A total of 329 farmers were neither at baseline nor endline a member of a farmer organization.

Given that adoption was not random, we would expect to observe differences between farmers who adopt the intervention and those who do not. Tables B.1 and B.2 in

[5] At baseline, we surveyed 520 households and could follow up with 462 households at endline. Nine households had to be dropped because of inconsistent or missing data. Table B.3 in Appendix B shows that the attrition between baseline and endline is uncorrelated to observed characteristics and the joint hypothesis tests on the set of program allocation, outcomes, covariates or all variables combined are insignificant with *p*-values .17, .76, .98, and .77, respectively. While the surveys were implemented at different points in the year, both the baseline and endline covered the two main seasons (March–May and October–December).

[6] The data was collected by the Partnership for Economic Policy (PEP) through the NWO-funded "*Productive Employment in the Segmented Markets of Fresh Produce*" initiative (https://www.nwo.nl/en/ projects/w-08370104), in collaboration with the Vrije Universiteit Amsterdam, Amsterdam Institute for International Development (AIID), Amsterdam Institute for Global Health and Development (AIGHD), University of Nairobi, and the Fresh Produce Exporters Association of Kenya (FPEAK) and with the cooperation of Wageningen Economics Research. The baseline survey is described in detail in Amare et al. (2019).

[7] As part of the study, we also collected baseline and endline data on 242 farmers that (at baseline) were already connected to the largest avocado exporting company in the region through one of 14 pre-existing farmer organizations. This was done as a fallback option in case the program was not implemented in time for our data collection. This worry turned out to be unjustified and the information on farmers with existing contracts at baseline was not needed to evaluate the program. Our budget restricted the total sample size to 700, which after accounting for the 112 households in the new farmer groups and the 242 households with existing contracts determined the size of the unregistered farmers group. The number of villages was chosen such that approximately 12 farmers per village would be interviewed.

[8] We have limited information on when exactly the farmers who joined after the baseline joined, but qualitative responses from the endline survey suggest that only five farmers joined in 2017 and that most farmers were members for multiple harvest seasons throughout 2016 and 2017. We have no evidence to suggest that any farmers in the baseline unregistered farmers group had joined a farmer organization intermittently for only a short duration between the baseline and endline. However, to the (limited) extent that some farmers may have benefited from the intervention before dropping out before the endline, our estimated impacts will be underestimated.

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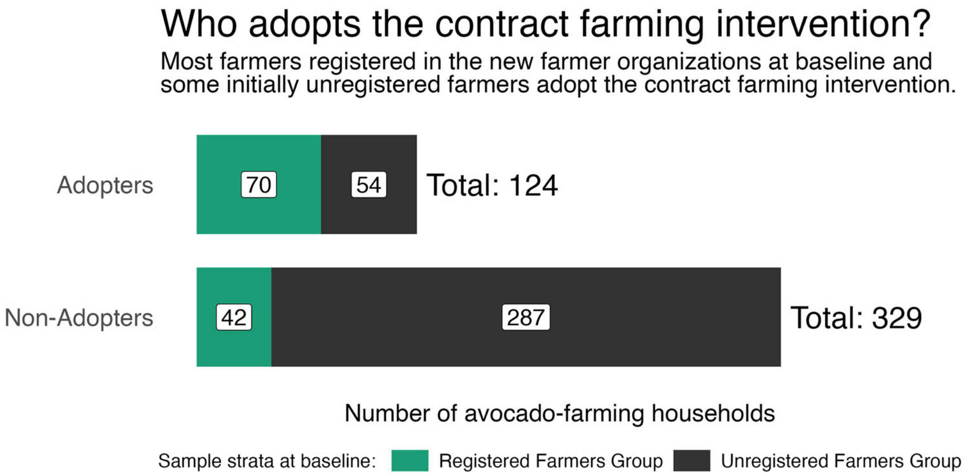
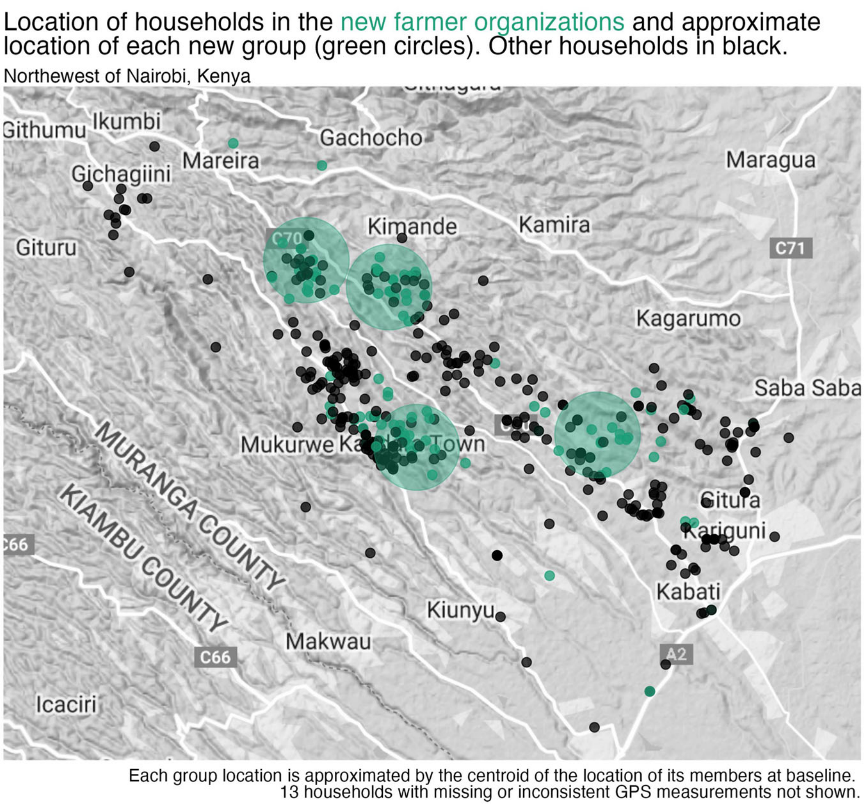


FIGURE 1 Adoption of contract farming intervention.

FIGURE 2 The location of farmers and newly created farmer organizations.



Appendix B show summary statistics at baseline for outcomes and explanatory characteristics respectively for the two groups. We observe that differences between households that adopted the intervention and those who did not are indicative of a slightly higher intensity of avocado farming (with a better knowledge of good agricultural practices related to avocado farming, a higher average Hass price, a larger share of Hass avocado of total sales and a higher income from avocado farming).

While we will control for these baseline differences between adopters and nonadopters with a difference-in-differences design under the parallel-trends assumption, we can also exploit the fact that an important determinant for contract farming adoption is the extent to which the placement of the new farmer organizations reduced the distance of farmers to the nearest avocado farmer organization. This can be seen by analyzing the effect of a reduction in the distance to the closest farmer

TABLE 1 Effect of distance to nearest farmer organization on adoption probability. Average marginal effects.

	All farmers	Unregistered farmers only
Distance changed (y/n)	.22** (.07)	.16+ (.09)
Reduction in distance (km)	.01 (.03)	.02 (.03)
Covariates (not shown)	Yes	Yes
Mean reduction in distance (km)	.63	.53
Max reduction in distance (km)	2.32	2.32
Num.Obs.	453	341
RMSE	.40	.34

Note: Significance-levels: $^+p < .1$, $^*p < .05$, $^{**}p < .01$ Logit regression on effect of changing distance to nearest farmer organizations on contract farming adoption, before and after the new groups were established. Reported coefficients are the average marginal effects. Location of groups is approximated by the centroid of the originally registered farmers' locations. Distance is included as an indicator (whether distance decreased at all) and as a linear regressor (the absolute change in the distance). Both models compare adopters with those who never take up contract farming. Column 1 uses the full sample, column 2 only farmers unregistered at baseline. Included covariates are the same as in the main analysis, see Section 3.2.

organization between the situation at baseline (without the four new farmer organizations) and at endline (with the four new farmer organizations) on the likelihood of adopting contract farming.[9]

We estimate the following logistic regression, where $I[\Delta\text{Distance}_i > 0]$ is an indicator of whether the distance to the nearest (contract farming) farmer organization has changed at all for farmer *i*—comparing a situation without the newly established groups to a situation with the new groups, $\Delta Distance_i$ is the reduction in the distance in kilometres, and X_i are baseline covariates that may also explain contract farming adoption (see details on covariates in the methodology Section 3):

$$\log\left(\frac{P[\text{adopter}_i|\Delta\text{Distance}_i, X_i]}{P[\text{non-adopter}_i|\Delta\text{Distance}_i, X_i]}\right) = \beta_0 + \beta_1 I\,[\Delta\text{Distance}_i > 0] + \beta_2\Delta\text{Distance}_i + \gamma X_i + \varepsilon_i \quad (1)$$

Table 1 shows that farmers for whom the distance to the nearest farmer organization was reduced due to the establishment of the four new farmer organizations are significantly more likely to adopt contract farming. Because the sampled households are representative of the villages' avocado farmer population in the unregistered farmers' villages, but not in the registered farmers' villages (only households that had registered with the new farmer organizations were sampled), we estimate the model for the full sample (column 1) but also for unregistered farmers only (column 2). The results are quite similar, however, suggesting that when a new farmer organization is closer, the probability of adoption increases by about 20 percentage points on average.

One may question to which extent we can treat the reduction in distance as (as good as) exogenous, given that the locations of the new farmer organizations were purposely chosen (taking into account the presence of avocado farming, the nonexistence of contract farming and the willingness of the village to participate in the program), and the unregistered farmers were sampled purposely from "similar" villages. However, when we regress the change in the distance on village-level characteristics (across all villages) and on (baseline) household-level characteristics (across farmers in unregistered farmers' villages only) we find that the reduction in distance is not significantly related to observable characteristics (Table F.1).[10]

2.3 | Data provided by farmers

The avocado-farming households provided information about the household composition, productive and non-productive assets, land holdings, (family) labor allocation, nonfarm income, access to information, training and financial services and food insecurity (measured using the "Household Food Insecurity Access Scale" (HFIAS) (Coates et al., 2007)). Further, we collected information on agricultural production (area planted, quantities harvested, use of inputs) and marketing (quantity sold and average price) of all crops, including livestock, which the farmers grew in each of the two annual seasons.[11] For avocado farming, we collected information on each avocado sale: the quantity, price, variety, quality, and buyer. In the case of contract sales, we also collected further aspects of the contract, namely whether agreements over

[9] We do not know the exact location of the farmer organization and therefore approximate it by using the centroid of the originally registered farmers' locations at baseline. Figure 2 shows the locations of farmers relative to the thus approximated locations of the four newly established farmer organizations.

[10] Except for the village-level distance variables no other village characteristics are unfortunately available.

[11] The study region has two main seasons, from October to December and from March to May.

delivery and price were made before or after the harvest and who would arrange the harvest and transportation of the avocado. Farmers also answered questions aimed at testing their knowledge of good agricultural practices in avocado farming. Households organized in farmer organizations provided information on the groups' contracts with avocado exporting companies, on the *GLOBALG.A.P.* certification and the availability and quality of training in good agricultural practices. They also answered questions about the internal regulations of the farmer organization concerning leadership, representation, trust, side-selling, and membership fees.

3 | METHODOLOGY

Because contract farming is ultimately a choice of the farmers, our empirical strategy needs to address selection into contract farming to identify the causal estimates credibly. We do this in two ways: first, we leverage the longitudinal aspect of our data to estimate a doubly robust difference-in-differences design. We focus on average treatment effects on the treated by comparing adopters with nonadopter households. Second, we exploit that the evaluated program set up farmer organizations in four targeted villages and not in 27 nontargeted villages, reducing the distance to the nearest farmer organization for some farmers. Also, this reduction in distance is not related to observable village- and farmer-level characteristics and can therefore plausibly be interpreted as exogenous, even if selected villages were purposely chosen by agricultural officers (Table F.1). Given that the likelihood of contract farming adoption is significantly higher for farmers who benefited from a reduction in the distance to the nearest farmer organizations (see Table 1 in Section 2.2), we can exploit this variation by including a measure for the change in distance in the remaining empirical analysis.

3.1 | Treatment and control for average treatment effects on the treated

Our treatment is whether farmers adopt the contract farming intervention between baseline and endline. We define farmers as treated by the intervention if they are members of one of the four new farmer organizations which were linked with a company through the program. To analyze the take-up of the three main activities of the contract farming intervention, we define *Selling to Contracted Company* as selling (any type of) avocado to the contracted avocado company; *Training* as having received training in avocado practices by the contracted company or the program officials and *Certification* as having received the *GLOBALG.A.P.* certification through their membership in a certified farmer organization.[12]

3.2 | Doubly-robust difference-in-differences estimation

We estimate the average treatment effect on the treated by comparing adopters with nonadopter farmers through the doubly robust difference-in-differences estimation method by Sant'Anna and Zhao (2020). The empirical strategy combines inverse probability weighting (as in Abadie, 2005) with outcome regression (as in Heckman et al., 1997). Combining both strategies assures that our estimates are consistent if the propensity score model or the outcome regression model is correctly specified, but not necessarily both. The average treatment effect on the treated forms the expectation over the weighted differences between the changes in the treatment group and the predicted changes in the control group:

$$\widehat{ATT} = \mathbb{E}\left[\left(\hat{w}_1(D) - \hat{w}_0(D, X; \hat{\gamma})\right)\left(\Delta Y - X'\widehat{\beta^{wls}_{0,\Delta}}\right)\right] \quad (2)$$

In Equation (2), D is the treatment indicator and X is a set of covariates measured at baseline. The included covariates are demographic information (gender, age, and education of household head, household size and distances to (motorable) road and local market), information about agricultural activity (owned land in acres, number of Hass avocado trees, usage of bank account to sell crops), nonfarm income and the two variables related to the change in the distance to the nearest farmer organization (whether distance changed at all and the absolute change in kilometers). The covariates are the same in the propensity score estimation and the outcome regression model. The weights, $\hat{w}_1$, $\hat{w}_0$ are calculated using the propensity scores from an inverse probability tilting estimator (Graham et al., 2012), using a logit regression (see Equations (3) and (4)), where π is the propensity score.

$$\hat{w}_1(D) = \frac{D}{\mathbb{E}_n[D]},\ \hat{w}_0(D, X; \hat{\gamma}) = \frac{\pi(X; \hat{\gamma})(1-D)}{1-\pi(X;\hat{\gamma})} / \mathbb{E}_n\left[\frac{\pi(X; \hat{\gamma})(1-D)}{1-\pi(X;\hat{\gamma})}\right] \quad (3)$$

$$\begin{aligned}\pi(X;\hat{\gamma}) &= \frac{\exp(X'\hat{\gamma})}{1+\exp(X'\hat{\gamma})}, \text{with } \hat{\gamma} \\ &= arg\max_{\gamma}\mathbb{E}_n\left[DX'\gamma - (1-D)\exp\left(X'\gamma\right)\right]\end{aligned} \quad (4)$$

[12] None of the activities were available at the baseline, because contracted companies only started operating after the baseline survey. GLOBALG.A.P. certification is in practice only available to farmer organizations because it is too expensive for all but the largest individual farmers. For members of the four newly established farmer organizations, we infer certification status from their membership.

In Equation (2), ΔY is the observed change from baseline to endline in the outcome for the treatment group and $X'\widehat{\beta^{wls}_{0,\Delta}}$ is the predicted change in the outcomes of the control group based on a linear regression using weighted least square estimates for the coefficients (see Equation (5)). Note that the outcome regression is estimated only on observations from the control group, not from the treatment group.

$$\widehat{\beta^{wls}_{0,\Delta}} = arg\min_{b} \mathbb{E}_n \left[\frac{\Lambda\left(X'\hat{\gamma}\right)}{1-\Lambda\left(X'\hat{\gamma}\right)} \left(\Delta Y - X'b\right)^2 \mid D = 0 \right] \tag{5}$$

When the distribution of a covariate or an outcome exhibits a long right tail or many zero-values we transform the values using the inverse hyperbolic sine (ihs) transformation.[13]

3.3 | Balance after inverse probability weighting

We can check to what extent weighting the observations by the estimated propensity scores reduces the imbalance in observable characteristics. Figure 3 shows that the reweighted data are significantly better balanced than the raw data and Table C.1 in the Appendix shows that after reweighting the differences between adopters and nonadopter farmers are not significant anymore.

3.4 | Common trend assumption

A key identifying assumption of a difference-in-differences design is the existence of common trends, c.q. that adopters and nonadopter farmers would show similar trends in behavior in the absence of an intervention. Although our data are limited in terms of information on preintervention trends in the outcome variables that we study, we have recall information on the number of planted (Hass, Fuerte, and local) avocado trees.[14] This allows us to verify that planting outcomes of farmers who adopted the contract farming intervention between baseline and endline and those who never participated in contract farming developed similarly before adoption. We construct a time-series of the number of planted trees per year for each farmer and estimate an event-study regression as in Equation (6).

$$y_{i,t} = \alpha_i + X_i'\beta + \sum_{t=2009}^{2017} \gamma_t \left(D_i * \text{year}_t\right) + \lambda_t + \varepsilon_{i,t} \tag{6}$$

In Equation (6), $y_{i,t}$ is the number of planted Hass trees per year,[15] X_i are the time-invariant control variables used in the previous analysis, year_t are year dummies (from 2009 until 2017, with 2015 as reference level) and D_i is the farmer-specific contract farming treatment status (adopter or nonadopter). Thus, the estimate γ_t for the interaction term between the year and the treatment dummy gives us the year-specific difference between adopters and nonadopters. We again reweight the sample by the inverse propensity score.[16]

Because the intervention started in 2016, we would expect γ_{2016} to be positive and the estimates γ_t for $t < 2016$ to be zero. Figure 4 shows that this is the case. There was a statistically significant increase in the number of planted Hass trees in 2016 and a flat trend before the intervention.[17] The event study plot shows that the adopters and nonadopter farmers behaved quite similarly before the intervention and notably differently afterwards. While we cannot exclude the possibility that there are still other confounding unobserved differences in trends, this finding strengthens our confidence that the common trend assumption underlying the difference-in-differences design is plausible.

4 | RESULTS

4.1 | Inspecting take-up for the three main contract farming activities

The contract farming intervention we study consists of three aspects: (i) the agreement to sell avocado to the contracted avocado exporting company (as opposed to selling to brokers or other companies), (ii) the opportunity to receive training in avocado production techniques, orchard management, pest and disease management, and postharvest handling, and (iii) receiving support for certification for the *GLOBALG.A.P.* production quality

[13] The ihs-transformation is an alternative to the common practice of taking a $\log(x+1)$ transformation but does not rely on adding a constant to observations with a zero value.

[14] For indicators other than the number of planted trees we only have access to two data points per farmer, which makes it impossible to repeat this analysis for other outcome variables.

[15] The results for the number of Fuerte and local avocado trees are reported in Figure C.1 in Appendix C.

[16] Figure C.2 in Appendix C shows that the event-study estimates are relatively similar whether or not we re-weight the data.

[17] For γ_{2017} we would also expect a positive effect but note that our endline survey was performed in August/September 2017 and there were fewer months for which the tree-planting activities of the farmers were recorded. Under the assumption that the difference between the groups from January until September is indicative of the (not included) difference from October until December, the estimate of the difference in 2017 is a lower bound of the true difference over 1 year.

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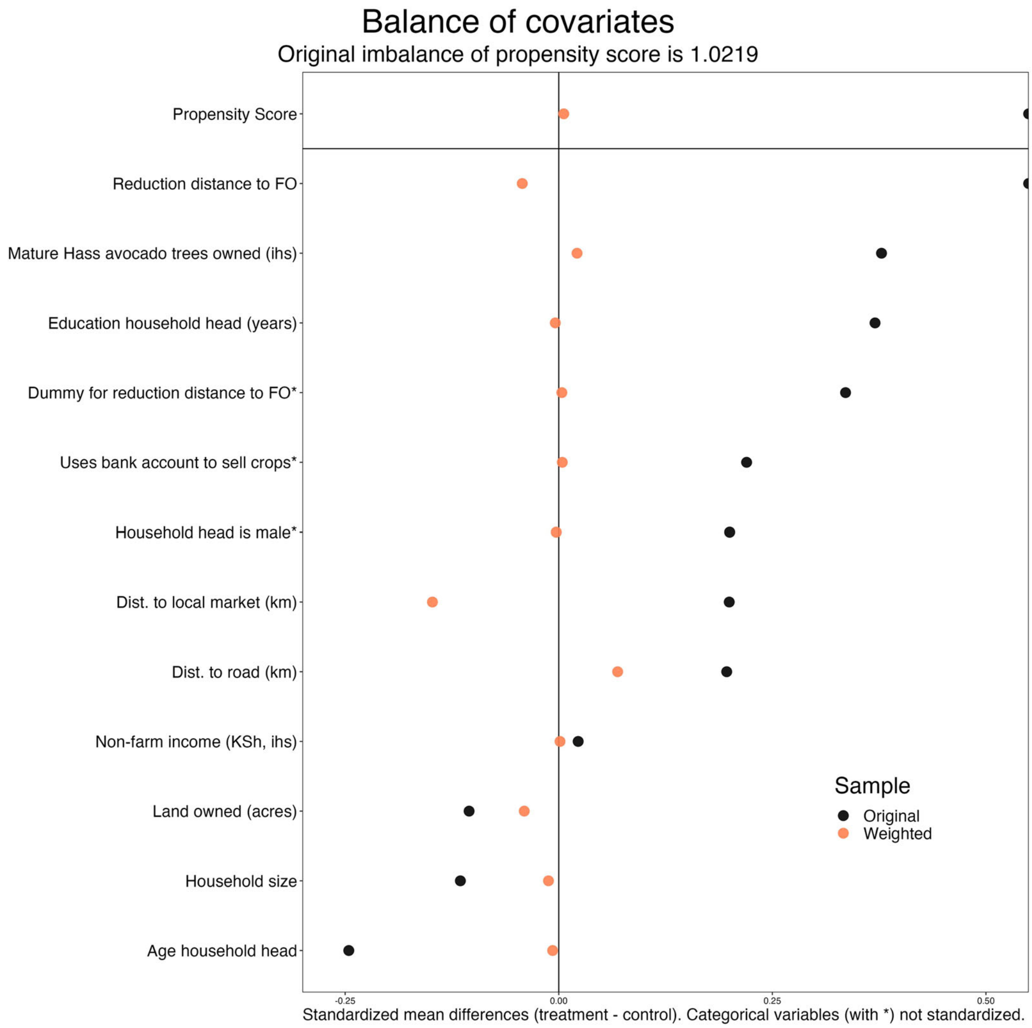

FIGURE 3 Observable characteristics are balanced after weighting by the propensity score. The plot compares adopters with nonadopter farmers.

standard. These three activities are seen as key for avocado-farming households' capability to integrate into export-oriented value chains, the explicit goal of the *Netherlands Trust Fund Export Sector Competitiveness Program*. Figure D.1 in Appendix D shows the take-up patterns between baseline and endline by sample strata for each of the three activities. We observe that, similarly to the overall contract farming intervention (Figure 1), many of the initially registered farmers take up the activities (especially training and certification). Additionally, some farmers who at baseline were not registered with the new farmer organizations take up the activities between baseline and endline as well.

Figure D.1 shows that 45 farmers begin selling to the contracted company between baseline and endline, 86 farmers are trained by the contracted company or program officials and 105 farmers receive the *GLOBALG.A.P.* certification between baseline and endline. The number of farmers who begin selling to the contracted company is relatively small relative to the number of farmers who became members of the new farmer organizations. This suggests that there are serious problems with side-selling, where avocado-farming households sell produce to brokers (or other companies) even though they entered into pre-harvest agreements with the contracted company. We will return to the issue of side-selling below.

Table 2 presents the regression estimates when estimating the average treatment effect on the treated for the uptake of each activity. The table shows that farmers who adopted the contract farming intervention are 36 percentage points more likely to sell avocados (of any variety) to the contracted company and, on average, increase the fraction of avocados sold to the contracted company by 31%. These effects are driven by the Hass avocado variety, which is in higher demand in export market and the contracted avocado variety. Avocado-farming households who adopt the contract farming intervention are 85 percentage points more likely to be certified according to the *GLOBALG.A.P.* production standard and 54 percentage points more likely to be trained. At baseline, the number of households that

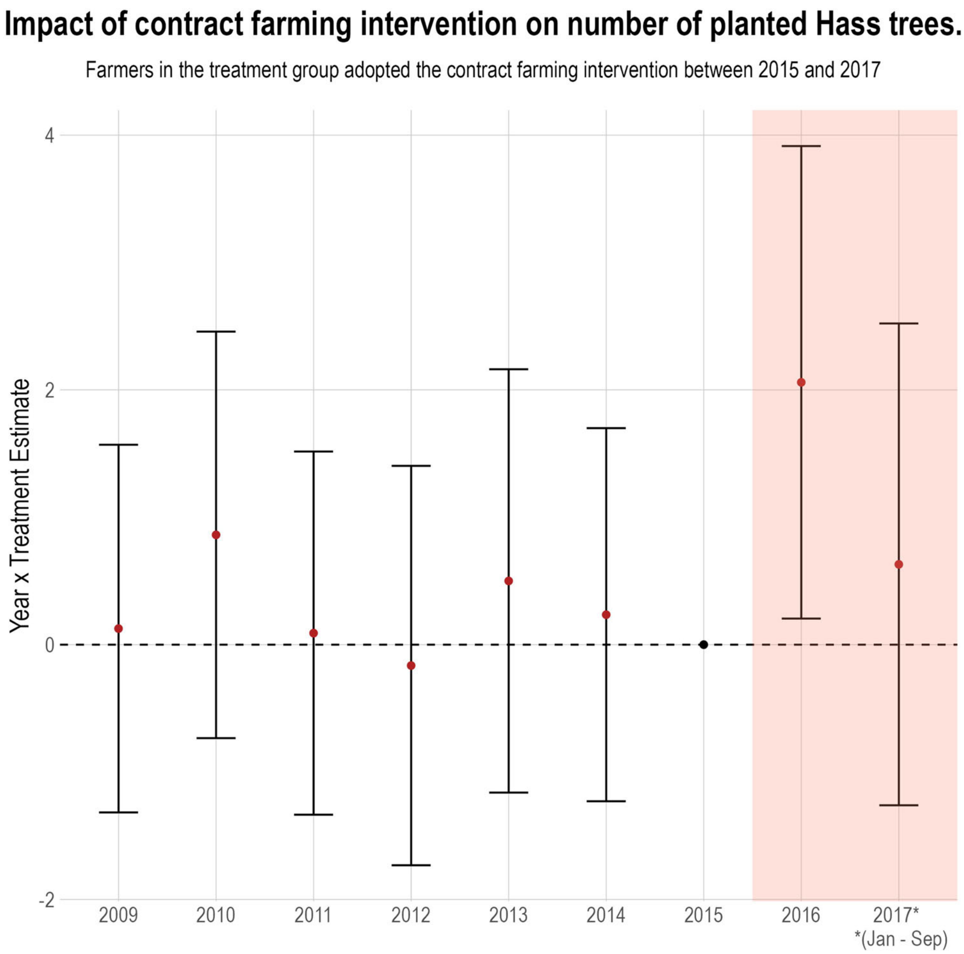

FIGURE 4 The number of planted Hass avocado trees increased significantly for the adopters after the contract farming intervention began at the end of 2015. In the years before the intervention, there are no differences between nonadopter farmers and those who adopt the contract farming intervention.

TABLE 2 Take-up of program components, doubly robust ATT estimates.

Variable	ATT	95% CI	*n*
Take-up: Selling to contracted company			
Sold (any avocado) to contracted company	.36 (.07)**	[.22, .51]	453
Sold Hass to contracted company	.32 (.05)**	[.22, .43]	453
Sold Fuerte to contracted company	.20 (.09)*	[.03, .37]	453
Fraction avocado sold to contracted company	.31 (.07)**	[.17, .46]	453
Take-up: Certification and training			
Received GLOBALG.A.P. certification	.85 (.06)**	[.74, .95]	453
Received training	.54 (.07)**	[.40, .68]	453

Note: Significance-levels: .1 ($^{+}$), .05 (*), .01 (**) Standard errors are clustered at sublocation level. The treatment is belonging to a contracted farmer organization. Households in the treatment group are adopters, households in the control group are nonadopters. The outcome variables are binary or fractions and thus between 0 and 1. The outcome fraction avocado sold is 0 if no sales occurred. The results are robust to instead dropping observations with no sales. Estimation is via doubly robust estimation following Sant'Anna, Zhao (2020). The propensity scores are estimated using the inverse probability tilting estimator (Graham, Pinto, Pinto 2012) and the outcome regression coefficients are estimated using weighted least squares with the propensity scores as weights.

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sold avocados to the contracted companies, were trained or certified is zero because the companies were only active after the baseline survey.

4.1.1 | Robustness and additional analysis

We test the robustness of our results to how we define the contract farming intervention and certification. For our main results, we defined the adoption of the contract farming intervention as being a member of a contracted farmer organization at endline. However, a few farmers sell to one of the contracted companies even though they report—perhaps mistakenly—not being a member of a farmer organization. Table D.1, Column 2 shows that our results are robust to adding these farmers to the group of adopters. The estimates are slightly smaller, which is intuitive, as these farmers are less tightly integrated into the farmer organizations and hence may not participate in all activities. Column 1 in Table D.1 repeats the results from our preferred specification. Second, our preferred way of measuring if a farmer received the *GLOBALG.A.P.* certification is based on whether a farmer is a member of a certified farmer organization, rather than on the farmers' response in the survey. *GLOBALG.A.P.* certification is not cost-effective among smallholder farmers at the individual level and therefore only offered at the group level in our context of smallholder farmers. We find that when we use the farmers' response about certification status, the endline levels of certification are lower and the treatment effect is only .33 percentage points compared to .85 points in the main results (see the row *Received GLOBALG.A.P. certification (individual)* outcome in Table D.1). This suggests that some smallholder farmers may not be aware of the fact that they received the certification via their farmer organization. However, since farmers (presumably) still receive the benefits of certification (if they market their avocado via their farmer organization), we prefer the group-based definition of certification.

4.2 | Contract farming is associated with improved marketing outcomes

We next estimate the impact of the contract farming intervention on production, marketing and welfare outcomes for avocado-farming households. The contracted companies prefer the Hass avocado and we expect the largest effects on those outcomes that are specific to the Hass variety. In Table 3 we therefore first present the production and marketing outcomes based on Hass avocado.

First, we would expect contract farmers to shift their production according to the demands of the buyers. Indeed, contract farmers are investing in the Hass variety by planting, on average, 2.46 additional Hass avocado trees. We also observe a small, and partly significant, shift toward sales of the Hass avocado variety (which is in higher demand by exporters), for which the fraction of total sales increased by 3.2 percentage points (not significant) and away from the Fuerte avocado variety, for which the fraction of total sales decreased by 4.0 percentage points (significant at 10% level, both results not reported in Table 3). The differential is made up by a change in sales of the local avocado variety. However, because any newly planted trees need time to mature (approximately 3–5 years) and grafting the Hass variety on an already developed stem of a local variety takes around 2 years to bear fruit, we would not expect a large shift after only 2 years, nor an effect on the quantity of Hass avocado sold yet.

Adopters of the contract farming intervention are more likely to sell (more) Hass avocado directly to a company as opposed to middlemen. This is intuitive, as these farmers can sell to the contracted company through their membership in a contracted farmer organization.

Interestingly, the estimated effects—38 percentage points for any Hass avocado sales and 37 percentage points for the fraction Hass avocado sold—are larger than the corresponding estimated increases for sales to the contracted company (32 respectively 31 percentage points, Table 2). This suggests that contract farmers are moving away from informal broker sales, but not only by increasing sales to the contracted company but also by engaging in side-selling to noncontracted companies.

Contract farmers also produce higher quality Hass avocado, increasing the share graded as high quality by 18 percentage points (an increase of 39%). Avocados sold to the contracted companies fetch higher prices than those sold to brokers and contract farmers receive on average 1.12 Kenyan Shilling more per Hass avocado across all buyers (contracted or not), an increase of 32% from the baseline price of 3.54 Kenyan Shilling. Price and quality information was missing for several farmers which explains the lower number of observations for these two outcome measures.

Adopters of the contract farming intervention have a significantly higher total cost of production.[18] However, because contract farmers also receive higher prices, the increased cost of production does not lead to a lower income for the farmers. Neither the income from Hass

[18] Total cost of production is the sum of costs of transport, hired labour, pesticides, inorganic fertilizer and manure. The increase of 105 percent in total cost seems to be driven by an increase in the cost of hired labor and pesticides, while the expenditure for inorganic fertilizer decreases among adopters. The cost of hired labor includes the labor costs for land preparation, harvesting, weeding, and marketing, with costs for land preparation increasing significantly.

TABLE 3 Outcomes for contracting, doubly robust ATT estimates.

Variable	ATT	95% CI	*n*
Production			
Number planted Hass trees	2.46 (.83)**	[.84, 4.08]	453
Cost of production (Hass, KSh), ihs	1.05 (.51)*	[.05, 2.05]	453
Knowledge index	.25 (.27)	[−.28, .78]	453
Marketing			
Sold Hass directly to a company	.38 (.04)**	[.31, .46]	453
Fraction Hass sold directly to a company	.37 (.04)**	[.29, .45]	453
Share high quality, Hass	.18 (.07)**	[.05, .32]	289
Avg. Hass price (KSh per unit)	1.12 (.53)*	[.09, 2.16]	289
Quantity Hass sold (units), ihs	−.17 (.28)	[−.73, .38]	453
Income (incl. consumption) from Hass (KSh), ihs	.03 (.39)	[−.74, .80]	453
Welfare			
Subjective satisfaction avocado farming	.04 (.10)	[−.15, .23]	453
Subjective stability avocado income	.05 (.07)	[−.08, .18]	453
Food insecurity index	1.15 (.85)	[−.51, 2.82]	453
Total income (KSh), ihs	.23 (.38)	[−.51, .98]	453

Note: Significance-levels: .1 (+), .05 (*), .01 (**) Standard errors are clustered at sublocation level. The treatment is belonging to a contracted farmer organization. Households in the treatment group are adopters, households in the control group are nonadopters. Households with no sales of the relevant avocado variety report no price or quality and are dropped from the analysis of the respective outcome. Food insecurity measured on HFIAS scale (Coates et al., 2007). Outcomes with ihs suffix are transformed using the inverse hyperbolic sine transformation and ATT estimates show semi elasticities. Transformed standard errors are calculated using the delta method. Estimation is via doubly robust estimation following Sant'Anna, Zhao (2020). The propensity scores are estimated using the inverse probability tilting estimator (Graham, Pinto, Pinto 2012) and the outcome regression coefficients are estimated using weighted least squares with the propensity scores as weights.

avocado, nor broader welfare measures show significant effects.[19] We also find no significant effect on a composite knowledge index.[20]

4.2.1 | Robustness and additional analysis

So far, we have focused on the production and marketing outcomes of the Hass avocado variety, which is where we would expect the largest impact of adopting the contract farming intervention. In Table D.2 we additionally show outcomes for all avocado varieties combined and for the Fuerte and local avocado varieties separately.[21] The largest positive effects are indeed for the Hass-specific outcomes. The overall quantity of avocados sold decreased by 51% because adopters of the contract farming intervention sold fewer avocados of each variety, although the individual varieties' estimates are not statistically significant.

5 | CONCLUSION

We have studied the impact of an avocado contract farming intervention aimed at improving the livelihood of households engaged in avocado farming in central Kenya. The contract between producer organizations and exporting companies covered procurement, access to training and

[19] The outcome variable of avocado income is defined as avocado revenue (including the value of own consumption) minus the cost of production and annual farmer organization membership fees. With respect to the impact variables, satisfaction with avocado-farming is based on the question "*Overall, how satisfied are you with avocado farming compared to cultivating the other crops?*" and stability of avocado income is based on the question "*How would you rate the stability of income from avocado farming compared to the income from other crops?*". The variables indicate a (very) positive response on a five-level Likert scale from "*Much less satisfied*" to "*Much more satisfied*" and from "*Much more instable*" to "*Much more stable*", respectively. Food insecurity is measured with "Household Food Insecurity Access Scale" (HFIAS, Coates et al. (2007)). Total income includes agricultural income (from avocado farming, non-avocado trees and other crops) and non-agricultural income (including employment, remittances and pension).

[20] The index ranges from 0 to 9 and asks about the factors affecting avocado quality and the benefits of pruning and record-keeping. The exact questions for each of these three benefits are: "*Can you mention the factors that affect avocado quality?*", "*Can you mention some benefits of pruning avocado trees?*" and "*Can you mention benefits of record keeping?*". The index is constructed by adding up the number of correct responses (max three) for the three questions.

[21] Prices and quality measures were not available for the local avocado variety and sometimes missing for the Hass and Fuerte variety, explaining the lower number of observations for these two outcome measures.

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support to gain *GLOBALG.A.P.* certification. We used a (doubly robust) difference-in-differences design to control for possible confounding factors due to nonrandom program placement and farmer self-selection, as well as (arguably as good as) exogenous variation in the reduction in distance to the nearest farmer organization. Using farm-level panel data, we are therefore able to control for (time invariant) unobservable and possible misspecification in either the propensity score model or outcome regression model (but not both).

Our identification strategy hinges on the common trend assumption which we can and do test for, but only for the outcome of Hass avocado tree planting for lack of historical data for the other outcomes. Our balancing tests suggest that there are no significant differences between treatment and control farmers, but, naturally, we cannot exclude the possibility that there are differences in terms of unobservable. Including the reduction in distance to the nearest farmer organization in our econometric specification introduces additional exogenous variation, but we can only test for whether this variation is orthogonal to various observable but not necessarily unobserved village and farmer characteristics. While these are possible shortcomings of our empirical approach, our use of panel data is likely to provide more credible estimates of the actual impact of our contract farming intervention than a naive with-without approach using only cross-sectional data. To demonstrate this, we redo the analysis under the assumption that only cross-sectional data are available and have the (expected) finding that a cross-sectional approach tends to give (somewhat) exaggerated effects for our case (see Appendix E).

The empirical analysis shows that the intervention succeeded in diverting sales from informal to formal marketing channels (i.e. from sales to brokers to direct sales to (exporting) companies), at higher prices. Also, farmers were more likely to be trained and working according to *GLOBALG.A.P* production standards, leading to an increase in the share of high-quality avocados. The intervention led farmers to increase their planting of the export oriented avocado variety Hass, suggesting the start of a transition from avocado production predominantly for the local market to production for the export market.

While encouraging, other findings point to possible challenges for contracting farming. Despite increased quality and prices for Hass avocado, estimated increases in Hass avocado income are not significant. While most of the literature has focused on the benefits of contract farming, we find that it significantly increases the cost of production, especially the cost of hired labor. Also, we find no statistically significant evidence that the intervention has increased welfare, measured not only in terms of total income but also income stability, satisfaction, and food security. These findings align with the six-country study by Meemken and Bellemare (2019), who shows that contract farming tends to increase the demand for hired labor but increases incomes only in some countries. The observed investment in Hass trees may lead to an increase in incomes when bearing fruit in the future, but this is not guaranteed if production costs increase concomitantly.

The study also finds what is a key challenge for contract farming schemes, namely a high prevalence of side-selling with only about a third of the contracted farmers actually selling to the contracted company. Previous research has highlighted challenges with contract farming schemes due to side-selling, opportunistic behavior by companies such as delaying and discounting payments, and governance issues in farmer organizations as reflected in misallocations or improprieties, resulting in drop-outs and even collapse of schemes (Jaffee, 1994; Singh, 2002).

While contract schemes have shown a relatively high rate of failure in developing countries, this has been particularly evident for Kenya resulting in low levels of trust among market participants (Minot & Sawyer, 2016). Also in our study area, a high level of churning has been observed among contract farmers—see Muriithi and Kabubo-Mariara (2021) for a detailed analysis of the dynamics of group membership using the same sample but including the farmers who were already connected to an avocado exporting company.[22] Of course, we study a new intervention and contract compliance may well improve over time with increasing trust and/or attrition of contract noncompliers, reducing the rate of side selling to acceptable levels. However, the sustainability of contract farming schemes remains an important (and understudied) issue for future research, calling for more in-depth and long-term studies of (previously studied) contracting schemes.

Another challenge forms the dynamic nature of the structure of avocado markets in Kenya. Even for the limited 2-year period between the baseline and the endline of our study, we observe new farmer organizations being formed, while others are dismantled and new avocado companies entering the area, while others drastically reduce their engagement with contracted farmers.[23] Macchiavello and Morjaria (2021) have recently emphasized that high churning makes it difficult to enforce contracts between smallholder farmers and companies. They show in the case of coffee farming in Rwanda that relational contracts between producers and buyers can be negatively affected by an excess of competition. Too much competition implies that farmers have too many outside options

[22] See footnote 7.

[23] For example, three of the original ten intervention companies left the market since our endline in 2017.

leading to side-selling and a breakdown of (informal) contracts. Also, too much competition depresses the profits of buyers, reducing their chances for survival and thereby limiting their time horizon and willingness to invest in long-term contracts that support traceability, quality standards, and/or provision of training, inputs or credit. More broadly, more market structure research looking at how contract farming affects and is affected by other supply chain actors such as middlemen should form an important contribution to the future literature. Finally, given the external validity challenge, metastudies are called for to understand whether and how the effects of contract farming vary systematically across different settings.

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APPENDIX A: INTERVENTION

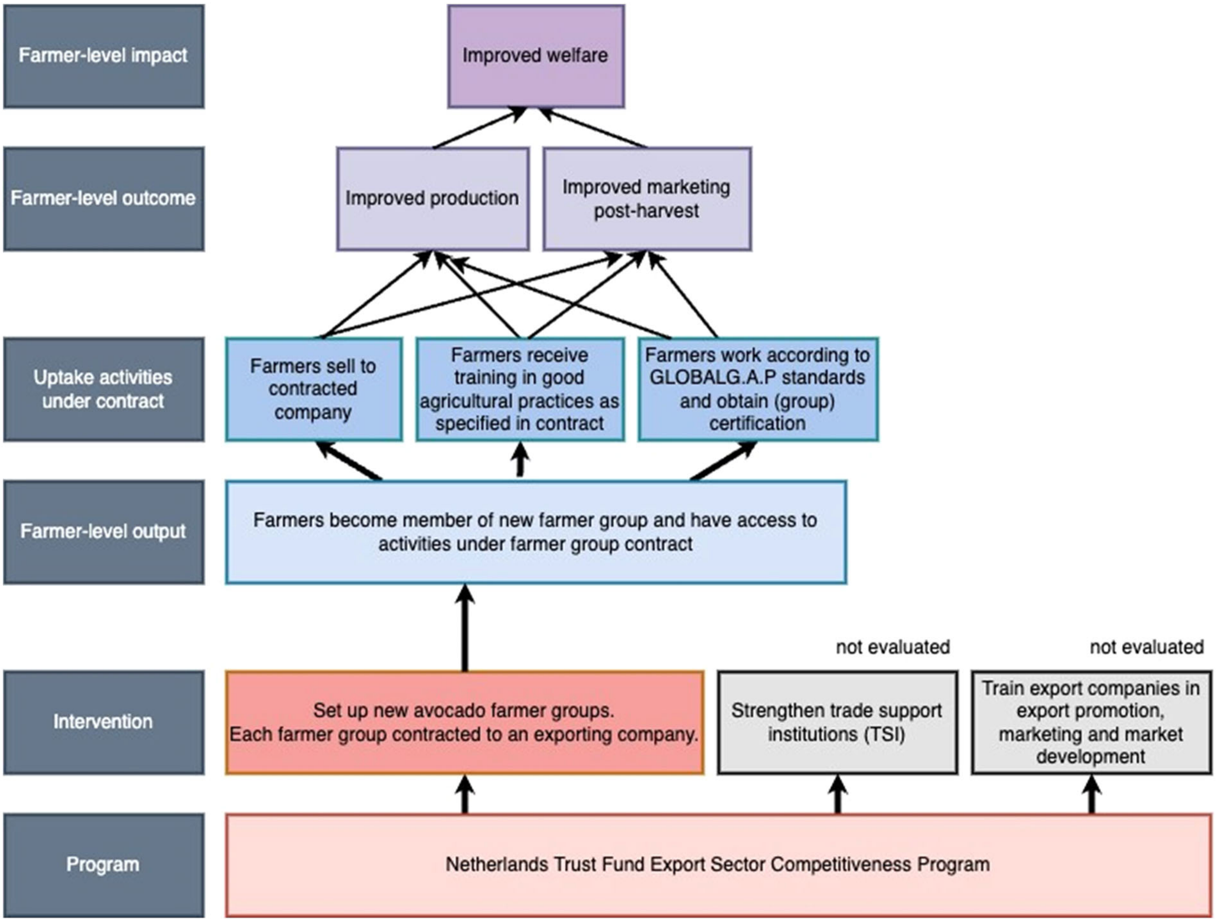

FIGURE A.1 Theory of change diagram.
Note: The dashed line encloses the part of the intervention evaluated in this article.

APPENDIX B: DATA

Descriptive results

Table B.1 shows summary statistics at baseline of the outcomes for farmers that end up adopting contract farming by becoming members of the newly established farmer organizations and for those who do not become members and serve as our control group. At baseline, none of the 453 avocado-farming households had received the *GLOBALG.A.P*. certification. Because selection into whether households would join the new farmer organizations at baseline was not random, we would expect to observe some differences in outcomes and explanatory variables between the two groups. Farmers who end up adopting contract farming by membership in one of the new farmer organizations indeed seem to have a slightly higher intensity of avocado farming at baseline (Table B.1). Table B.2 supports this, as farmers who do not end up becoming a member of one of the new farmer organizations have higher nonfarm income at baseline. Other differences in explanatory household characteristics are in line with the findings of Muriithi and Kabubo-Mariara (2021)—with avocado contract farmers being more likely to be male and higher educated. Other characteristics are relatively similar.

TABLE B.1 Summary of outcomes at baseline.

Variable	Adopters Mean	Adopters SD	Control farmers Mean	Control farmers SD	Difference
Production					
Number planted avocado trees	1.99	7.24	1.35	4.66	.65
Number planted Hass trees	1.76	6.97	1.1	4.42	.65
Number planted Fuerte trees	.19	1.07	.11	.81	.08
Number planted local trees	.05	.31	.13	.99	−.08
Cost of production (all avocado, 1000 KSh)*	.79	2.62	.48	1.22	.3
Cost of production (Hass, 1000 KSh)*	.55	2.42	.27	.76	.28
Cost of production (Fuerte, 1000 KSh)*	.17	.41	.15	.49	.01
Knowledge index	4.97	2.17	4.42	2.13	.55*
Marketing					
Fraction avocado sold directly to a company	.08	.24	.03	.17	.05*
Fraction Hass sold directly to a company	.12	.33	.03	.17	.09**
Fraction Fuerte sold directly to a company	.04	.19	.02	.15	.01
Sold (any avocado) directly to a company	.15	.36	.05	.21	.11**
Sold Hass directly to a company	.13	.34	.03	.18	.1**
Sold Fuerte directly to a company	.04	.2	.03	.16	.01
Share high quality	.37	.45	.34	.44	.03
Share high quality, Hass	.48	.5	.49	.5	−.01
Share high quality, Fuerte	.3	.46	.28	.44	.03
Avg. avocado price (KSh per unit)	2.6	1.21	2.29	1.06	.31*
Avg. Hass price (KSh per unit)	3.51	1.85	2.89	1.34	.62**
Avg. Fuerte price (KSh per unit)	2.01	1.09	1.99	1.16	.02
Quantity avocado sold (units)	7263	10931	5522	8018	1740.8
Quantity Hass sold (units)*	3208	7008	2354	4207	853.4
Quantity Fuerte sold (units)*	3548	7790	2657	5192	891.45
Quantity local sold (units)*	508	2245	512	1470	−4.05
Welfare					
Fraction Hass of total sales	.45	.33	.39	.36	.07+
Fraction Fuerte of total sales	.46	.34	.46	.37	0
Income from any avocado (1000 KSh)*	20.99	31.76	15.32	30.35	5.67+
Income from Hass (1000 KSh)*	10.87	17.92	7.69	15.3	3.18+
Income from Fuerte (1000 KSh)*	9.14	24.61	6.13	14.63	3.01
Income from local (1000 KSh)*	.97	3.66	1.5	7.35	−.52
Subjective satisfaction avocado farming	.84	.37	.77	.42	.07+
Subjective stability avocado income*	.81	.4	.74	.44	.07
Food Insecurity index	4.99	4.54	5.57	5.3	−.58
Total income (1000 KSh)*	151	164.59	171.84	255.5	−20.84

Note: Significance levels: .1 (+), .05 (*), .01 (**) Significance of differences evaluated with two-sided *t*-test. No farmers sold to the contracted company or were trained or certified for GLOBALG.A.P at baseline. Variables marked with * are transformed using the inverse hyperbolic sine (ihs) transformation, because the distribution exhibits a long right tail and many zero-values. Negative values for income are set to 0. Price and quality for local variety not reported because too few farmers report it. Income variables include value of own consumption.

TABLE B.2 Summary of explanatory variables at baseline.

Variable	Adopters Mean	Adopters SD	Control farmers Mean	Control farmers SD	Difference
Access to contract farming					
Reduction distance to FO	.94	.76	.52	.75	.42**
Dummy for reduction distance to FO	.73	.44	.40	.49	.34**
Household composition					
Dist. to local market (km)	3.19	2.58	2.68	2.06	.52*
Dist. to road (km)	.70	.89	.53	.68	.17*
Age household head	60.94	10.45	63.51	13.34	−2.57*
Education household head (years)	9.19	3.78	7.79	3.78	1.4**
Household head is male	.91	.29	.71	.45	.2**
Household size	3.48	1.47	3.65	1.90	−.17
Assets and land ownership					
Land owned (acres)	1.86	1.19	1.99	1.89	−.12
Mature Hass avocado trees owned	6.91	14.21	4.59	8.30	2.33+
Diversified income					
Non-farm income (1000 KSh)*	69.22	128.67	97.35	177.09	−28.13+
Access to banking and finance					
Uses bank account to sell crops	.00	.00	.00	.00	0

Note: Significance levels: .1 (+), .05 (*), .01 (**) Significance of differences evaluated with two-sided t-test. Variables marked with * are transformed using the inverse hyperbolic sine (ihs) transformation in the analysis, because the distribution exhibits a long right tail and many zero-values. Negative values for income are set to 0. The ihstransformation is an alternative to the common practice of taking a $\log(x+1)$ transformation, but does not rely on adding a constant to observations with a zero value. Results using the $\log(x+1)$ transformation are available upon request.

TABLE B.3 Determinants of attrition, outcome is attrition indicator.

	Estimate	95% CI
Program allocation (*F*-test = 1.88, *p* = .17)		
Member of new farmer group	−.0308 (.03)	[−.09, .03]
Outcomes (*F*-test = .76, *p* = .76)		
Cost of production (all avocado, KSh), ihs	−.0048 (.01)	[−.02, .01]
Cost of production (Hass, KSh), ihs	.0063 (.01)	[−.01, .02]
Cost of production (Fuerte, KSh), ihs	−.0042 (.01)	[−.02, .01]
Knowledge index	.0017 (.01)	[−.01, .01]
Avg. avocado price (KSh per unit)	.0094 (.02)	[−.02, .04]
Quantity avocado sold (units), ihs	−.0180 (.04)	[−.10, .06]
Quantity Hass sold (units), ihs	.0170 (.01)	[−.01, .05]
Quantity Fuerte sold (units), ihs	−.0096 (.02)	[−.04, .02]
Quantity local sold (units), ihs	.0022 (.01)	[−.01, .02]
Fraction Hass of total sales	.0363 (.11)	[−.17, .24]
Fraction Fuerte of total sales	.1797 (.11)+	[−.03, .39]
Income (incl. consumption) from any avocado (KSh), ihs	.0296 (.04)	[−.04, .10]
Income (incl. consumption) from Hass (KSh), ihs	−.0108 (.01)	[−.03, .01]
Income (incl. consumption) from Fuerte (KSh), ihs	−.0019 (.01)	[−.03, .03]
Income (incl. consumption) from local (KSh), ihs	.0011 (.01)	[−.01, .01]
Subjective satisfaction avocado farming	−.0124 (.03)	[−.08, .05]
Subjective stability avocado income	.0177 (.03)	[−.04, .08]
Food Insecurity index	−.0006 (.00)	[−.01, .00]
Total income (KSh), ihs	−.0018 (.01)	[−.01, .01]

(Continues)

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TABLE B.3 (Continued)

	Estimate	95% CI
Controls (*F*-test = .27, *p* = .98)		
Household size	−.0031 (.01)	[−.02, .01]
Age household head	.0001 (.00)	[.00, .00]
Household head is male	−.0115 (.03)	[−.07, .05]
Education household head (years)	−.0001 (.00)	[−.01, .01]
Land owned (acres)	.0057 (.01)	[−.01, .02]
Mature Hass avocado trees owned (ihs)	−.0082 (.02)	[−.04, .03]
Non-farm income (KSh, ihs)	.0028 (.00)	[.00, .01]
Uses bank account to sell crops	.0033 (.03)	[−.05, .05]
F-test of all variables	*F* = .79	*p*.val = .77

Note: Significance-levels: .1 (+), .05 (*), .01 (**). Linear regression comparing baseline data of 33 households that dropped out of the sample for attrition-relevant reasons (declined, unavailable, moved, not known in area) with households that appear in baseline and endline. In the full sample 453 households appear in both waves, but for the attrition analysis all households with missing data for any of the potential determinants of attrition are dropped, leaving 440 households for the attrition analysis. F-test statistics test the joint significance of (sets of) variables.

APPENDIX C: METHODOLOGY

TABLE C.1 Covariate balance between treatment and control group, original and weighted sample.

Variable	$Mean^{Original}_{Adopters}$	$Mean^{Original}_{Control}$	$Difference^{Original}$	$Mean^{Weighted}_{Control}$	$Difference^{Weighted}$
Reduction distance to FO	.9365	.5158	.4207**	.9688	−.0324
Dummy for reduction distance to FO	.7339	.3982	.3357**	.7303	.0036
Dist. to road (km)	.7036	.5292	.1744*	.6425	.0612
Dist. to local market (km)	3.1907	2.6754	.5153*	3.5726	−.3819
Household size	3.4839	3.6535	−.1696	3.5016	−.0177
Age household head	60.9435	63.5106	−2.5671*	61.0178	−.0743
Household head is male	.9113	.7112	.2000**	.9142	−.0029
Education household head (years)	9.1855	7.7872	1.3982**	9.2008	−.0153
Land owned (acres)	1.8623	1.9869	−.1246	1.9102	−.0479
Mature Hass avocado trees owned (ihs)	1.9196	1.4772	.4424**	1.8945	.0251
Non-farm income (KSh, ihs)	9.6016	9.5074	.0943	9.5955	.0061
Uses bank account to sell crops	.5968	.3769	.2199**	.5927	.0041

Note: Significance-levels: .1 (+), .05 (*), .01 (**) Weights are based on propensity scores and ATT estimand, where covariates of treatment group are weighted with 1 and covariates of control group are weighted with ps/ (1-ps) and scaled by the relative size of the control group.

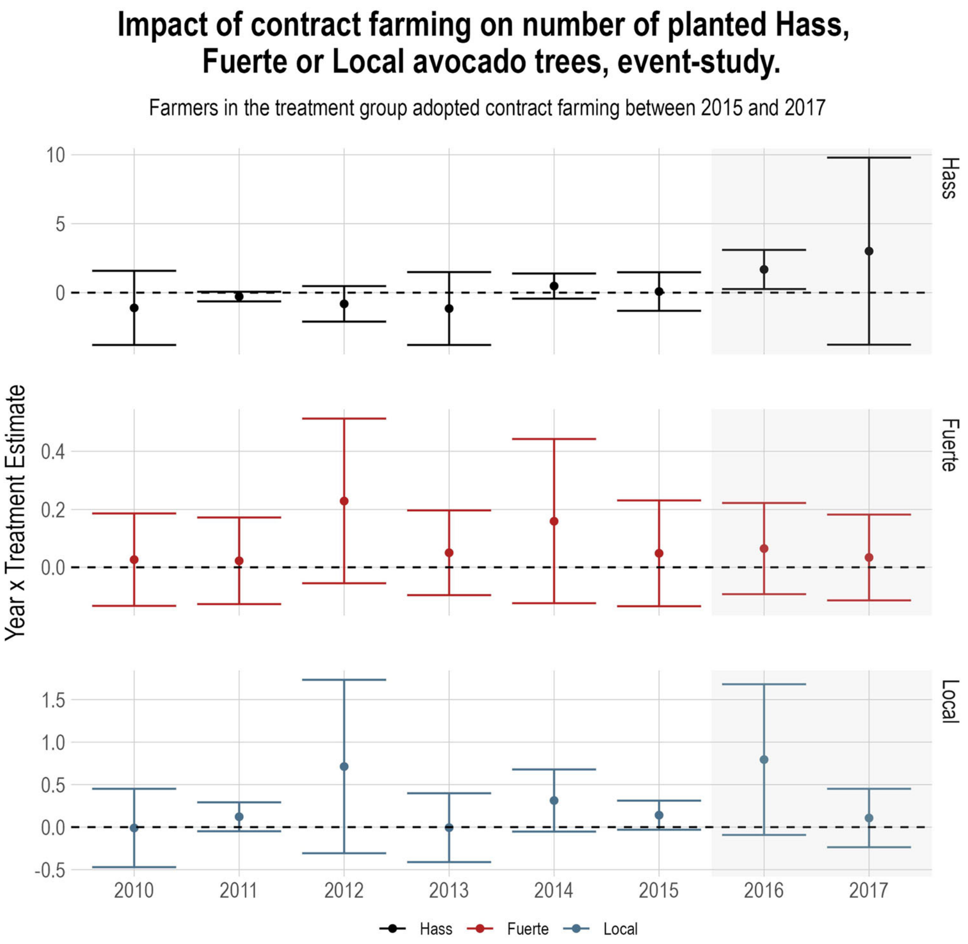

FIGURE C.1 Impact of contract farming on number of planted Hass, Fuerte, or local avocado trees, event-study.

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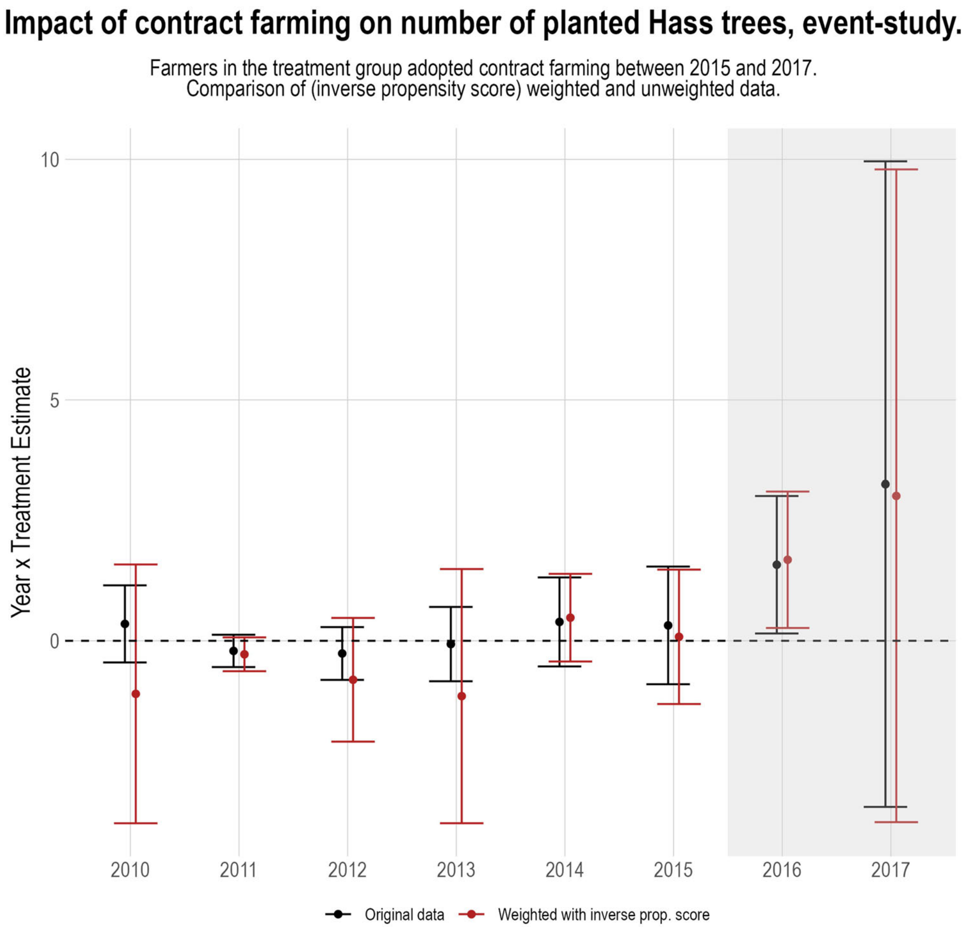

FIGURE C.2 Impact of contract farming on number of planted Hass trees, event-study.

APPENDIX D: RESULTS

Figure D.1.

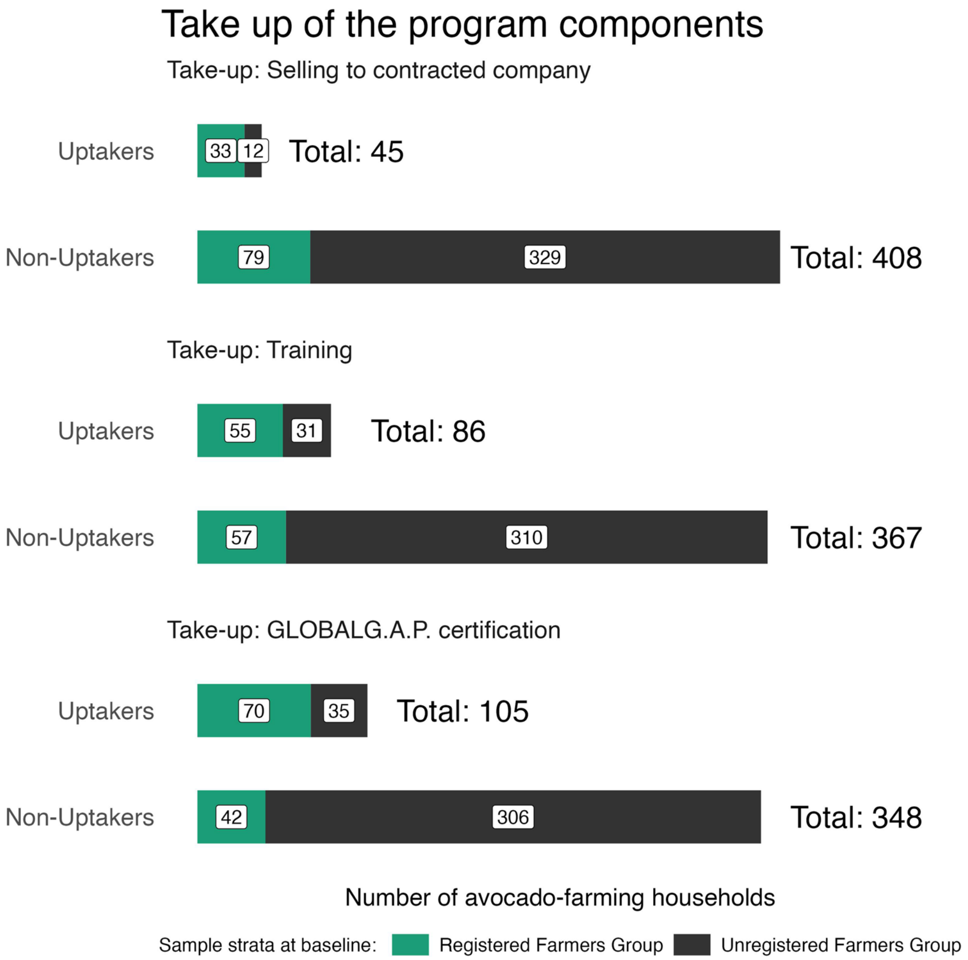

FIGURE D.1 Take-up of program components, descriptive evidence.

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TABLE D.1 Take-up of program components, comparing different definitions of contract treatment, doubly-robust ATT estimates.

	Contract			Contract including sales		
	ATT	**95% CI**	***n***	**ATT**	**95% CI**	***n***
Take-up: Selling to contracted company						
Sold (any avocado) to contracted company	.36 (.07)**	[.22, .51]	453	.29 (.06)**	[.17, .41]	412
Sold Hass to contracted company	.32 (.05)**	[.22, .43]	453	.25 (.04)**	[.17, .33]	412
Sold Fuerte to contracted company	.20 (.09)*	[.03, .37]	453	.16 (.07)*	[.03, .29]	412
Fraction avocado sold to contracted company	.31 (.07)**	[.17, .46]	453	.25 (.06)**	[.13, .37]	412
Take-up: Certification and training						
Received GLOBALG.A.P. certification	.85 (.06)**	[.74, .95]	453	.74 (.10)**	[.55, .93]	412
Received GLOBALG.A.P. certification (individual)	.33 (.06)**	[.21, .45]	453	.30 (.05)**	[.20, .40]	412
Received training	.54 (.07)**	[.40, .68]	453	.48 (.08)**	[.33, .63]	412

Note: .1 ($^+$), .05 (*), .01 (**) Standard errors are clustered at sublocation level. Column 1: The treatment is belonging to a contracted farmer organization. Column 2: The treatment is belonging to a contracted farmer organization and/or any sales under contract were made. Households in the treatment group are adopters, households in the control group are nonadopters. The outcome variables are binary or fractions and thus between 0 and 1. The outcome fraction avocado sold is 0 if no sales occurred. The results are robust to instead dropping observations with no sales. Estimation is via doubly robust estimation following Sant'Anna, Zhao (2020). The propensity scores are estimated using the inverse probability tilting estimator (Graham, Pinto, Pinto 2012) and the outcome regression coefficients are estimated using weighted least squares with the propensity scores as weights.

TABLE D.2 Marketing outcomes for different avocado types, doubly robust ATT estimates.

Variable	ATT	95% CI	*n*
Outcome: Production			
Number planted avocado trees	2.88 (.84)**	[1.23, 4.53]	453
Number planted Hass trees	2.46 (.83)**	[.84, 4.08]	453
Number planted Fuerte trees	−.11 (.15)	[−.40, .18]	453
Number planted local trees	.53 (.13)**	[.27, .79]	453
Cost of production (all avocado, KSh), ihs	.80 (.50)	[−.17, 1.77]	453
Cost of production (Hass, KSh), ihs	1.05 (.51)*	[.05, 2.05]	453
Cost of production (Fuerte, KSh), ihs	.38 (.40)	[−.41, 1.16]	453
Outcome: Marketing			
Sold (any avocado) directly to a company	.40 (.04)**	[.32, .49]	453
Fraction avocado sold directly to a company	.37 (.05)**	[.27, .47]	453
Sold Hass directly to a company	.38 (.04)**	[.31, .46]	453
Fraction Hass sold directly to a company	.37 (.04)**	[.29, .45]	453
Sold Fuerte directly to a company	.23 (.08)**	[.07, .38]	453
Fraction Fuerte sold directly to a company	.22 (.08)**	[.06, .37]	453
Share high quality	.07 (.09)	[−.10, .25]	432
Share high quality, Hass	.18 (.07)**	[.05, .32]	289
Share high quality, Fuerte	−.04 (.12)	[−.27, .19]	303
Avg. avocado price (KSh per unit)	.90 (.50)+	[−.08, 1.87]	424
Avg. Hass price (KSh per unit)	1.12 (.53)*	[.09, 2.16]	289
Avg. Fuerte price (KSh per unit)	.42 (.51)	[−.57, 1.41]	301
Quantity avocado sold (units), ihs	−.51 (.22)*	[−.94, −.09]	453
Quantity Hass sold (units), ihs	−.17 (.28)	[−.73, .38]	453
Quantity Fuerte sold (units), ihs	−.32 (.45)	[−1.21, .57]	453
Quantity local sold (units), ihs	−.22 (.29)	[−.80, .36]	453
Income (incl. consumption) from any avocado (KSh), ihs	−.27 (.29)	[−.85, .31]	453
Income (incl. consumption) from Hass (KSh), ihs	.03 (.39)	[−.74, .80]	453
Income (incl. consumption) from Fuerte (KSh), ihs	−.27 (.60)	[−1.46, .91]	453
Income (incl. consumption) from local (KSh), ihs	.41 (.39)	[−.37, 1.18]	453

Note: .1 (+), .05 (*), .01 (**) Standard errors are clustered at sublocation level. The treatment is belonging to a contracted farmer organization. Households in the treatment group are adopters, households in the control group are nonadopters. Households with no sales of the relevant avocado variety report no price or quality and are dropped from the analysis of the respective outcome. Food insecurity measured on HFIAS scale (Coates et al., 2007). Outcomes with ihs suffix are transformed using the inverse hyperbolic sine transformation and ATT estimates show semielasticities. Transformed standard errors are calculated using the delta method. Estimation is via doubly robust estimation following Sant'Anna, Zhao (2020). The propensity scores are estimated using the inverse probability tilting estimator (Graham, Pinto, Pinto 2012) and the outcome regression coefficients are estimated using weighted least squares with the propensity scores as weights.

APPENDIX E: RESULTS FROM THE CROSS-SECTION

Previous studies on the impact of contract farming typically rely on cross-sectional data and compare contract farmers with noncontract farmers at one point in time. In our preferred research design, we improve on this data limitation by using a doubly robust difference-indifferences design and thus comparing changes over time between farmers that adopt contract farming and farmers that—during our sample period—never engage in contract farming. To understand the importance of having access to panel data it is instructive to redo our main empirical analysis underlying Table 3 presented in Section 4, but pretend that we only had cross-sectional data from the endline available.[24] In Table E.1 we contrast the results from our preferred doubly robust difference-in-differences estimates (Column 1) with the hypothetical situation where we only have access to the endline data (Column 2).

With access to panel data we previously based our treatment definition on whether farmers adopted contract farming between baseline and endline by becoming a member of the contracted new farmer organizations. With only access to cross-sectional data, such a definition focusing on adopters is often not feasible. Instead, researchers would ask farmers whether or not they are members of a contracted farmer organization at the time of the survey and compare the two groups (potentially after accounting for selection into contract farming with, e.g., matching techniques). This is the situation we envision for the analysis underlying Column 2 in Table E.1. Specifically, we compare farmers with group-level contracts with farmers without contracts at endline.

We estimate the effect of having a contract on the same outcomes as in our previous analysis and control for the same covariates but only use the values from the endline.[25] Equation (E.1) shows the estimating equation, where y_i is the outcome at endline, X_i is the set of control variables and Contract_i indicates whether the farmer has a group-level contract to sell (any type of) avocado at endline by being a member of a contracted farmer organization. γ is the estimate for the treatment effect, which we compare with the ATT estimates from the doubly robust difference-in-differences framework

[24] Theoretically, we can also repeat the analysis on take-up of the activities (Table 2). However, because take-up at baseline is zero by definition for both groups, the results are virtually the same.

[25] In the difference-in-differences specifications, we used the baseline values of the covariates, whereas in column two of Table E.1 we used the endline values. Additionally, we exclude the two variables related to the reduction in distance to the new farmer organization, because these would not be available with only endline data.

TABLE E.1 Outcomes for contracting, comparing doubly robust difference-in-differences with cross-sectional endline-only ATT estimates.

	ATT	95% CI	n	ATT	95% CI	n
Production						
Number planted Hass trees	2.46 (.83)**	[.84, 4.08]	453	1.76 (1.03)	[−.92, 4.44]	453
Cost of production (Hass, KSh), ihs	1.05 (.51)*	[.05, 2.05]	453	1.23 (1.93)	[−2.55, 5.02]	453
Knowledge index	.25 (.27)	[−.28, .78]	453	.73 (.23)*	[.15, 1.32]	453
Marketing						
Sold Hass directly to a company	.38 (.04)**	[.31, .46]	453	.46 (.07)**	[.29, .64]	453
Fraction Hass sold directly to a company	.37 (.04)**	[.29, .45]	453	.45 (.07)**	[.26, .63]	453
Share high quality, Hass	.18 (.07)**	[.05, .32]	289	.09 (.08)	[−.11, .30]	289
Avg. Hass price (KSh per unit)	1.12 (.53)*	[.09, 2.16]	289	1.85 (.91)+	[−.46, 4.16]	289
Quantity Hass sold (units), ihs	−.17 (.28)	[−.73, .38]	453	.22 (.45)	[−.66, 1.10]	453
Income (incl. consumption) from Hass (KSh), ihs	.03 (.39)	[−.74, .80]	453	.66 (.85)	[−1.00, 2.32]	453
Welfare						
Subjective satisfaction avocado farming	.04 (.10)	[−.15, .23]	453	.12 (.05)+	[−.01, .24]	453
Subjective stability avocado income	.05 (.07)	[−.08, .18]	453	.11 (.04)+	[.00, .22]	453
Food Insecurity index	1.15 (.85)	[−.51, 2.82]	453	.75 (.73)	[−1.14, 2.64]	453
Total income (KSh), ihs	.23 (.38)	[−.51, .98]	453	2.00 (3.24)	[−4.36, 8.36]	453

Note: .1 (+), .05 (*), .01 (**) Standard errors are clustered at sublocation level. Households with no sales of the relevant avocado variety report no price or quality and are dropped from the analysis of the respective outcome. Column 1 repeats the estimates from the preferred doubly robust difference-in-differences specification which fully exploits the available panel data. Column 2 is a cross-sectional regression with propensity score matching using only information from the endline. In column 2, households are classified into participating in contract farming (treated) or not participating (control) at endline because focussing on adopters is not possible with cross-sectional data.

in Equation (2). Equation (E.1) is estimated on data reweighted with the propensity score, for a fair comparison with the doubly robust difference-in-differences estimation, which also uses inverse propensity score weighting.

$$y_i = \alpha + X_i'\beta + \gamma \text{ Contract}_i + \varepsilon_i \tag{E.1}$$

The second column in Table E.1 shows that if we had only access to the endline survey and compared contract farmers with noncontract farmers, we would find larger impact estimates for 10 of the 13 outcome variables. This shows that propensity score matching alone is most likely insufficient to account for the endogeneity due to the farmers' self-selection into contract farming. We would expect farmers with higher potential, more motivation and better information to select into contract farming which explains why estimates that do not sufficiently account for this source of endogeneity are likely to be biased upwards.

APPENDIX F: VILLAGE REGRESSIONS

TABLE F.1 Average distance reduction and village and household characteristics.

	Reduction in distance (km)		Distance changed (y/n)	
	Est.	**S.E.**	**Est.**	**S.E.**
Panel A: Village-level characteristics (across all villages)				
(Intercept)	.83**	.26	.52**	.18
Dist. to road (km)	−.18	.28	.09	.19
Dist. to local market (km)	−.07	.06	−.04	.04
F-test for joint significance	*F* = .79 (p.val = .46)		*F* = 1.85 (p.val = .18)	
Panel B: Village- and household characteristics (across farmers in unregistered farmers' villages)				
(Intercept)	.59*	.24	.24	.15
Dist. to road (km)	−.01	.10	.05	.07
Dist. to local market (km)	−.05	.06	−.01	.05
Household size	.03	.03	.02	.01
Age household head	.00	.00	.00	.00
Household head is male	−.06	.10	−.02	.07
Education household head (years)	.00	.01	.00	.01
Land owned (acres)	−.01	.02	−.01	.02
Mature Hass avocado trees owned	.00	.01	.00	.01
Non-farm income (1000 KSh)*	.00	.00	.00	.00
Uses bank account to sell crops	.17	.12	.14*	.06
F-test for joint significance	*F* = 1.26 (p.val = .25)		*F* = 1.54 (p.val = .12)	

Note: $^+$ $p < .1$, * $p < .05$, ** $p < .01$ Location of groups is approximated by the centroid of the originally registered farmers' locations. Distance is the absolute change in distance (Column 1) and an indicator of whether the distance decreased at all (Column 2). Variables marked with * are transformed using the inverse hyperbolic sine (ihs) transformation in the analysis, because the distribution exhibits a long tail and many zero-values. Panel A uses all villages (village-level regression), Panel B only uses farmers in unregistered farmers' villages because respondents in registered farmers' villages are not representative of their village (household-level regression).