Ripe for contracts? Avocado contract farming in Kenya improves agricultural investments, knowledge and prices. ⋆

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Abstract

We evaluate the impact of a multi-layered contract farming intervention that connected smallholder farmers in central Kenya to avocado exporting companies, provided training in good agricultural practices and certified farmer organizations according to the global good agricultural practices (*GAP*) production standard. Using panel data from 2015 and 2017 we show that the intervention was successful at delivering its immediate goals. It increased the share of farmers that sold to companies, were recently trained and received the GAP certification. Contract farming significantly improved sales prices of farmers, knowledge of avocado-farming practices and led to increased investments into the Hass avocado variety which is in higher demand in export markets. We find suggestive, albeit not statistically significant, evidence that contract farming improved farmer income and shifted labor from family to hired labor. At the same time, contract farmers produced less of the local avocado variety, leading to a significant decrease in total quantity sold during the transition to the export-oriented Hass avocado variety. We contribute to the literature by quantifying the impact of a multi-layered contract farming intervention. Panel data allows us to estimate a doubly-robust difference-in-differences design, giving us more confidence to interpret our estimates as causal evidence of contract farming than traditional cross-sectional studies allow for.

Keywords: Contract Farming, Smallholder Farmers, Exporting

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1. Introduction

Agricultural markets in low-income countries are changing. In many export-oriented value chains buyers prefer to contract farmers directly, to ensure a reliable supply, high-quality harvest and to satisfy the international demand for traceable and sustainably produced fruits and vegetables. For smallholder farmers, this holds the promise of improved prices and easier access to knowledge, technology and inputs (Minten, Randrianarison and Swinnen, 2009; Bellemare, Lee and Novak, 2018; Meemken and Bellemare, 2019; Debela, Ruml and Qaim, 2021). However, contract farming is a result of the choices of companies — who choose whether to engage with farmers — and of farmers — who choose whether to join farmer groups and abide by the terms of the contract. Costs of contract farming, both in the form of higher production costs (harvesting and transportation, fees for farmer group memberships, expensive inputs) and opportunity costs (reduced production of other crops, inflexible timing of harvests, delayed payments) affect these choices and make the implications of contract farming a context-specific, empirical question. Additionally, contract farming often consists not only of purchase agreements, but also of extension services (e.g. training, input provision and access to finance) and certification of production quality standards. It is important to understand which of these aspects of contract farming contribute the most to smallholder farmers' integration into value chains and improvements in livelihoods.

We study the impact of contract farming — combined with training and certification — in Murang'a County, in central Kenya, by evaluating a the *Netherlands Trust Fund's Export Sector Competitiveness Program*, a program which set up farmer organizations for avocado-farming households and connected those farmer organizations to avocado exporting companies.[1] We interviewed avocado-farming households in two waves, a baseline survey in November – December 2015 and an endline survey in August – September 2017. We interviewed 789 avocado-farming households, of which 702 households were included in both waves. These 702 households can be classified into three groups: a *targeted group* of 112 households who were identified as part of the intervention, organized in four new farmer organizations and adopted contract farming after the baseline; an *existing contract* group of 242 households who at baseline were organized in 14 farmer organizations with an existing contract with the dominant regional avocado exporting company; and a *no contract* group of 348 avocado-farming households who had no contract at baseline and who were

[1] The intervention is part of a multi-layered program, which targeted various stakeholders in the avocado value chain in Murang'a County between 2014 and 2017. Section 2.2 provides a detailed description of the program and its theory of change can be seen in Figure A.7. We focus on the part of the program that directly targeted smallholder farmers.

not supported by the program to join farmer organizations. We want to emphasize that households were not allocated to one of the three groups randomly. Instead, agricultural officers in Murang'a County identified ten villages and invited avocado-farming households from those villages to establish ten new farmer organizations that would each be matched with a different avocado exporting company. In four of these villages, farmer organizations were formed successfully at the time of the baseline survey, and members of these four organizations are our targeted group.[2] The farmers in the existing contract group are members of the 14 farmer organizations that engaged in contract farming with the largest regional avocado exporting company at baseline. To identify farmers for the no contract group, we randomly sampled avocado-farming households from 27 villages. In these villages no avocado exporting companies had been active at the time of the baseline survey. These villages were not part of the ten targeted villages, but were similar to the target villages based on observable village-level characteristics.[3]

The aforementioned classification of farmers into three groups is based on whether farmers participated in — or were poised to participate in — contract farming at baseline. Given the panel nature of our data, we can observe how farmers' actual participation in contract farming changes between baseline and endline. For some farmers, the classification into targeted, existing and no contract group accurately describes their contracting behavior, i.e. targeted farmers adopt, existing contract farmers always participate and no contract farmers never participate. However, there is a non-negligible number of farmers that deviate, by entering a farmer organization and finding ways to begin contract farming without support of the program or by leaving their baseline farmer organization and disadopting contract farming (or by never adopting, in the case of farmers in targeted farmer organizations). At the same time, other parts of the intervention targeted up-stream actors (avocado companies and local government agencies) in the avocado value chains in the study region (see Figure A.7).

Non-compliance and non-random selection into the targeted groups present a challenge to identify the impact of contract farming on farmers' behavior, production, marketing and welfare outcomes. We address these issues in two ways. First, we leverage the longitudinal aspect of our data to estimate a doubly-robust

[2]Farmers in the remaining six villages had neither successfully formed organizations nor established contracts with their matched company at the time of the baseline. Because it was uncertain whether farmers from these six villages would ever successfully organize, the household survey (baseline and endline) only covers members of the four farmer organizations that had successfully formed and could provide a list of members during the baseline survey. The remaining six farmer organizations eventually formed successfully and linked with their assigned company during the course of the program, but their members are not part of our sample (in neither the targeted, existing contract or no contract group).

[3]Section 3.1 provides details about the sampling of the avocado farming households.

difference-in-differences design, following Sant'Anna and Zhao (2020). We thus compare changes in outcomes between groups over time, rather than comparing contract farmers with regular farmers at any one point in time. Second, we focus our analysis on average treatment effects on the treated and classify avocado-farming households according to the changes in their observed behavior between baseline and endline.[4] We compare farmers that adopt contract farming between baseline and endline with farmers that never participated in contract farming during our study period. Contract farming in our context consists of three main aspects: i) selling (any type of) avocado to an avocado exporting company (as opposed to selling to brokers), ii) being recently trained and iii) being GAP certified. We record and analyze the take-up of these three activities and additionally estimate the impact of adopting either one of them on household-level outcomes, similarly to what we do for contract farming in general.[5]

The *export sector competitiveness program* achieved its immediate goals: farmers who adopt contract farming are 50 percentage points more likely to sell their

[4]A natural starting point to evaluate an intervention would be to define farmers in targeted villages as the treatment group, farmers in comparison villages as the control group and estimate intent-to-treat effects of the intervention on village-level outcomes (or household-level outcomes aggregated to the village level). This would be consistent with the observation that the intervention created variation in contract farming at the village-level, since farmer organizations were created and matched with avocado exporting companies in targeted villages, but not in comparison villages. However, such an empirical strategy is infeasible in our context because the sample of targeted farmers included in our data is not representative for the population of avocado farming households in targeted villages. Instead we only have information for those farmers in the targeted villages that took-up the treatment, since only members of the newly formed farmer organization were included in the survey. Note that in the comparison villages — where no new farmer organizations were formed and this layer of selection does not exist — the no contract farmers are representative for avocado farming households in the comparison villages. Besides this conceptual problem, a practical challenge in our data is that the initial classification into farmers from targeted and no contract villages has limited explanatory power for their actual adoption of contract farming between baseline and endline. From the targeted farmers only 52% adopt contract farming and from the no contract farmers 19% adopt contract farming regardless. As an approximation to estimate the effect of the intervention on farmers from targeted villages, we estimate the effect of being a member of a targeted farmer organization at baseline as compared to being in the no contract group (Table D.10) or in the existing contract group (D.11) and report those results in Appendix D.1.

[5]Besides adoption and never participating, farmers in our sample could also disadopt or always participate in contract farming. We excluded farmers that belong to the latter two groups in the analysis of this paper, because we wanted to evaluate the impact of a roll-out of contract farming, in line with the goals of the intervention. Since our identifying variation comes from the switchers, we could include farmers that always engage in contract farming in the control group. Additionally, we could define disadoption as the relevant change and estimate the impact of phasing out contract farming. Results of these two alternative empirical strategies are available upon request.

avocado to companies, almost three times as likely to be trained within the last two years and 73 percentage points more likely to be certified according to the global *good agricultural practices* (GAP) production standard.

Contract farming also results in changes that are consistent with intensified Hass avocado farming[6] and improved marketing outcomes, although the implications for different dimensions of welfare are mixed. Farmers who adopt contract farming plant 4.05 additional Hass avocado trees, an increase of 214 percent compared to the baseline level and shift their labor from family labor to hired labor. They also score 13 percent higher on a knowledge index related to avocado-farming practices. The avocado exporting companies pay about 3 KSh[7] more per Hass avocado, roughly double the farm-gate price. Because contract farmers only end up selling about half of their Hass avocado to the companies, the average price a contract farmer receives per Hass avocado increases by 1.18 KSh. However, this still reflects a statistically significant increase in the average price by 37 percent compared to the baseline level. We find that income from Hass avocado increases by 20 percent and total income increases by 69 percent. However, these changes are not statistically significant at conventional levels.

Contract farming in our context consists of three aspects which may influence farmer outcomes differently: selling to companies, receiving training and being certified. Because we focus on impact on the treated, we can analyse the effects of these three aspects separately, focussing on adopters of that specific activity / mechanisms. We find that selling to avocado exporting companies has a large and significant impact on the average Hass avocado price, which increases by 2.58 KSh. Certification and training increase the price by less (0.89 KSh and 1.11 KSh respectively), but have a larger effect on the knowledge of avocado-farming practices, which increase by 0.87 points and 0.55 points respectively. Certification has a significant effect on the number of Hass trees planted, which we interpret as an increased investment into future avocado production for export.

There exists a vast empirical literature on contract farming (see Minot and Sawyer (2014) and Bellemare, Lee and Novak (2018) for recent surveys). Several of these studies have shown benefits for smallholder farmers (Glover and Kusterer, 1990; Little and Watts, 1994; Porter and Phillips-Howard, 1997; Singh, 2002; Warning and Key, 2002; Guo, Jolly and Zhu, 2005; Birthal, Joshi and Gulati, 2005; Miyata, Minot and Hu, 2009), including increased employment, price stability, a more reliable income, access to new technologies and credit, and improved export

[6]There are three main avocado varieties in the study region: *Hass* avocado (dark green-brown skinned) is the preferred variety for export, *Fuerte* (thin bright-green skinned) and the local *Kienyeji* are more common.

[7]100 KSh ≈ $1.00 USD during the study period.

market access. But — as Bellemare, Lee and Novak (2018) note — a shortcoming of the literature is that many empirical results can not be interpreted as causal evidence, because of the strong selectivity into contract farming: farmers select to participate in contract farming and companies select which farmers to work with. Contracts are rarely (quasi-)randomly assigned. A notable exception is the study by Arouna, Michler and Lokossou who study rice farming in Benin through a field experiment. They offer a contract to a random subset of farmer organizations and find that smallholder contract farmers increase their planted area, yields, output and income compared to the control group (Arouna, Michler and Lokossou, 2021). Our study contributes to the literature by providing more robust evidence for the empirical benefits of contract farming through the use of panel data, the absence of which Minot and Sawyer (2014) explicitly lament as a shortcoming of the literature. In Section 6 we compare our main (panel data) results with what we would have reported had we only used the endline data. When we compare contract farmers with non-contract farmers based on their participation at endline in a cross-sectional analysis we would overestimate the (positive) impact of contracting on avocado prices and incomes, compared to our preferred results from the doubly-robust difference-in-differences estimation.

The remainder of this article is structured as follows. Section 2 describes the local context in which the export competitiveness intervention took place. In Section 3 we describe the panel data and explain how avocado-farming households were sampled and how their participation in contract farming (and in the three main activities of the intervention) is distributed in the different groups. Section 4 explains the methodology to estimate the average treatment effects on the treated and Section 5 presents the results. In Section 6 we show that we would overestimate the (positive) impact of contract farming if we would only have used cross-sectional endline data. Section 7 concludes.

2. Context

2.1. Avocado production in Kenya

With 217,688 tons of avocados produced in 2017, 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 their own consumption and for the sale on local and international markets. Most smallholder farmers sell their avocados through middlemen – either government certified agents or unofficial brokers – especially in the case of exporting. Few farmers sell their avocados directly to exporters or enter long-term relationships with buyers

through contract farming. 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). Only 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 (Mulubrhan et al., 2019). 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 (better harvest management, grafting on rot resistant rootstocks, pest and disease management), fixed costs in production (collection centers and refrigeration facilities) and insufficient production of the Hass variety (Wasilwa et al., 2004). Additionally, the dominant role of middlemen in avocado export markets and the low level of organization among smallholder farmers raises the question whether the farmers can partake in the surplus generated from increased international demand for avocados.

2.2. Improving export competitiveness through a multi-layered program

In light of the potential for avocado exports to be an avenue of pro-poor growth in Kenya, the *Netherlands Trust Fund Export Sector Competitiveness Program* aimed to build employment and enhance export competitiveness of the avocado sector. From 2014 until 2017, the program targeted various stakeholders of the avocado value chain: trade supporting institutions, small-and medium-sized companies in the avocado value chain, farmer organizations and individual smallholder farmers (Dengerink and van Rijn, 2018).[8] In this paper we focus our attention on the part of the program that targeted smallholder farmers and the linkages between farmer organizations and avocado exporters. The program set up four farmer organizations before the baseline survey in 2015 and matched each farmer organization with one avocado exporting company.[9] The program delivered a multi-layered intervention to newly established farmer organizations consisting of i) contracts between the group members and an avocado exporting company and ii) training in production techniques, orchard management, pest and disease management and post-harvest handling in preparation of iii) accreditation of the farmer organization through the Kenya Global GAP production quality standard. The villages in which the farmer organizations were established were not randomly selected, but rather identified together with local stakeholders. Any avocado farming household from that village

[8] Appendix A provides more detail with regard to the entire program, including the proposed theory of change.

[9] In total, 10 farmer organizations were linked with one company each, but at the time of the baseline survey only four organizations were sufficiently advanced to be included in the survey. See footnote 2.

could then join the farmer organization and thus self-select into the target group, provided they owned at least one mature Hass avocado tree (some farmer organizations require at least two trees) and paid the membership fees.

2.3. The study area

The Export Sector Competitiveness Program targeted stakeholders in the avocado value chain in Murang'a County, Kenya. Murang'a County is part of Kenya's central region, roughly two hours driving distance north-east of the capital Nairobi and is home to 1,056,640 people according to the 2019 National Population Census. Within Murang'a County, the Kandara sub-county was chosen because it is one of the main avocado-producing regions of Kenya and the local government had been actively promoting avocado production. Many smallholder farmers in the region grow avocados, mostly for the local market, and some are members of farmer organizations other than those supported by the program. Prior to the baseline survey, avocado exports were aggregated by numerous informal brokers, a small number of companies (which together account for five percent of the transactions at baseline) and one dominant avocado exporting company with existing contract farming relations to local farmer organizations. At the same time, the market for the aggregation of avocado sales proved to be quite dynamic and we observed multiple entries and exits of companies in the study period.

3. Data

3.1. Sampling design

We surveyed 789 avocado-farming households in November – December 2015 and were able to follow up with 711 households in August – September 2017. After dropping observations with inconsistent or missing data, our balanced panel consists of 702 households observed in both periods.[10,11] The sample of avocado-farming households was generated as follows:

First, we included all 112 households that were members of the four new farmer organizations[12]. These four farmer organizations received support through the evaluated

[10] B.8 in Appendix B shows that the attrition is mostly random. Members of farmer organizations with an existing contract are slightly less likely to exit, but the joint hypothesis tests on the set of treatment allocation, outcomes, covariates or all variables combined are insignificant with p-values 0.12, 0.43, 0.79 and 0.92 respectively.

[11] The data used for this study 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 Mulubrhan et al. (2019).

[12] The names of these four groups are Gituya, Gaichanjiru, Marigu Greens and Mutito.

intervention and — as newly formalized organizations — had no prior contracts, but were poised to begin contractual arrangements with their matched avocado exporting company after the baseline. The villages in which the four farmer organizations were established and in which avocado farming households were invited to join were decided by local agricultural officers from Murag'a County, together with the team managing the export sector competitiveness program. In principle any household from the four selected villages could then join the new farmer organization, provided they paid the registration fee and owned at least one mature Hass avocado tree (some farmer organizations require at least two trees). The members of these four farmer organizations are the targeted beneficiaries of the intervention and therefore the targeted group.

Second, we received information from the largest avocado exporting company in the region about its pre-existing contracts with local farmer organizations and consequently surveyed the members of the 14 farmer organizations that had a contract with that company at baseline. We call this group the existing contract group.

Lastly, we identified 27 villages with no prior involvement of an avocado exporting company with the help of local stakeholders in the Kandara region. These villages were selected to match the characteristics of the villages included as targets of the intervention in terms of size, road- and market-access, crops produced and socioeconomic- and agroclimatic conditions. We then randomly sampled 348 avocado-farming households from these villages and call this the no contract group. 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.

Figure 1 shows where the surveyed avocado-farming households are located. Those from the targeted group are clustered in the four villages where the supported farmer organizations were formed. Households without contractual agreements are spread over the entire study area. Many villages in the study region are located close to each other, which explains the seeming overlap of farmers' locations in the three different groups. The limited distance between villages may also help explain why a number of farmers in the no contract group took up contract farming and joined farmer organizations in the neighboring, targeted villages.

3.2. Data collection and balance on observable characteristics

The avocado-farming households included in the sample provided information about the household composition, productive and non-productive assets, land holdings, (family) labor allocation, non-farm income, access to information, training and financial services, measures of food security, risk aversion and time preferences. Further, we collected information on agricultural production (area planted, quantities

Figure 1: The location of farmers included in the sample

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.[13] Specifically 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 collect further aspects of the contract, namely whether agreements over 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 that were organized in farmer organizations provided information on the groups' contracts with avocado exporting companies, on the global GAP certification and on the availability and quality of training in good agricultural practices. They also answered questions about the internal regulations of the farmer organization with respect to leadership, representation, trust, side-selling and membership fees.

Although the villages in which the no contract households were located were selected to be similar to the villages in which the targeted households were located, we stress that the selection into the three groups was not randomized. As such, we would expect to observe differences in outcomes and explanatory variables between the three groups, even without the intervention. Table 1 shows summary statistics of the outcomes for the three groups at baseline based on the balanced sample of 702

[13]The study region has two main seasons, a short season from October to February and a long season from March to September.

households. Households in the existing contract group are different from households in the targeted and no contract group. Because of their existing contract, they are more likely to sell to a company (as opposed to selling to brokers): regardless of the avocado variety, they sell a larger fraction of their avocado to companies, are more likely to be recently trained and receive higher prices. In line with the increased demand for the Hass variety in contract farming, farmers with an existing contract sell more Hass avocados in total and get higher income from Hass avocado farming. Conversely, they sell fewer avocados of the local variety. At baseline none of the 702 avocado-farming households had received the global GAP certification. In terms of inputs into avocado production, we observe that households with an existing contract, plant more Hass avocado trees (planting an avocado tree is a long-term investment that only pays off after about four years), hire more workers for tasks connected to avocado farming[14], have more knowledge about good agricultural practices and are more likely to use bank accounts and mobile banking for avocado sales. We see no clear differences in non-avocado related labor or in the number of Fuerte or local trees planted.

Households in the no contract and targeted groups are relatively similar to each other. Table B.7 in Appendix B shows how the three groups differ in other explanatory household characteristics. We see a similar pattern to that presented in Table 1. Households in the existing contract group own more Hass avocado trees. The increased intensity of avocado farming does not seem to come at the expense of other farm activities: all households have a similar number of different farm- and tree crops, livestock revenue and non-farm income.

3.3. Embracing the dynamic contract farming environment

With two time periods, households can be either *adopters* (who have no contract at baseline, but adopt at endline), *disadopters* (who have a contract at baseline, but not anymore at endline), *always-treated* (who have a contract in both periods) and *never-treated* (who never have a contract in our study period). Our sample is drawn from three distinct groups, targeted farmers, existing contract farmers and no contract farmers. If contracting behavior was perfectly stable over time, we would expect only farmers in the targeted group to be adopters of contract farming. Farmers in the existing contract group would be always-treated and farmers in the no contract group would be never-treated. However, as we noted previously, we observe considerable non-compliance with this initial classification: some farmers in the targeted group leave the farmer organization between baseline and endline and

[14]The reason is that brokers harvest the avocados they buy immediately. With contract farming, in contrast, the farmer organization usually needs to arrange harvesting and transportation in exchange for higher prices.

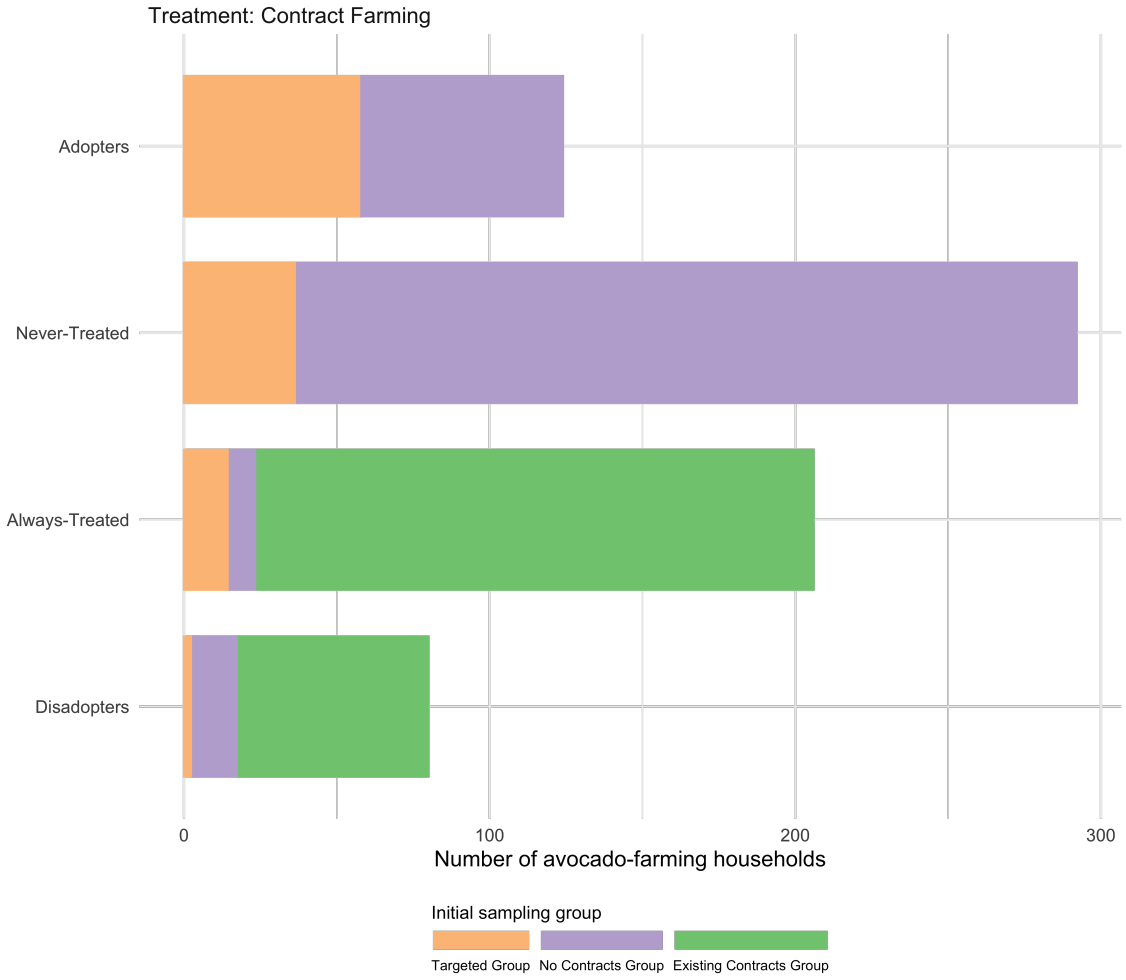

Figure 2: Which farmers adopt contract farming?

do not become contract farmers. Conversely, some farmers in the no contract group become contract farmers by either joining one of the targeted farmer organizations or by entering in a contract with one of the new companies that became active in the study region but that are not part of the intervention. Figure 2 shows how farmers' contracting behavior changes between baseline and endline.

There are 124 farmers that adopt contract farming between baseline and endline, 58 from the targeted group and 66 from the (initial) no contract group. 294 farmers in our sample never took up contract farming during the study period, of which the vast majority (258 farmers) came from the no contract group. As expected, always-treated and disadopters come predominantly from the existing contract group, but we see that some farmers that were classified in the targeted or the no contract group in reality had a pre-existing contract with an incumbent company and are therefore classified as always-treated or disadopters, respectively.

We focus our attention on classifying avocado farming households based on their

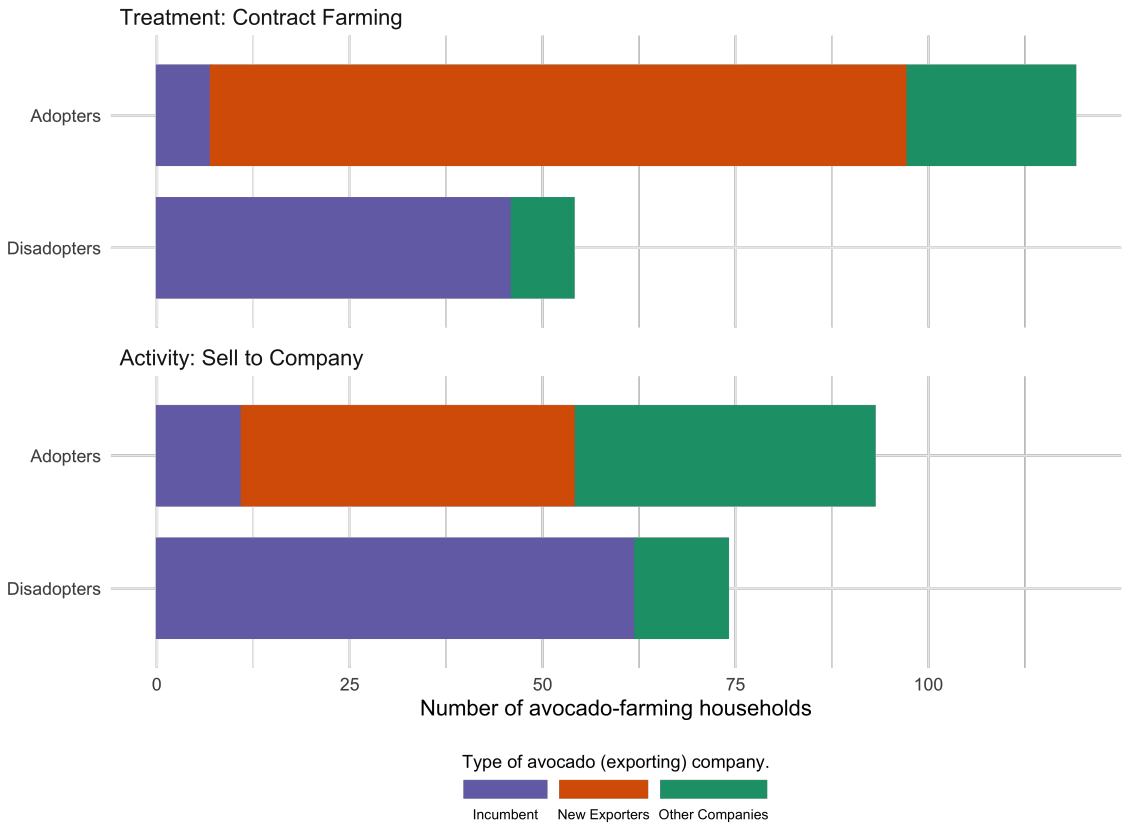

Figure 3: With what type of company do farmers adopt contract farming?

observed behavior at baseline and endline and estimate average treatment effects on the treated for those farmers that take-up contract farming. To estimate the effect of a roll-out in contract farming — in line with the goals of the intervention — we thus compare adopters with never-treated farmers and exclude disadopters and always-treated farmers from the analysis.

An additional descriptive insight comes from looking at which type of avocado exporting companies adopters and disadopters of contract farming engage with. In Figure 3 we differentiate between three types of companies: the dominant avocado exporting company at baseline, source of many pre-existing contracts (*the incumbent*), the avocado exporting companies that contract with the targeted farmer organizations between baseline and endline (*the new exporters*), and a group of smaller companies that had been active in the region throughout the study period with generally low numbers of transactions (*the other companies*).

Figure 3 shows that adopters of contract farming predominantly enter into agreements with the new exporters that become active in the region as part of the intervention. This was one aim of the intervention, because all farmers that join one of the four newly established farmer organizations adopt contract farming and are matched to one of the new exporters through their farmer organization. Interest-

ingly, the incumbent is the source of most disadoption: farmers that stop contract farming (or stop selling to a company) between baseline and endline had mostly sold to the incumbent at baseline.

3.4. Inspecting take-up for the three main contract farming activities

Contract farming in our context consists of three aspects that potentially affect farmers decisions and outcomes differently: i) selling (any type of) avocado to an avocado exporting company (as opposed to selling to brokers), ii) receiving training in production techniques, orchard management, pest and disease management and post-harvest handling and iii) receiving a certification for the Kenya global GAP production quality standard. In Figure 4 we show to what extent farmers from the three sampling groups change their behavior with respect to the three activities between baseline and endline and how they are consequently classified as adopters, never-treated, always-treated or disadopters.

Figure 4 shows that 124 farmers begin selling to a company for the first time between baseline and endline, 135 farmers are recently trained at endline (but not at baseline) and 117 farmers receive the global GAP certification between baseline and endline.[15] For each of the activities related to contract farming we observe that the farmers in the targeted group form a large share of the adopters. However, there are also targeted farmers who never take up any of the contract farming activities and, conversely, farmers from the no contract group who do begin selling to avocado exporting companies or receive training or certification between baseline and endline. We would expect that farmers with an existing contract at baseline are more likely to sell to an avocado exporting company and be recently trained and to (mostly) continue doing so. Figure 2 confirms this: farmers in the existing contract group are mostly classified as always-treated for selling and training. Nonetheless, there is a substantial number of disadopters among the farmers who had a contract at baseline with the large incumbent company. This supports qualitative evidence from field interviews with farmers during the study period. Many mentioned that they were unsatisfied with the services offered by the incumbent company and complained about a lack of continuing engagement from the company with its contracted farmers.

[15]Some farmers report being trained many years prior to the baseline. We introduce a cut-off of two years before the baseline to count the training (consistent with the two years between baseline and endline), thus implicitly modelling training to loose its effectiveness over time. Farmers therefore disadopt training when they were trained in the two years prior to the baseline survey, but not between baseline and endline. The global GAP certification was not available to any of the farmers in our sample at baseline, so - for certification - we have no disadopters or always-treated in our sample.

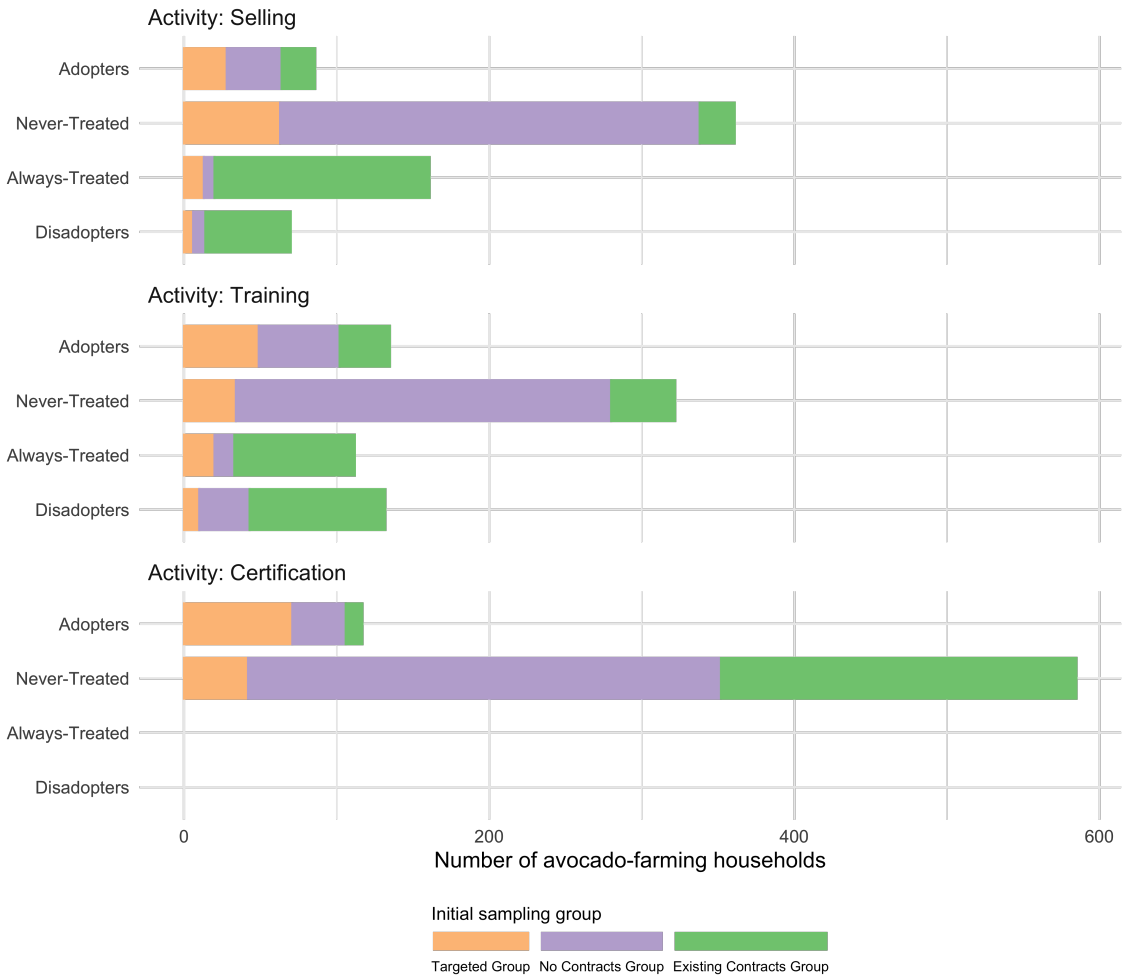

Figure 4: Which farmers adopt which of the aspects of contract farming?

In light of non-random selection into contract farming, selling, training and certification and the non-compliance of avocado farming households with how we expected their contracting status to develop over time (according to their classification at baseline), we need to carefully address the issues of selectivity in any estimation method we use. We do this by leveraging the longitudinal aspect of our data, combined with a robust estimation method, which we discuss in the next section.

Table 1: Summary of outcomes

	Targeted Group		Existing Contract Group		No Contract Group	
Outcome	Mean	SD	Mean	SD	Mean	SD
Activity: Selling						
Fraction avocado sold to company	0.11	0.27	0.54	0.37	0.03	0.15
Fraction Hass sold to company	0.18	0.38	0.73	0.41	0.04	0.20
Fraction Fuerte sold to company	0.04	0.19	0.18	0.38	0.03	0.17
Sold (any avo) to company	0.17	0.38	0.81	0.39	0.05	0.21
Sold Hass avocado to company	0.19	0.40	0.81	0.39	0.05	0.22
Sold Fuerte avocado to company	0.05	0.23	0.20	0.40	0.04	0.20
Activity: Certification						
Received GAP certification	0.00	0.00	0.00	0.00	0.00	0.00
Received GAP certification (individual)	0.00	0.00	0.00	0.00	0.00	0.00
Activity: Training						
Received training	0.27	0.44	0.69	0.46	0.13	0.34
Production						
Number planted avo trees	1.27	3.39	4.43	15.97	1.71	6.29
Number planted Hass trees	1.17	3.23	3.95	15.86	1.36	5.81
Number planted Fuerte trees	0.10	0.72	0.18	1.00	0.18	1.32
Number planted local trees	0.00	0.00	0.31	1.85	0.17	1.30
Total family labor (avo, labor days)*	8.14	15.21	8.05	11.74	5.09	9.48
Total family labor (non-avo, labor days)*	110.23	122.11	79.01	83.52	74.75	73.83
Cost hired labor (avo, 1000 KSh)*	0.65	2.03	2.65	4.52	0.30	0.89
Cost hired labor (non-avo, 1000 KSh)*	0.14	0.51	0.15	0.54	0.13	0.72
Knowledge index	5.11	1.99	5.45	2.17	4.38	2.17
Marketing						
Share high quality, avo	0.41	0.47	0.48	0.44	0.33	0.43
Share high quality, Hass	0.52	0.50	0.58	0.47	0.47	0.50
Share high quality, Fuerte	0.28	0.45	0.30	0.45	0.28	0.45
Avg. avo price (KSh per unit)	2.50	1.00	4.41	2.50	2.33	1.14
Avg. Hass price (KSh per unit)	3.42	1.63	5.44	3.06	2.95	1.48
Avg. Fuerte price (KSh per unit)	1.90	0.56	2.66	1.92	2.02	1.26
Quantity avo sold (units)*	7165.66	11364.72	9636.36	12034.46	5574.05	7899.06
Quantity Hass sold (units)	3675.13	7721.27	6188.84	9475.02	2225.07	3843.65
Quantity Fuerte sold (units)	3108.41	7807.23	3169.77	6372.32	2797.10	5275.49
Quantity local sold (units)*	382.12	817.66	277.75	883.39	551.88	1909.77
Fraction Hass of total sales	0.48	0.35	0.63	0.30	0.40	0.35
Fraction Fuerte of total sales	0.43	0.36	0.33	0.29	0.48	0.35
Income (incl. consumption) from avo (1000 KSh)*	19.87	31.08	43.04	64.56	15.74	30.53
Income (incl. consumption) from Fuerte (1000 KSh)*	7.22	23.28	8.69	17.13	6.79	15.72
Income (incl. consumption) from Hass (1000 KSh)*	11.88	19.57	33.60	61.93	7.42	14.57
Income (incl. consumption) from local (1000 KSh)*	0.77	1.63	0.74	3.45	1.53	7.44
Welfare						
Subjective satisfaction	0.85	0.36	0.84	0.36	0.77	0.42
Subjective stability	0.76	0.43	0.84	0.36	0.76	0.43
Food INsecurity index	4.75	4.40	4.02	3.88	5.63	5.35
Total income (1000 KSh)*	150.02	161.81	215.05	242.02	172.74	252.43

Note: 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 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. Results using the log(x+1) transformation are available upon request.

4. Methodology

Given non-random assignment and observable differences in outcomes and explanatory variables at baseline, our empirical strategy needs to address selection into contract farming (and its three main aspects) to credibly identify the causal impact of contract farming on smallholder farmers. We address this in two ways: first, we leverage the longitudinal aspects of our data to estimate a doubly-robust difference-in-differences design. Second, we focus on the average treatment effects on those that adopt contract farming and can therefore add to our treatment group of targeted farmers those households that adopt contract farming without support from the intervention (and who were sampled in the no contract group). This means that our results should be interpreted as evidence of the impact of contract farming in general, rather than as an evaluation focused strictly on the impact of the export sector competitiveness program.[16]

4.1. Treatment and control for average treatment effects on the treated

We compare avocado-farming households that adopted contract farming after the baseline with never treated households that never took up contract farming in our study period. We focus on contract farming in general and on the three aspects of contract farming (selling to companies, training and certification) in particular.

We define the different treatments that households may or may not adopt between baseline and endline as follows:

Contract Farming Farmers are treated if they sell (any type of avocado) to an avocado exporting company *under contract* or are a member of a farmer organization which contracts with a company.[17]

Selling to Company Farmers are treated if they sell (any type of avocado) to an avocado exporting company with or without contract. Farmers are in the control group if they only sell to brokers and excluded if they sell no avocado at all at either baseline or endline.

Training Farmers are treated if they have received training in the two years prior to the baseline or endline respectively.

[16] Our sample size is too small to compare the heterogeneity in treatment effects for farmers that adopt contract farming with either one of the matched new exporting companies, the established incumbent or other companies.

[17] In the main analysis we focus on contracting to sell any type of avocado. In Table D.12 and D.16 in Appendix D we explore contracts for either Hass or Fuerte avocado. We also show results for defining contract treatment purely based on the membership in farmer organizations, without using information about observed contract sales in D.13.

Certification Farmers are treated if they have received the global GAP certification through their membership in a GAP certified farmer organization. The certification was only available at endline.[18]

We compare farmers that adopt contract farming with those that are never treated in a difference-in-differences framework. To explore the three related aspects of contract farming in more detail, we additionally estimate average treatment effects for adopting one of the three aspects, selling to a company, being recently trained and being certified.

4.2. Doubly-robust difference-in-differences estimation

We estimate the average treatment effect on the treated by comparing adopters with never-treated farmers through the doubly-robust difference-in-differences estimation proposed by Sant'Anna and Zhao (2020). The empirical strategy combines inverse probability weighting (as in Abadie (2005)) with outcome regression (as in Heckman, Ichimura and Todd (1997)). Combining both strategies assures that our estimates are consistent if either the propensity score model or the outcome regression model are correctly specified.

$$\widehat{ATT} = \mathbb{E}_n\big[(\hat{w}_1(D) - \hat{w}_0(D, X; \hat{\gamma}^{ipt}))\big(\Delta Y - X'\hat{\beta}^{wls}_{0,\Delta}\big)\big] \tag{1}$$

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. In equation 1, D is the treatment indicator, π is the propensity score estimated from a logit regression with a set of covariates X. The set of covariates X is the same in the propensity score estimation and in the outcome regression model and contains only baseline values. The included covariates are shown on the y-axis of Figure 5. The weights, $\hat{w}_1, \hat{w}_0$ are calculated using the propensity scores from an inverse probability tilting estimator (Graham, Campos De Xavier Pinto and Egel, 2012), using a logit regression (see equation 2 and 3).

$$\hat{w}_1(D) = \frac{D}{\mathbb{E}_n[D]} \qquad \hat{w}_0(D, X; \hat{\gamma}) = \frac{\pi(X; \hat{\gamma})(1 - D)}{1 - \pi(X; \hat{\gamma})} \Big/ \mathbb{E}_n\big[\frac{\pi(X; \hat{\gamma})(1 - D)}{1 - \pi(X; \hat{\gamma})}\big] \tag{2}$$

$$\pi(X, \hat{\gamma}) = \frac{\exp(X'\hat{\gamma})}{1 + \exp(X'\hat{\gamma})}, \quad \text{with} \quad \hat{\gamma} = \arg\max_{\gamma} \; \mathbb{E}_n\Big[DX'\gamma - (1 - D)\exp(X'\gamma)\Big] \tag{3}$$

[18] GAP certification is only available to farmer organizations and not available to individual farmers. For members of the four newly established farmer organizations we infer certification status from their membership. Alternatively, Table D.13 in Appendix D reports the results if certification status is inferred from the (less reliable) individual survey responses.

In equation 1, ΔY is the observed change from baseline to endline in the outcome for the treatment group and $X'\hat{\beta}^{wls}_{0,\Delta}$ 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 4). Note that the outcome regression is estimated only on observations from the control group, not from the treatment group.

$$\hat{\beta}^{wls}_{0,\Delta} = \arg\min_{b} \ \mathbb{E}_n\left[\frac{\Lambda(X'\hat{\gamma})}{1-\Lambda(X'\hat{\gamma})}\left(\Delta Y - X'b\right)^2 \middle| D=0\right] \tag{4}$$

We use the same covariates X in the outcome regression model (to predict the change in outcomes of the control group) and in the estimation of the propensity score (to calculate the weights for the inverse probability weighting). We use only the baseline values and include demographic characteristics of the household (the household size, number of children, the gender, age, education of the household head and whether he or she is married), measures for the assets of the household (whether they own a house, the number of rooms, the value of non-agricultural assets and of trees, the amount of owned land), information about their agricultural production at baseline (the number of crops, trees and livestock, revenue from livestock and from non-agricultural sources, whether they have a bank account or a mobile phone and use it for agricultural transactions) and whether they have been credit constraint in the past. When the distribution of a covariate or an outcome exhibits a long right tail and many zero-values we transform the values using the inverse hyperbolic sine (ihs) transformation.[19]

4.3. Evidence in support of the identifying assumptions

4.3.1. Balance after inverse probability weighting

We cannot test the identifying assumptions, but we can check to what extent weighting the observations by the estimated propensity scores reduces the imbalance on observable characteristics. Figure 5 shows that - for the contract treatment, adopters versus never-treated - the re-weighted data is significantly better balanced than the raw data.[20]

[19] The ihs-transformation is an alternative to the common practice of taking a log(x+1) transformation, but does not rely on adding an arbitrary constant to observations with a zero value. Results using the log(x+1) transformation are available upon request.

[20] Table C.9 shows that after re-weighting with the propensity scores contract farmers and non-contract farmers show no significant differences in observable covariates at conventional significance levels. Similar plots like 5 for the selling, training and certification treatments are presented in Figures C.8, C.9 and C.10 in Appendix C. Also for these three contract farming activities balance is greatly improved through re-weighting the observations.

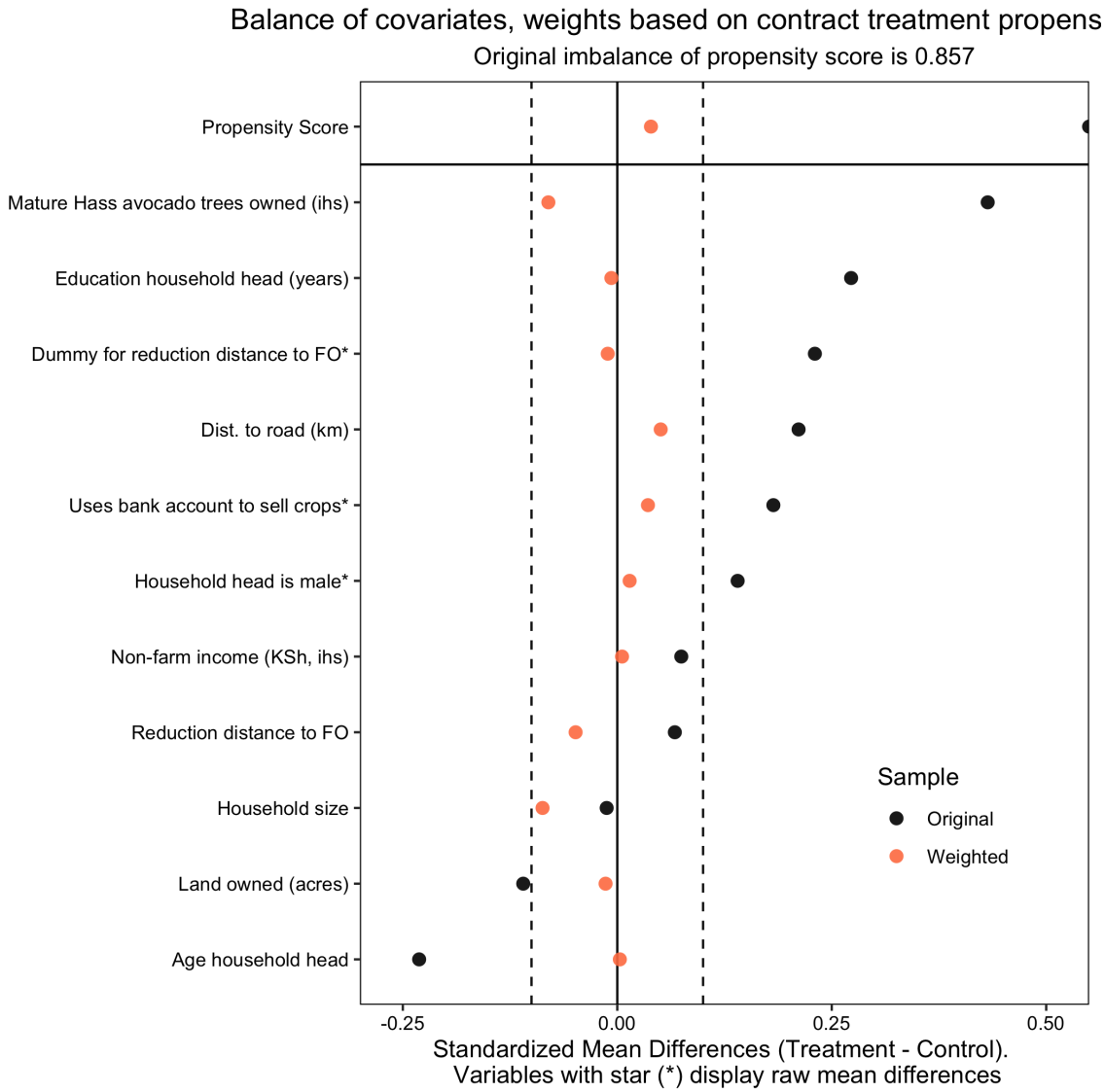

Figure 5: Observable characteristics are balanced after weighting by the propensity score. The plot compares adopters with never-treated for the contract farming treatment

4.3.2. Common trend assumption for number of grown trees per year

For the majority of outcomes that we study in this paper we only have access to baseline and endline data. This makes it difficult to verify whether the outcomes of farmers in the adoption and in the never-treated group developed similarly before the start of the intervention. In this subsection, we turn to the number of planted (Hass) trees, for which we can construct yearly data for the pre-intervention period and which therefore provides deeper insights about the group composition. Specifically, in the endline survey, all farmers report the number *and year* in which they have planted Hass, Fuerte and local avocado trees. Using this information 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 5.

$$y_{i,t} = \alpha_i + X_i'\beta + \sum_{t=2009}^{2017} \gamma_t\big(D_i * \text{year}_t\big) + e_{i,t} \qquad t \in \{2009, 2010, ..., 2017\} \tag{5}$$

In Equation 5, $y_{i,t}$ is the number of planted Hass trees per year[21] , X_i are the time-invariant control variables used in the previous analysis, year_t are year dummies (from 2009 until 2017) and D_i is the farmer-specific treatment status (adopter or never-treated) for each of the four treatment definitions: contracting, selling, training and certification. Thus, the estimate γ_t for the interaction term between the year and the treatment dummy give us the year-specific difference between adopters and never-takers. We again re-weight the sample by the inverse propensity score.[22] Because the intervention took place in 2015, we would expect $\gamma_{2016,2017}$ to be positive and the estimates γ_t for $t < 2016$ to be zero. Figure 6 shows that for the contracting and selling treatment this is clearly the case. There is a statistically significant increase in the number of planted Hass trees in 2016 and a relatively precisely estimated flat trend before the intervention. The planted trees also increase in 2017, but the increase is not statistically significant. A reason might be that the endline survey was performed in August / September 2017 and there were fewer months in 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 one year. The bottom row of Figure 6 shows that there is already a difference in the number of planted Hass trees for recently trained farmers in 2015, although the effect is only significantly different

[21] We also have access to the number of planted Fuerte trees (see C.12 in Appendix C) and to measures of how many trees survived or are still productive per year and whether the farmer grafted their trees.

[22] Figure C.11 in Appendix C shows that the event-study estimates are relatively similar whether or not we re-weight the data.

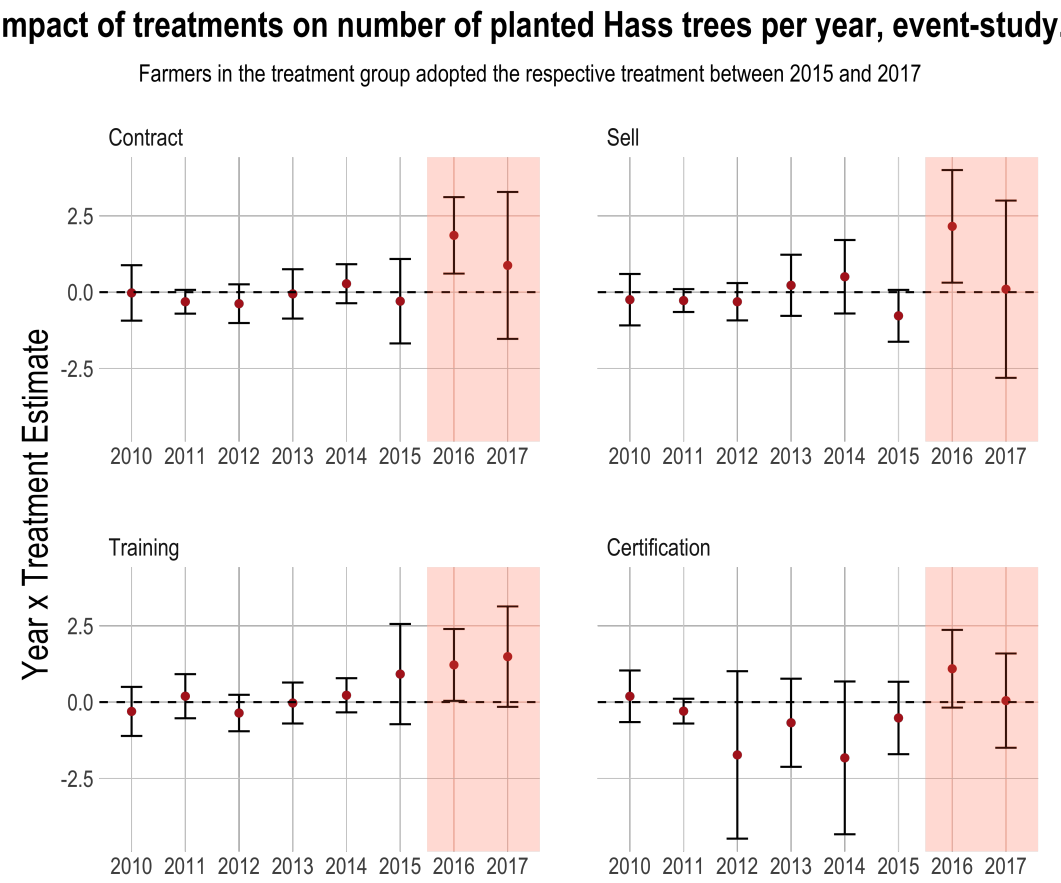

Figure 6: The number of planted Hass trees increases significantly for the treatment groups after the contract farming intervention begins at the end of 2015. In the years prior to the intervention there are no differences between never-treated farmers and those that end up adopting contract farming.

from zero in 2016. For certification the event study plots show no significant pattern.

To summarize, the event study plots - especially for contracting and selling - show that the adopters and never-treated farmers behaved quite similarly before the intervention and notably different afterwards. Because of data limitations we are not able to repeat such an analysis for other outcome variables, but it nonetheless strengthens our confidence that the common trend assumption underlying the difference-in-differences design is satisfied.

4.3.3. Alternative estimation methods

In the empirical analysis we follow the doubly-robust difference-in-differences estimation procedure proposed by Sant'Anna and Zhao (2020). We additionally report the results for three alternative estimation methods: outcome regression (as

in Heckman, Ichimura and Todd (1997)), inverse probability weighting (also called weighted difference-in-differences, as in Abadie (2005)) and the traditional doubly-robust estimator (also from Sant'Anna and Zhao (2020)). The latter differs from our preferred estimator by estimating the $\hat{\beta}_{0,\Delta}$ coefficients with ordinary least squares and the propensity score $\pi(X, \hat{\gamma})$ by maximum likelihood.
Equation 6 shows the estimation equation if only outcome regression is used. ΔY_1 is the change in the outcome in the treatment group and $\hat{\mu}_{0,t}(x)$ is an estimate of the true expected outcome for individuals from the control group, at time t and who share the characteristics x. $\hat{\mu}_{0,t}(x)$ is estimated with ordinary least squares in our case.

$$\widehat{ATT}^{or} = \Delta Y_1 - \frac{1}{n_{treat}} \sum_{i|D_i=1} \big(\hat{\mu}_{0,1}(X_i) - \hat{\mu}_{0,0}(X_i)\big) \tag{6}$$

Equation 7 shows the estimation equation if we only use inverse probability weighting. Again, ΔY is the change in the outcome, D is the treatment status indicator and $\hat{\pi}(X)$ is an estimate for the propensity score, which we estimated with maximum likelihood.

$$\widehat{ATT}^{ipw} = \frac{1}{\mathbb{E}_n[D]} \mathbb{E}_n\big[\frac{D - \hat{\pi}(X)}{1 - \hat{\pi}(X)} \Delta Y\big] \tag{7}$$

4.4. Evaluating the impact of the intervention: comparing farmers according to their group membership at baseline

The standard way to evaluate a (randomized) intervention is to compare outcomes in the treatment group with those in the control group, regardless of who in the treatment group actually took up the treatment. The resulting estimates for the intent-to-treat effect acknowledge that take-up may not be perfect and that those who do take-up treatment are a (self-) selected group which is not comparable to the control group anymore. In our context, the intervention creates variation in contract farming at the village-level, since farmer organizations are established in targeted villages but not in comparison villages. However, while our data is representative for avocado farming households in the comparison villages, it is not representative for avocado farming households in the targeted villages because we included only farmers that are members of the new farmer organizations. We therefore cannot pursue the strategy described above to evaluate the impact of the intervention.
Instead, we estimate the average treatment effect on the treated for those farmers in the targeted villages that are members of the four new farmer organizations at baseline. This gives us an estimate of the impact of the intervention for those farmers that became members of the new farmer groups (but not for a representative sample of farmers from the targeted villages). We stay in the doubly-robust

difference-in-differences framework described in Section 4.2 and compare targeted farmers with two available comparison groups. In Table D.10, Appendix D.1 we choose a representative sample of farmers in the comparison villages and who are part of the no contract group as the control group. In Table D.11, Appendix D.1 we choose farmers with an existing contract at baseline and who are members of the 14 farmer organizations working with the large incumbent avocado exporting company as the control group.

5. Results

5.1. Contract farming achieves the immediate goals of the intervention

We first consider the question whether contract farming influences selling to an avocado exporting company (as opposed to selling to brokers), being recently trained or being global GAP certified - the three activities that were the target of the intervention and through which we believe that the intervention can improve households' livelihoods. Integrating avocado-farming households into export-oriented value chains is the explicit goal of the *Netherlands Trust Fund Export Sector Competitiveness Program*, so the results presented in Table 2 can also be seen as an assessment into whether the intervention achieved its immediate goals.
Table 2 shows that farmers who adopt contract farming are 50 percentage points more likely to sell avocado (of any variety) to an exporting company compared to the comparison group of farmers who never have a contract in the sample period. Contract farmers also increase the fraction of avocado sold to companies by 40 percentage points and consequently sell fewer avocados to brokers. At baseline, the number of households who sell avocados to exporting companies is essentially zero.[23]

Avocado-farming households who access contract farming between baseline and endline are 73 percentage points more likely to be certified according to the Kenya GAP production standard and 48 percentage points more likely to be trained within the last two years. Training increases by 258 percent compared to the baseline training rate of 18.6 percent in the treatment group. In the comparison group the training rate at baseline was 10.5 percent and hardly changed between baseline and endline. Although not statistically significant, we see some evidence that contract farmers (already) shift their sales from the fuerte avocado variety to the Hass avocado variety (which is in higher demand by exporters). However, because any newly planted trees need to mature, we would not expect a significant shift after only two years.

[23]This is of course an artifact of the exclusion of always-treated and disadopters from the estimation sample. In the entire sample 36 percent of farmers sold any avocado to a company at endline and of those that had an existing contract at baseline 67 percent continue to sell to a company at endline. It is extremely rare that farmers sell to avocado-exporting companies without a contract.

5.1.1. Robustness and additional analysis.

The avocado variety that is preferred by exporters is the dark-green Hass variety and therefore many contracts are limited to the Hass variety. Nonetheless, some companies also contract smallholder farmers to purchase the Fuerte variety, in addition to Hass. In Table 2 we based the treatment definition on the contract sale of any kind of avocado (or on the membership of any farmer organization with contractual arrangements with a company). In Table D.12 we differentiate between contracts for Hass avocado (Column 2) and contracts for Fuerte avocado (Column 3).[24] The average treatment effects on the treated in Table D.12 are slightly bigger for the respective avocado type specific treatment, i.e. farmers with contracts to sell Hass avocado increase the fraction of Hass sold to companies by 51 percentage point and the fraction of Fuerte sold to companies by only 27 percentage points. A similar pattern holds for farmers with a contract to sell Fuerte avocado.

We additionally test the impact of (somewhat arbitrary) decisions in the our definitions of contract farming and certification and find that the results presented in the preceding section continue to hold. First, in our main analysis, one part of the definition of contract farming adoption is whether a farmer begins selling to a company *with contract*. Thus, we would expect the share of farmers that sell under contract to a company to be mechanically higher in the treatment group. Table D.13, Column 2 shows that the results are very similar if we base the contract farming treatment only on the farmers membership in a farmer organization, without incorporating information on whether (any) farmer sales were under contract. Column 1 in Table D.13 repeats the main results. Second, our preferred certification outcome is based on whether a farmer is a member of a certified farmer organization, rather than on the farmers individual response in the survey. GAP certification is not cost-effective among smallholder farmers at the individual-level and therefore only offered on the group-level in our context. We find that when we use the farmers' response about certification, the endline levels of certification are lower and the treatment effect is only 0.3 points compared to 0.73 points in the main results (see *Received GAP certification (individual)* outcome in Table D.13). 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.

Lastly we show in Figure D.13 and Table D.14 the results of alternative estimations methods (inverse probability weighting (Abadie 2005), outcome regression (Heckman, Ichimura, Todd 1997) or traditional doubly robust estimation (Sant'Anna,

[24]Most notably, the four companies that were introduced through the program accept Hass and Fuerte avocado while the large company that had pre-existing arrangements with farmers only accepts Hass avocado.

Zhao 2020)). The results are identical.

5.2. Contract farming improves marketing outcomes and leads to production changes consistent with an intensification of avocado farming for export.

We next estimate the impact of contract farming on production, marketing and welfare outcomes for the avocado-farming households. As before, we compare adopters of contract farming with households that had no contract in either period. Table 3 shows that farmers who adopt contract farming have more knowledge about good agricultural practices. The increase of 0.6 points reflects an increase of 13 percent from the baseline level of 4.77 in the knowledge index.[25] Adopters of contract farming also transition from family labor to hired labor: the number of family labor days for avocado-related tasks decreases by 18 percent and the cost of hired labor for avocado and non-avocado tasks increases by 34 percent and 63 percent respectively. However, these effects are not statistically significant, neither individually, nor jointly.[26]

Exporting companies prefer Hass avocado and we would therefore expect the largest effects on those marketing and production outcomes that are specific to the Hass variety. In Table 3 we therefore only include production and marketing outcomes based on Hass avocado and show outcomes for all avocado varieties combined and for the Fuerte and local variety in D.15 in Appendix D. First, we would expect contract farmers to shift their production according to the demands of the buyers. We see that contract farmers are indeed making the investment of planting, on average, four additional Hass avocado trees. Although not statistically significant, this reflects an economically large increase of 214 percent compared to the 1.89 planted trees in the two year period before the baseline. Because it takes time until newly planted Hass avocado trees bear fruit (literally!) we see no effect on the quantity of Hass avocado units sold by contract farmers (yet). Avocados sold to exporting companies fetch higher prices and contract farmers receive 1.18 Kenyan Shilling more for Hass avocados, an increase of 37 percent from the baseline price of 3.21 Kenyan Shilling.

Adopters of contract farming also have higher income, both from the sale of Hass avocado (20 percent) and total income (69 percent), but the difference to the comparison group is not statistically significant. We see no significant improvements in other welfare measures, such as subjective satisfaction with avocado-farming or

[25] 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 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?*

[26] See Figure D.14 for a joint significance test of the decrease in family labor and the increase in hired labor based on bootstrapping.

perceived stability of income. In contrast, food insecurity increases by 17 percent, although - like the other estimates of welfare outcomes - this estimate is not statistically significant.

5.2.1. 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 contract farming. In Table D.15 we additionally show outcomes for all avocado varieties combined and for the Fuerte and local avocado variety separately.[27] We indeed see the largest positive effects for the Hass-specific outcomes: there is no effect on planted trees or the price for varieties other than Hass. Interestingly, the overall quantity of avocado sold and the income from all avocado sales combined decreases. This is because new contract farmers sell 48 percent fewer local avocado than farmers that never begin contract farming. This suggests a strong shift away from the local variety to the contracted varieties. Another way to investigate the influence of the different avocado varieties is to differentiate the adopters of contract farming by the variety of avocado they begin contracting for. This is similar to Table D.12, but in Table D.16 we look at the production, marketing and welfare outcomes. We find that the knowledge increase only occurs for farmers that adopt a Hass avocado contract. The positive impact on prices is strongest for the contracted variety, but whereas a contract to sell Fuerte avocado results in higher prices for Fuerte (up 0.69 KSh) *and* Hass (up 0.66 KSh), a contract to sell Hass avocado only results in higher prices for Hass avocado (up 1.12 KSh). The decrease in the total quantity of avocado sold is significant in all specifications, but if a farmer adopts a Fuerte contract they also significantly reduce the quantity of Hass avocado sold and have lower income from avocado sales in general.
As before, we show the results of alternative estimation methods in Table D.17. The results are almost identical.

5.3. A closer look at which of the three aspects of contract farming - selling, certification, training - drive the reduced form outcome.

Section 5.1 shows that contract farmers are more likely to sell to avocado exporting companies, to be certified and to have been recently trained. We next analyze each of the three activities connected to contract farming in our context separately. Not all farmers that adopted contract farming also adopted each of the three activities and some farmers were already trained at baseline, although they did not yet participate in contract farming. The average treatment effects on the treated for the reduced form outcomes in Table 3 do not differentiate by the specific activity

[27] Note, however, that prices and quality were not available for the local avocado variety.

the new contract farmer participated in. We report the results of this differentiation in Table 4, where we classified households as treated if they began selling (any variety of) avocado to an avocado exporting company (as opposed to selling only to brokers) - Column 1 -, received certification at endline - Column 2 - or received training between baseline and endline, but not in the two years before the baseline - Column 3. To make the results comparable across columns, we only include farmers that are part of the treatment (adopters) or comparison group (never-treated) for all three activities. It is important to note that there is considerable overlap between the treatment groups for the three different activities, and as such we should not interpret the average treatment effects in Table 4 as a linear decomposition of the general contract farming impact from Tables 2 and 3. First, the impact from the three activities might combine non-linearly and second participation in the activities overlap for many farmers. Training and certification in particular are two activities that are closely related and in principle, training is a prerequisite for getting GAP certified. However, GAP is a group-based certification whereas training is administered (and reported) on the farmer-level, so some farmers may have received certification via their membership in a certified farmer organization without having attended the training.

Table 4 shows that improvements in knowledge of agricultural practices are larger for certification and training than for selling. The changes in farmers production choices are consistent with the results in Table 3: the number of planted Hass trees increase (significantly so for certification) and farmers shift from family labor to hired labor (especially pronounced for the sell treatment). Table 3 reported that contract farmers receive higher prices and have (statistically insignificantly) higher incomes. Comparing the average treatment effects across the different contract farming activities shows that these results are mainly driven by farmers that begin selling to avocado exporting companies. In Column 1, the price increase is 2.58 Ksh and income from Hass avocado almost doubles. However, total income decreases by 32 percent.

Table 2: The immediate impacts of contracting, doubly-robust ATT estimates.

Outcome	ATT	95% CI	n
Activity: Selling			
Fraction avocado sold to company	**0.41 (0.04)****	[0.32, 0.49]	395 (119)
Fraction Hass sold to company	**0.49 (0.06)****	[0.38, 0.60]	259 (95)
Fraction Fuerte sold to company	**0.25 (0.05)****	[0.16, 0.35]	273 (86)
Sold (any avo) to company	**0.51 (0.05)****	[0.41, 0.61]	395 (119)
Sold Hass avocado to company	**0.51 (0.06)****	[0.40, 0.63]	259 (95)
Sold Fuerte avocado to company	**0.27 (0.05)****	[0.16, 0.37]	273 (86)
Fraction Hass of total sales	0.05 (0.04)	[-0.03, 0.13]	395 (119)
Fraction Fuerte of total sales	-0.03 (0.03)	[-0.09, 0.04]	395 (119)
Activities: GAP and Training			
Received GAP certification	**0.73 (0.04)****	[0.65, 0.80]	416 (124)
Received training	**0.50 (0.06)****	[0.37, 0.62]	416 (124)

Note: Significance levels: 0.1 ($^+$), 0.05 (*), 0.01 (**)
Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. The treatment is having a contract (to sell any type of avocado), as indicated by belonging to a farmer organization or selling (any type of avocado) under contract. In 2015, farmers in newly created farmer organizations were not treated, because the farmer organizations were formed immediately preceding the survey and the contracts were only effective for the coming harvest period. Households in the treatment group are adopters (no treatment in 2015, treatment in 2017), households in the control group are never-treated (no treatment in 2015 and 2017). 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 3: Outcomes for contracting, doubly-robust ATT estimates.

Outcome	ATT	95% CI	n
Production			
Number planted Hass trees	4.27 (3.59)	[-2.76, 11.29]	416 (124)
Total family labor (avo, labor days), ihs	-0.12 (0.17)	[-0.45, 0.20]	415 (123)
Total family labor (non-avo, labor days), ihs	0.05 (0.16)	[-0.27, 0.37]	415 (123)
Cost hired labor (avo, KSh), ihs	0.03 (0.56)	[-1.07, 1.14]	416 (124)
Cost hired labor (non-avo, KSh), ihs	0.28 (0.62)	[-0.94, 1.50]	416 (124)
Knowledge index	**0.70 (0.33)***	[0.05, 1.34]	416 (124)
Marketing: Hass			
Share high quality, Hass	0.12 (0.10)	[-0.08, 0.33]	259 (95)
Avg. Hass price (KSh per unit)	**1.25 (0.32)****	[0.63, 1.88]	258 (91)
Quantity Hass sold (units), ihs	0.02 (0.40)	[-0.77, 0.80]	416 (124)
Income (incl. consumption) from Hass (KSh), ihs	0.21 (0.56)	[-0.88, 1.31]	416 (124)
Welfare			
Subjective satisfaction	0.01 (0.06)	[-0.11, 0.14]	416 (124)
Subjective stability	0.03 (0.06)	[-0.09, 0.15]	416 (124)
Food INsecurity index	1.17 (0.76)	[-0.32, 2.66]	416 (124)
Total income (KSh), ihs	0.27 (0.44)	[-0.60, 1.14]	416 (124)

Note: Significance levels: 0.1 ($^+$), 0.05 (*), 0.01 (**)

Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. Outcomes with the ihs suffix are transformed using the inverse hyperbolic sine transformation and ATT estimates show semi-elasticities, calculated as $\frac{P}{100} \approx \exp(\hat{\beta}) - 1$ following Bellemare, Wichman 2020 equation 11. Transformed standard errors and CIs are calculated using delta method (multiplying old se with exp(beta)). The treatment is having a contract (to sell any type of avocado), as indicated by belonging to a farmer organization or selling (any type of avocado) under contract. In 2015, farmers in newly created farmer organizations were not treated, because the farmer organizations were formed immediately preceding the survey and the contracts were only effective for the coming harvest period. Households in the treatment group are adopters (no treatment in 2015, treatment in 2017), households in the control group are never-treated (no treatment in 2015 and 2017). 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 4: Reduced form outcomes for different aspects of contract farming, doubly-robust ATT estimates.

Treatment Type	Sell			Certification			Training		
	ATT	95% CI	n	ATT	95% CI	n	ATT	95% CI	n
Production									
Number planted Hass trees	2.12 (1.81)	[-1.43, 5.68]	377 (62)	**3.46 (1.53)***	[0.45, 6.47]	377 (76)	1.56 (1.40)	[-1.19, 4.30]	377 (107)
Total family labor (avo, labor days), ihs	-0.06 (0.21)	[-0.48, 0.36]	377 (62)	-0.01 (0.24)	[-0.48, 0.47]	377 (76)	0.01 (0.19)	[-0.37, 0.39]	377 (107)
Total family labor (non-avo, labor days), ihs	-0.07 (0.15)	[-0.37, 0.23]	377 (62)	-0.20 (0.15)	[-0.50, 0.10]	377 (76)	0.05 (0.15)	[-0.25, 0.35]	377 (107)
Cost hired labor (avo, KSh), ihs	0.70 (1.35)	[-1.96, 3.35]	377 (62)	-0.29 (0.47)	[-1.22, 0.63]	377 (76)	-0.44 (0.32)	[-1.06, 0.18]	377 (107)
Cost hired labor (non-avo, KSh), ihs	2.87 (10.17)	[-17.06, 22.81]	377 (62)	0.05 (0.60)	[-1.12, 1.22]	377 (76)	0.17 (0.52)	[-0.85, 1.20]	377 (107)
Knowledge index	0.20 (0.39)	[-0.57, 0.98]	377 (62)	**0.72 (0.40)**$^{+}$	[-0.07, 1.51]	377 (76)	0.41 (0.34)	[-0.26, 1.08]	377 (107)
Marketing: Hass									
Share high quality, Hass	0.12 (0.12)	[-0.12, 0.35]	246 (53)	0.08 (0.13)	[-0.18, 0.35]	246 (58)	0.11 (0.10)	[-0.08, 0.30]	246 (82)
Avg. Hass price (KSh per unit)	**2.46 (0.37)****	[1.73, 3.20]	246 (50)	**1.15 (0.38)****	[0.41, 1.89]	246 (53)	**1.05 (0.32)****	[0.41, 1.68]	246 (78)
Quantity Hass sold (units), ihs	0.20 (0.55)	[-0.87, 1.27]	377 (62)	0.01 (0.49)	[-0.96, 0.97]	377 (76)	0.18 (0.44)	[-0.69, 1.05]	377 (107)
Income (incl. consumption) from Hass (KSh), ihs	1.22 (1.68)	[-2.07, 4.51]	377 (62)	0.01 (0.56)	[-1.09, 1.11]	377 (76)	0.39 (0.62)	[-0.83, 1.61]	377 (107)
Welfare									
Subjective satisfaction	0.06 (0.08)	[-0.10, 0.22]	377 (62)	0.03 (0.08)	[-0.12, 0.18]	377 (76)	-0.01 (0.07)	[-0.15, 0.14]	377 (107)
Subjective stability	0.03 (0.06)	[-0.10, 0.15]	377 (62)	0.07 (0.08)	[-0.08, 0.23]	377 (76)	0.08 (0.06)	[-0.04, 0.20]	377 (107)
Food INsecurity index	-0.32 (0.88)	[-2.04, 1.40]	377 (62)	0.56 (0.86)	[-1.12, 2.24]	377 (76)	-0.25 (0.69)	[-1.60, 1.10]	377 (107)
Total income (KSh), ihs	-0.08 (0.34)	[-0.74, 0.58]	377 (62)	0.18 (0.48)	[-0.76, 1.12]	377 (76)	0.32 (0.45)	[-0.57, 1.21]	377 (107)

Note: Significance levels: 0.1 ($^{+}$), 0.05 (*), 0.01 (**)

Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. Across the three contract farming activities, the panel has been balanced to only include households with non-missing treatment status in all three treatment types. Outcomes with the ihs suffix are transformed using the inverse hyperbolic sine transformation and ATT estimates show semi-elasticities, calculated as $\frac{P}{100} \approx \exp(\hat{\beta}) - 1$ following Bellemare, Wichman 2020 equation 11. Transformed standard errors and CIs are calculated using delta method (multiplying old se with exp(beta)). Activity 1: The treatment is selling (any avocado type) to a company as opposed to selling only to brokers. Activity 2: The treatment is having group-level GAP certification (inferred via survey response and farmer organization membership). Activity 3: The treatment is having been trained in the last two years (inferred via survey response). Households in the treatment group are adopters (no treatment in 2015, treatment in 2017), households in the control group are never-treated (no treatment in 2015 and 2017). 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.

5.3.1. Robustness and additional analysis.

As before, we show the results of alternative estimation methods in Table D.18, D.19 and D.20.

6. Results from the cross-section

Many previous studies on the impact of contract farming rely on cross-sectional data and compare farmers at one point in time. In our preferred research design (presented previously), we improve on this data limitation by using a doubly-robust difference-in-differences 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 re-do our main empirical analysis underlying Table 2 and Table 3 presented in Section 5, but pretend that we only had cross-sectional data from the endline available. Below we contrast the results from our preferred doubly-robust difference-in-differences estimates (Column 1) with the situation where we only have access to the endline data (Column 2). Table 5 shows the impact on contract farming activities, such as selling to companies, receiving training and certification. Table 6 shows the impact on production, marketing and welfare outcomes of the avocado-farming households.

With access to panel data we previously based our treatment definition on whether farmers adopted contract farming between baseline and endline. 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 participate in contract farming at the time of the survey and compare the two groups (potentially after accounting for selection into contract farming with e.g. matching techniques). We envision this situation for the analysis underlying Column 2 in Tables 5 and 6. Specifically, we compare contract farmers with farmers without contract at endline, regardless of their contracting status before the baseline (hence the larger number of observations).[28]

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.[29] Equation 8 shows the estimating equation, where y_i is the outcome at endline,

[28] Alternatively, one could imagine a survey that asks farmers about their contracting status in the preceding years and consequently restricting the sample to farmers that at some point prior to the survey had no contract and then comparing farmers that adopted contract farming with farmers that did not adopt contract farming. This is similar to our comparison of adopters versus never-treated farmers, since we excluded all farmers who participate in contract farming at baseline from our main analysis. We do this in Appendix E, Tables E.21 and E.22

[29] In the difference-in-differences specifications we used the baseline values of the covariates, whereas in this section we use the endline values. The variables *Houses owned, Rooms in main*

X_i is the set of control variables and Contract_i indicates whether the farmer has a contract to sell (any type of) avocado at endline or is a member of a farmer organization that contracts with an avocado exporting company. γ is the estimate for the treatment effect, which we compare with the ATT estimates from the doubly-robust difference-in-differences framework in Equation 1. Equation 8 is estimated on data reweighted with the propensity score, for a fair comparison with the doubly-robust difference-differences estimation which uses inverse propensity score weighting as well.

$$y_i = \alpha + X_i'\beta + \gamma \ \text{Contract}_i + e_i \tag{8}$$

The second column in Table 5 and Table 6 shows that if we would have only access to the endline survey and compared contract farmers with non-contract farmers, we would overestimate the (positive) impact of contract farming on prices and income (Table 6).

house, Tree assets (KSh), Total livestock units owned (2014), Revenue livestock (Ksh), Different types of livestock owned, Uses bank account to sell non-avo crops, Uses bank account to sell avocado, Uses mobile banking to sell non-avo crops, Uses mobile banking to sell avocado are not included in the endline data and therefore not included in the regression model.

Table 5: The impacts of contracting, comparing doubly-robust difference-in-differences with cross-sectional endline-only ATT estimates.

Comparison	Adopters vs. never-treated (doubly-robust DiD)			Treated vs. untreated (endline only)		
	ATT	95% CI	n	ATT	95% CI	n
Activity: Selling						
Fraction avocado sold to company	**0.41 (0.04)****	[0.32, 0.49]	395 (119)	**0.59 (0.03)****	[0.53, 0.64]	678 (325)
Fraction Hass sold to company	**0.49 (0.06)****	[0.38, 0.60]	259 (95)	**0.67 (0.03)****	[0.61, 0.73]	523 (288)
Fraction Fuerte sold to company	**0.25 (0.05)****	[0.16, 0.35]	273 (86)	**0.40 (0.04)****	[0.33, 0.47]	469 (225)
Sold (any avo) to company	**0.51 (0.05)****	[0.41, 0.61]	395 (119)	**0.69 (0.03)****	[0.62, 0.75]	678 (325)
Sold Hass avocado to company	**0.51 (0.06)****	[0.40, 0.63]	259 (95)	**0.70 (0.03)****	[0.64, 0.76]	523 (288)
Sold Fuerte avocado to company	**0.27 (0.05)****	[0.16, 0.37]	273 (86)	**0.41 (0.04)****	[0.34, 0.49]	469 (225)
Fraction Hass of total sales	0.05 (0.04)	[-0.03, 0.13]	395 (119)	0.04 (0.02)	[-0.01, 0.08]	675 (321)
Fraction Fuerte of total sales	-0.03 (0.03)	[-0.09, 0.04]	395 (119)	-0.01 (0.02)	[-0.05, 0.03]	675 (321)
Activities: GAP and Training						
Received GAP certification	**0.73 (0.04)****	[0.65, 0.80]	416 (124)	**0.35 (0.03)****	[0.30, 0.40]	702 (330)
Received training	**0.50 (0.06)****	[0.37, 0.62]	416 (124)	**0.48 (0.04)****	[0.41, 0.55]	701 (329)

Note: Significance levels: 0.1 ($^+$), 0.05 (*), 0.01 (**)

Table 6: Outcomes for contracting, comparing doubly-robust difference-in-differences with cross-sectional endline-only ATT estimates.

Comparison	Adopters vs. never-treated (doubly-robust DiD)			Treated vs. untreated (endline only)		
	ATT	95% CI	n	ATT	95% CI	n
Production						
Number planted Hass trees	4.27 (3.59)	[-2.76, 11.29]	416 (124)	**3.38 (1.70)***	[0.05, 6.72]	702 (330)
Total family labor (avo, labor days), ihs	-0.12 (0.17)	[-0.45, 0.20]	415 (123)	0.06 (0.11)	[-0.15, 0.28]	701 (329)
Total family labor (non-avo, labor days), ihs	0.05 (0.16)	[-0.27, 0.37]	415 (123)	0.10 (0.12)	[-0.13, 0.33]	701 (329)
Cost hired labor (avo, KSh), ihs	0.03 (0.56)	[-1.07, 1.14]	416 (124)	2.66 (4.39)	[-5.94, 11.25]	702 (330)
Cost hired labor (non-avo, KSh), ihs	0.28 (0.62)	[-0.94, 1.50]	416 (124)	0.78 (0.50)	[-0.20, 1.76]	702 (330)
Knowledge index	**0.70 (0.33)***	[0.05, 1.34]	416 (124)	0.26 (0.17)	[-0.07, 0.59]	702 (330)
Marketing: Hass						
Share high quality, Hass	0.12 (0.10)	[-0.08, 0.33]	259 (95)	**0.08 (0.05)**$^{+}$	[-0.01, 0.18]	521 (287)
Avg. Hass price (KSh per unit)	**1.25 (0.32)****	[0.63, 1.88]	258 (91)	**2.10 (0.21)****	[1.68, 2.52]	521 (281)
Quantity Hass sold (units), ihs	0.02 (0.40)	[-0.77, 0.80]	416 (124)	0.14 (0.20)	[-0.25, 0.53]	702 (330)
Income (incl. consumption) from Hass (KSh), ihs	0.21 (0.56)	[-0.88, 1.31]	416 (124)	**0.67 (0.40)**$^{+}$	[-0.11, 1.46]	702 (330)
Welfare						
Subjective satisfaction	0.01 (0.06)	[-0.11, 0.14]	416 (124)	**0.08 (0.03)****	[0.02, 0.14]	702 (330)
Subjective stability	0.03 (0.06)	[-0.09, 0.15]	416 (124)	**0.09 (0.03)****	[0.03, 0.14]	702 (330)
Food INsecurity index	1.17 (0.76)	[-0.32, 2.66]	416 (124)	**0.72 (0.38)**$^{+}$	[-0.02, 1.46]	701 (330)
Total income (KSh), ihs	0.27 (0.44)	[-0.60, 1.14]	416 (124)	1.26 (0.92)	[-0.55, 3.07]	702 (330)

Note: Significance levels: 0.1 ($^{+}$), 0.05 (*), 0.01 (**)

7. Conclusion

We study the impact of contract farming adoption, in part induced by a multi-layered intervention aimed at improving the livelihood of households engaged in avocado farming in central Kenya. We find that the export sector competitiveness program achieved its immediate goals: increasing farmers' access to export markets via sales to avocado exporting companies, improving knowledge of good agricultural practices through facilitating training and providing farmer group-level certification for high quality production standards. Farmers who adopt contract farming between the baseline and endline received higher prices for the Hass avocado variety (which is preferred by exporters) compared to farmers who did not adopt contract farming. On the other hand, adopters of contract farmers reduce the marketed quantity of local avocado, leading to an overall decrease in the quantity of avocado sold. Contract farmers also increase their planting of Hass avocado trees. These latter two results are evidence for a transition of the smallholder farmers that adopt contract farming from avocado production for the local market towards producing Hass avocado for the export market. However, for the duration of the transition period and until the newly planted Hass avocado trees bear fruits, smallholder farmers may not experience the full magnitude of the benefits of contract farming. Indeed, while we see increases in total income for contract farmers, these changes are not statistically significant.

There are many interventions that aim to improve the livelihood of smallholder farmers by nudging them to adopt crop varieties that are more profitable in the long-run. Our results show the importance of evaluating these interventions using a comprehensive set of outcome variables, which can inform the policy maker about overall welfare effects and not only about the first-order effects of the intervention. For example, higher prices for the targeted crop variety may not directly translate to improved incomes if smallholder farmers substitute away from other crops or reduce their quantity sold to meet increased quality demands.
In our study, we find clear evidence that the intervention leads to a transition towards Hass avocado production. But, we also see that the transition is not yet completed. Adopters of contract farming receive higher prices for Hass avocado and plant more Hass trees, but the increases in marketed Hass quantity, income from Hass avocado and total income are not (yet) statistically significant. Because the transition towards more profitable crops takes time, it is important for policy makers to support farmers during the transition and give them the ability to smooth income over a longer time-horizon.

Our panel data about smallholder farmers' avocado transactions allows us to gain unique insights into the dynamic environment that is typical for agricultural markets

in low-income countries. Even within the limited two year period between baseline and endline of our study, we observe new farmer organizations being formed, while others are dismantled; new avocado companies entering the area, while others drastically reduce their engagement with contracted farmers. Such a high fluctuation makes it difficult to enforce contracts between smallholder farmers and companies, let alone establish more informal agreements on traceability, quality standards, or provision of training, inputs or credit. The intervention we study in this paper aimed to facilitate long-term relations between smallholder farmers and avocado exporting companies by formalizing and strengthening farmer organizations. While we observe that the farmer organizations engage with their assigned company at endline, the time horizon of our study is too short to say much about whether these contracting relations will prove to be long-lasting.

Our transaction-level data shows that smallholder farmers engage with multiple buyers simultaneously. Further research should account for this facts and aim to dis-aggregate and identify the buyers with whom smallholder farmers interact. We believe that collecting farmer-buyer relations over a longer time horizon would allow us to improve our understanding of the market structure of agricultural markets in low-income countries and identify the aspects that can best facilitate long-run and mutually beneficial relations between smallholder farmers and their buyers.

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Appendix A. Intervention Appendix

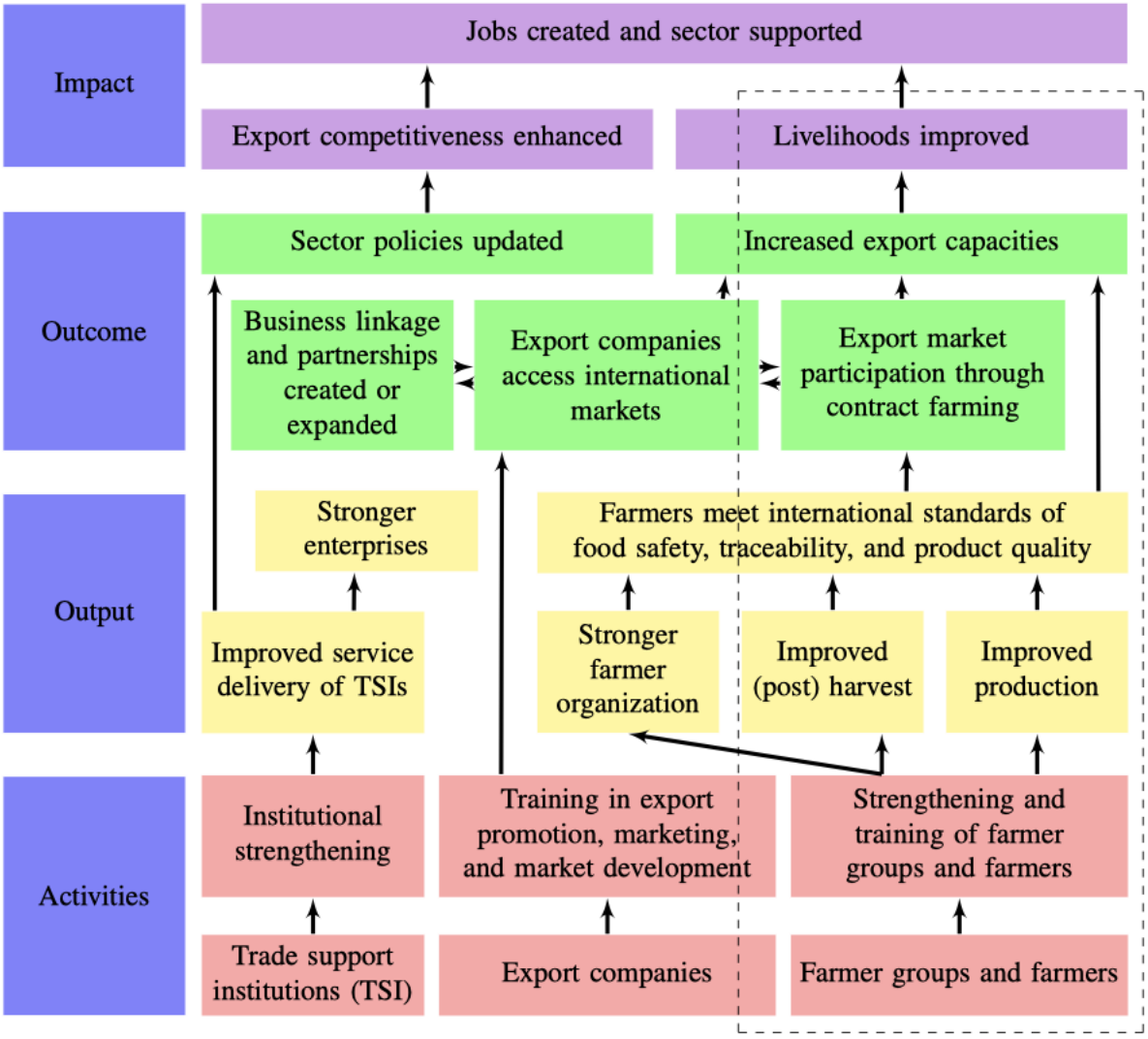


Figure A.7: **Theory of change diagram**
Note: The dashed line encloses the part of the intervention evaluated in this article.

Appendix B. Data Appendix

Data Collection.

Data Cleaning.

Descriptive Results. Table B.7 shows summary statistics for the explanatory variables included in the analysis. We show baseline values, separated by the sampling group, i.e. whether a farmer was a member of a targeted farmer organization, a member of a farmer organization with existing contracts or a farmer with no contracts at baseline.

Table B.7: Summary of explanatory variables

	Targeted Group		Existing Contract Group		No Contract Group	
Outcome	Mean	SD	Mean	SD	Mean	SD
Access to Contract Farming						
Reduction distance to FO	0.83	1.06	0.14	0.48	0.49	0.94
Dummy for reduction distance to FO	0.67	0.47	0.18	0.38	0.36	0.48
Household Composition						
Dist. to road (km)	0.74	0.90	0.74	0.93	0.53	0.70
Age household head	62.01	10.79	64.26	12.27	62.98	13.24
Education household head (years)	8.82	3.57	8.38	3.44	7.96	3.91
Household head is male	0.88	0.32	0.83	0.38	0.73	0.44
Household size	3.46	1.59	3.67	1.75	3.67	1.86
Assets and Land Ownership						
Land owned (acres)	1.74	1.15	2.32	1.89	2.03	1.86
Mature Hass avocado trees owned	7.96	16.28	14.38	18.10	4.55	8.16
Diversified Income						
Non-farm income (1000 KSh)*	76.60	123.50	104.70	158.73	95.03	176.67
Access to Banking and Finance						
Uses bank account to sell crops	0.00	0.00	0.00	0.00	0.00	0.00

Note: 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 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. Results using the log(x+1) transformation are available upon request.

Test for non-random attrition.

Table B.8: Determinants of attrition, outcome is attrition indicator

	Estimate	95% CI
Treatment Allocation (F-Test = 1.51, p = 0.18)		
Member of targeted FO	-0.0210 (0.03)	[-0.08, 0.04]
Member of existing contract FO	-0.0630 (0.04)	[-0.15, 0.02]
Has (any) avocado contract	0.0453 (0.05)	[-0.05, 0.14]
Sold (any avo) to company	0.0240 (0.05)	[-0.08, 0.13]
Received training	**-0.0435 (0.02)**$^{+}$	[-0.09, 0.01]
Outcomes (F-Test = 1.07, p = 0.37)		
Fraction avocado sold to company	0.0097 (0.06)	[-0.10, 0.12]
Fraction Hass of total sales	0.0172 (0.09)	[-0.16, 0.20]
Fraction Fuerte of total sales	0.0730 (0.09)	[-0.11, 0.25]
Share high quality, avo	-0.0122 (0.02)	[-0.06, 0.03]
Avg. avo price (KSh per unit)	**0.0146 (0.01)***	[0.00, 0.03]
Quantity Hass sold (units), ihs	0.0131 (0.01)	[-0.01, 0.04]
Quantity Fuerte sold (units), ihs	-0.0099 (0.01)	[-0.03, 0.01]
Quantity local sold (units), ihs	0.0050 (0.01)	[-0.01, 0.02]
Quantity avo sold (units), ihs	-0.0049 (0.02)	[-0.05, 0.04]
Income (incl. consumption) from Hass (KSh), ihs	-0.0105 (0.01)	[-0.03, 0.01]
Income (incl. consumption) from Fuerte (KSh), ihs	0.0050 (0.01)	[-0.01, 0.02]
Income (incl. consumption) from local (KSh), ihs	-0.0055 (0.00)	[-0.01, 0.00]
Income (incl. consumption) from avo (KSh), ihs	0.0113 (0.02)	[-0.02, 0.04]
Knowledge index	0.0013 (0.00)	[-0.01, 0.01]
Total family labor (avo, labor days), ihs	-0.0128 (0.01)	[-0.03, 0.00]
Total family labor (non-avo, labor days), ihs	0.0143 (0.01)	[-0.01, 0.03]
Cost hired labor (avo, KSh), ihs	**-0.0059 (0.00)**$^{+}$	[-0.01, 0.00]
Cost hired labor (non-avo, KSh), ihs	0.0041 (0.00)	[0.00, 0.01]
Total income (KSh), ihs	-0.0015 (0.01)	[-0.01, 0.01]
Food INsecurity index	0.0001 (0.00)	[0.00, 0.00]
Subjective satisfaction	-0.0134 (0.03)	[-0.06, 0.04]
Subjective stability	0.0226 (0.03)	[-0.03, 0.07]
Controls (F-Test = 0.74, p = 0.66)		
Household size	-0.0023 (0.01)	[-0.01, 0.01]
Age household head	0.0004 (0.00)	[0.00, 0.00]
Household head is male	-0.0065 (0.02)	[-0.05, 0.04]
Education household head (years)	0.0018 (0.00)	[0.00, 0.01]
Land owned (acres)	**0.0087 (0.01)**$^{+}$	[0.00, 0.02]
Mature Hass avocado trees owned (ihs)	-0.0124 (0.01)	[-0.04, 0.01]
Non-farm income (KSh, ihs)	0.0022 (0.00)	[0.00, 0.01]
Uses bank account to sell crops	-0.0219 (0.02)	[-0.06, 0.02]
F-Test of all variables	F = 0.93	p.val = 0.59

Note: Linear regression comparing households that dropped out of the sample (n=45) with households that appear in endline (n=670). In full sample 705 households stay and 49 drop out, in the regression households with missing data for any of the potential determinants of attrition are dropped. F-test statistics test joint significance of (sets of) variables. None are statistically significant at the 10% level.

Appendix C. Methodology Appendix

Table C.9: Covariate balance between treatment and control group, for unadjusted and weighted sample

Xname	meanT_unadj.	meanC_unadj.	diff_unadj.	meanC_wgt.	diff_wgt.
Reduction distance to FO	0.6216	0.5572	0.0644	0.6683	-0.0467
Dummy for reduction distance to FO	0.5968	0.3664	**0.2303****	0.6079	-0.0111
Dist. to road (km)	0.7028	0.5144	**0.1884***	0.6577	0.0451
Household size	3.5887	3.6096	-0.0209	3.7357	-0.1470
Age household head	60.7419	63.3322	**-2.5903***	60.7084	0.0335
Household head is male	0.8629	0.7226	**0.1403****	0.8485	0.0144
Education household head (years)	8.9435	7.8664	**1.0771***	8.9709	-0.0273
Land owned (acres)	1.7875	1.9219	-0.1345	1.8042	-0.0168
Mature Hass avocado trees owned (ihs)	1.9128	1.3904	**0.5224****	2.0100	-0.0972
Non-farm income (KSh, ihs)	9.7991	9.5028	0.2963	9.7771	0.0220
Uses bank account to sell crops	0.5484	0.3664	**0.1819****	0.5126	0.0357

Note: Significance levels: 0.1 ($^+$), 0.05 (*), 0.01 (**) 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.

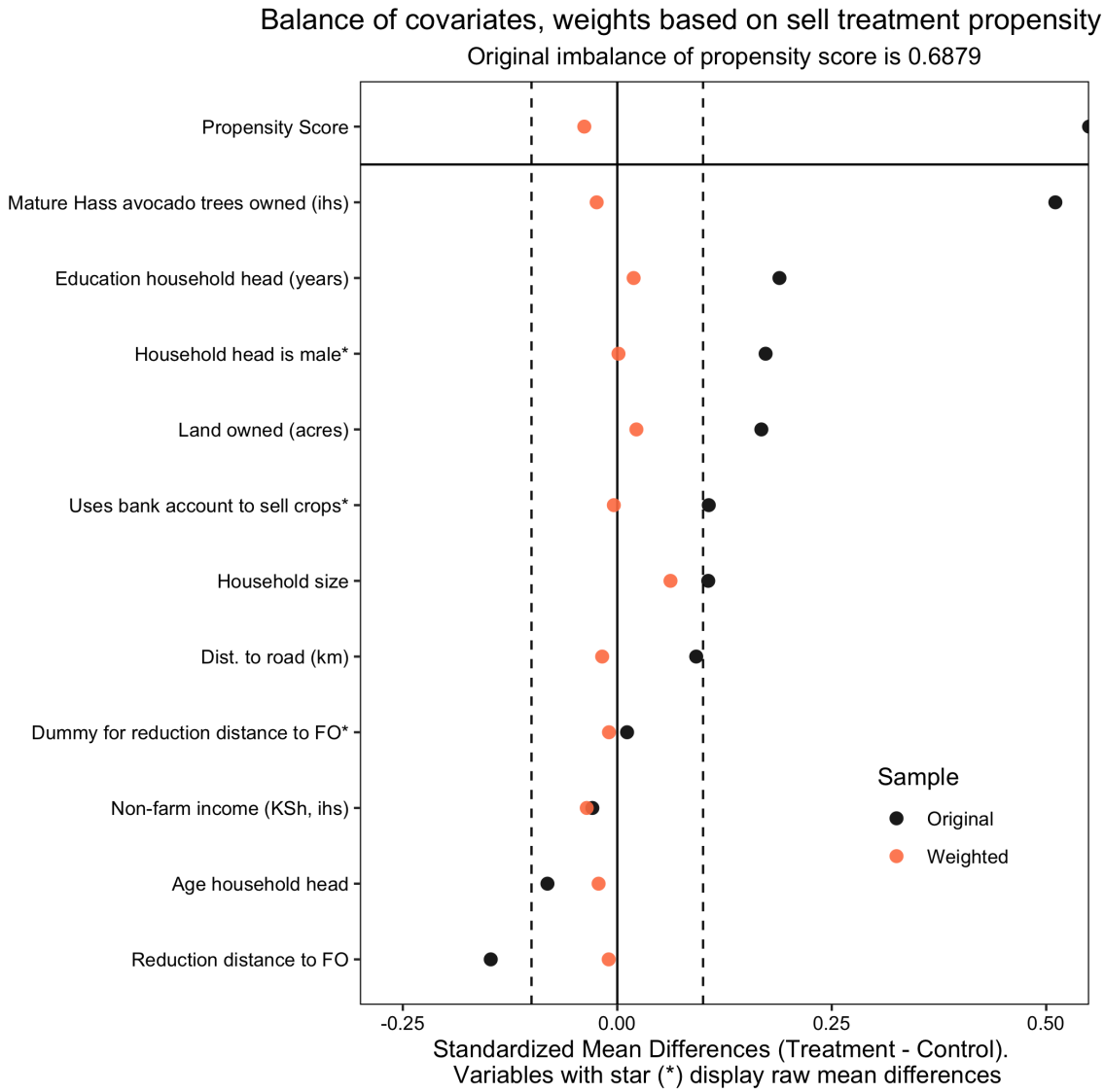


Figure C.8: Observable characteristics are balanced after weighting by the propensity score. The plot compares adopters with never-treated for the selling treatment

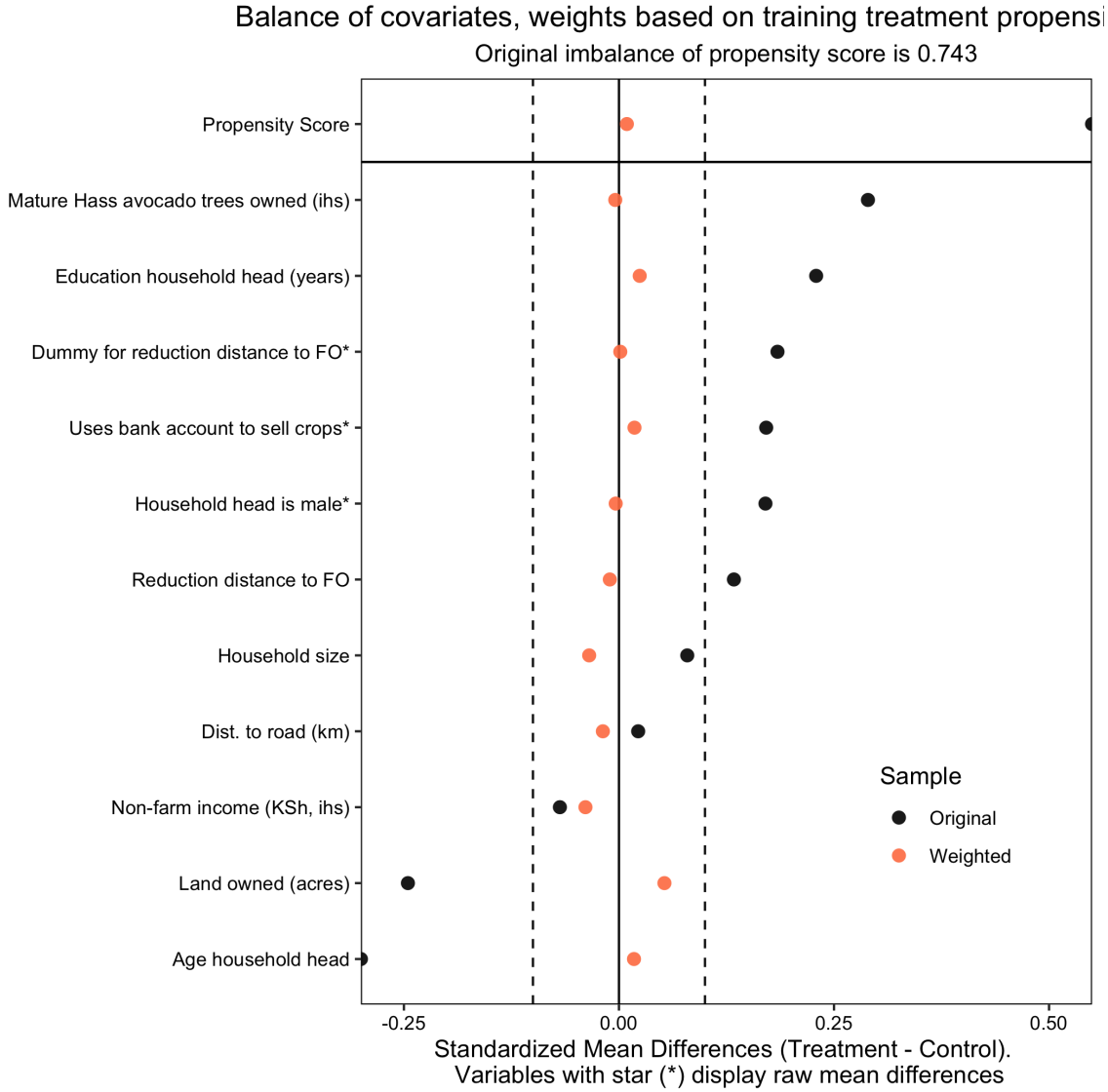


Figure C.9: Observable characteristics are balanced after weighting by the propensity score. The plot compares adopters with never-treated for the training treatment

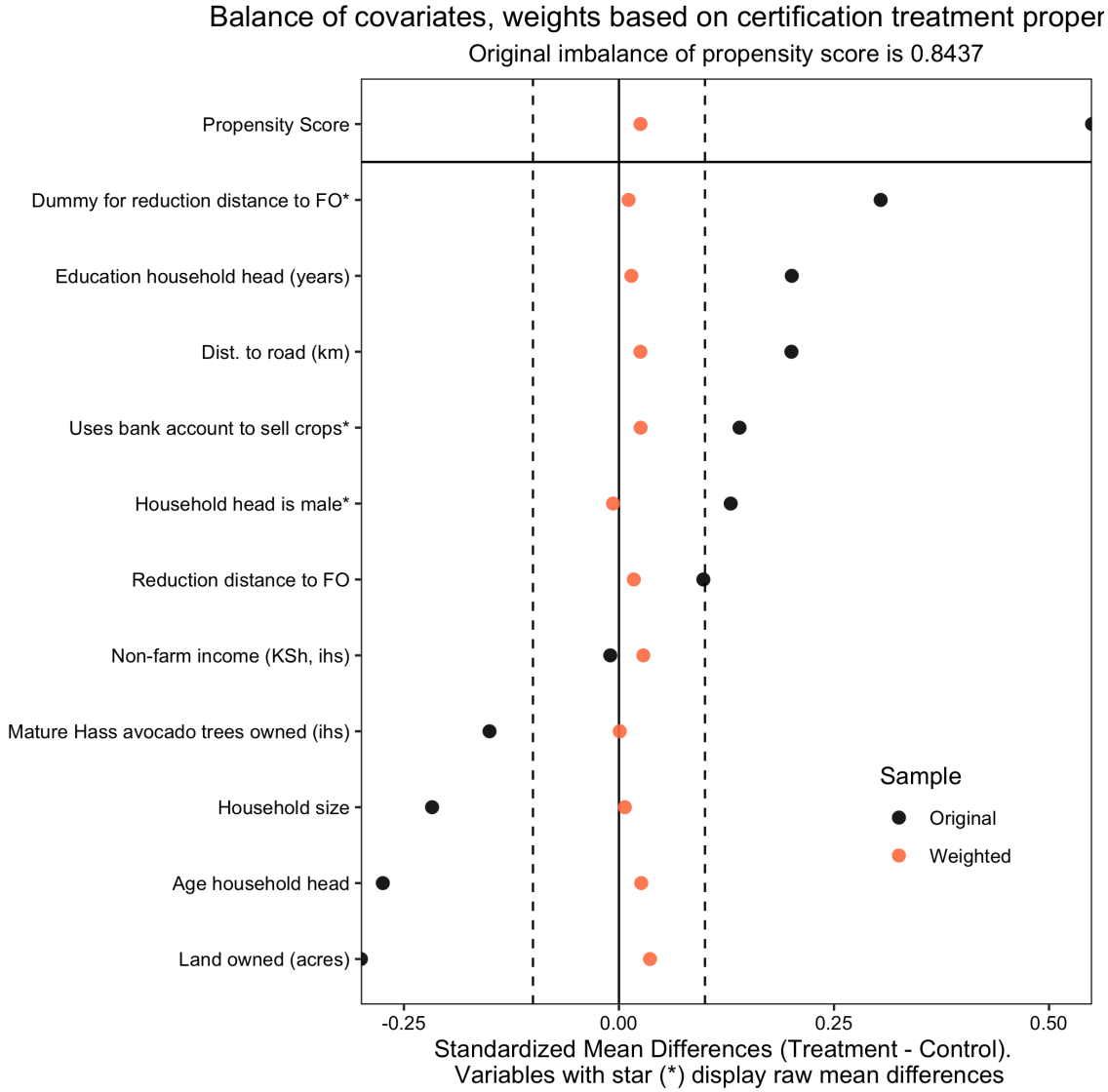


Figure C.10: Observable characteristics are balanced after weighting by the propensity score. The plot compares adopters with never-treated for the certification treatment

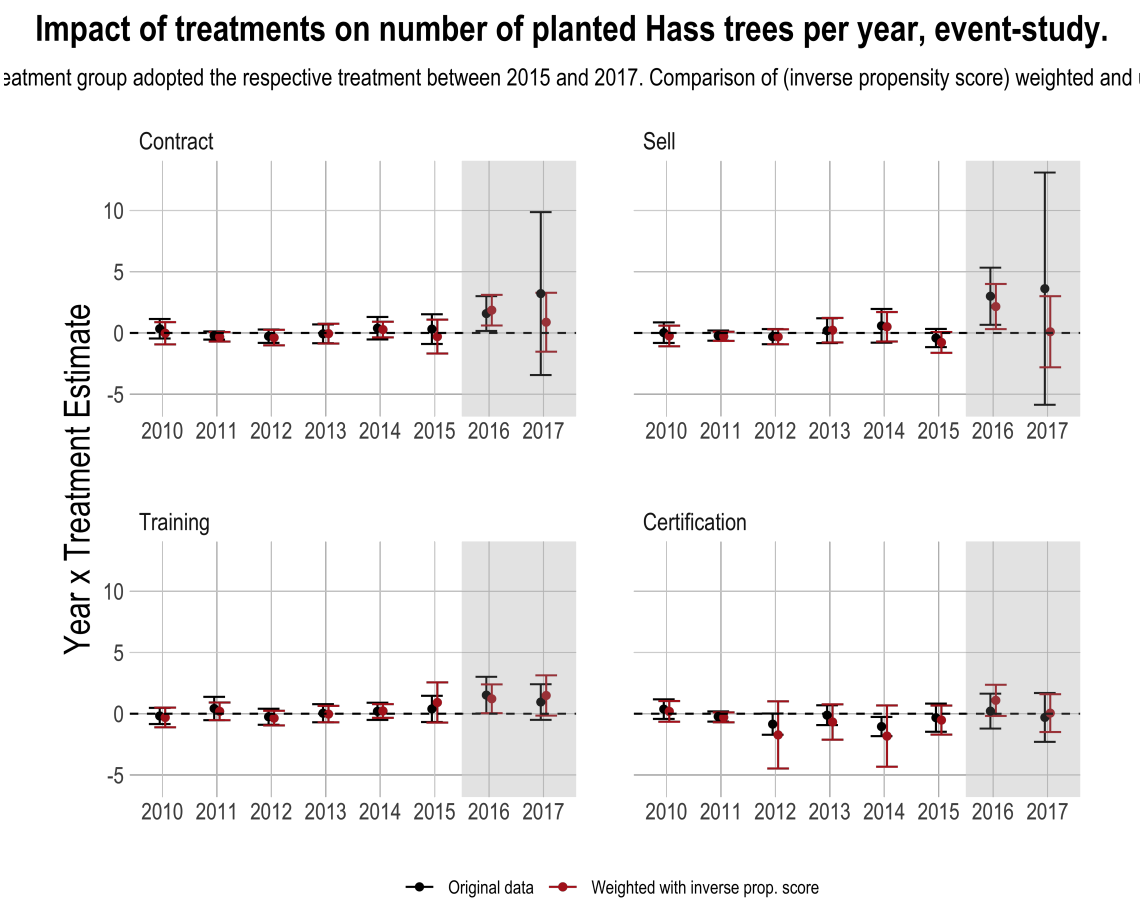

Impact of treatments on number of planted Hass trees per year, event-study.
eatment group adopted the respective treatment between 2015 and 2017. Comparison of (inverse propensity score) weighted and
Contract
Sell
Training
Certification
Year x Treatment Estimate
10
5
0
-5
2010 2011 2012 2013 2014 2015 2016 2017
Original data
Weighted with inverse prop. score

Figure C.11

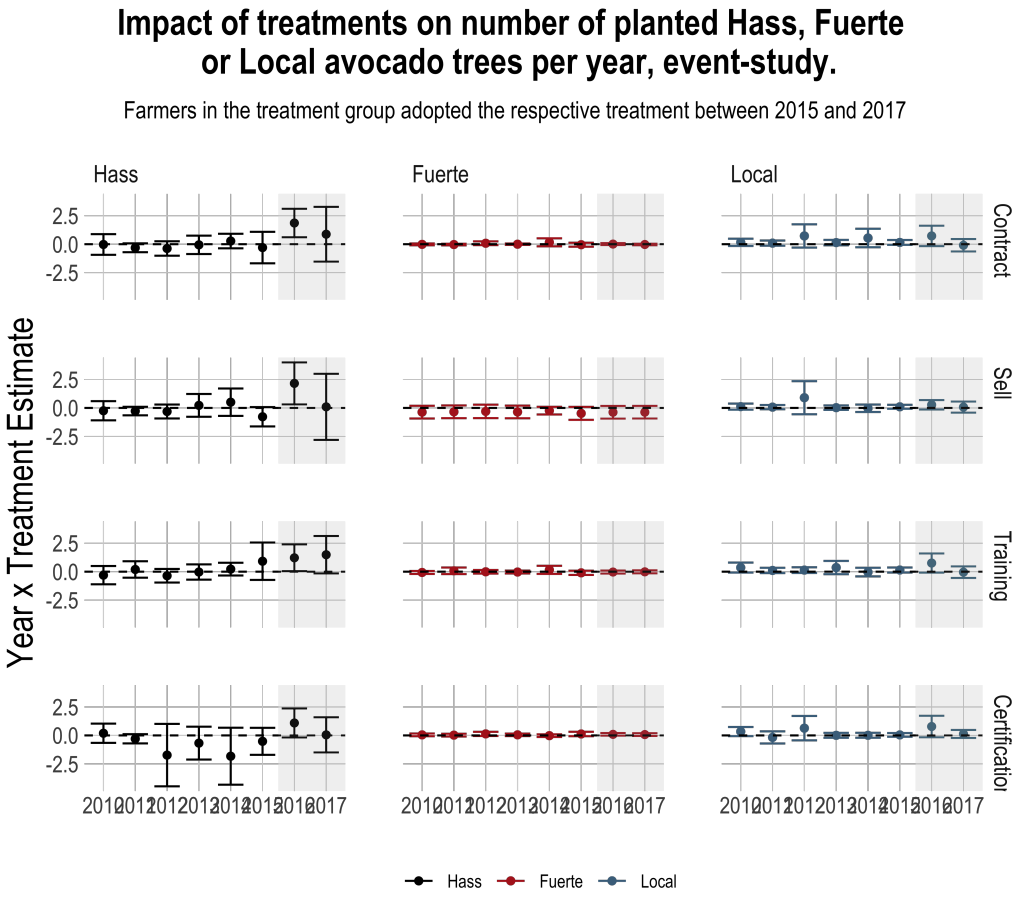

Impact of treatments on number of planted Hass, Fuerte or Local avocado trees per year, event-study.
Farmers in the treatment group adopted the respective treatment between 2015 and 2017
Hass
Fuerte
Local
Contract
Sell
Training
Certificatio
Year x Treatment Estimate
2.5
0.0
-2.5
2012
2013
2014
2015
2016
2017
Hass
Fuerte
Local

Figure C.12

Appendix D. Results Appendix

Appendix D.1. Classification based on targeting of the intervention at village level

Appendix D.2. Corresponding to first results presented in Section 5.1

Table D.10: The effect of being a member of the targeted farmer organizations at baseline, compared to the no contract group, doubly-robust ATT estimates.

Outcome	ATT	95% CI	n
Activity: Selling			
Fraction avocado sold to company	**0.10 (0.06)**$^{+}$	[-0.01, 0.21]	436 (110)
Fraction Hass sold to company	**0.15 (0.08)**$^{+}$	[-0.01, 0.30]	294 (83)
Fraction Fuerte sold to company	**0.15 (0.06)***	[0.03, 0.27]	308 (73)
Sold (any avo) to company	0.07 (0.06)	[-0.05, 0.19]	436 (110)
Sold Hass avocado to company	**0.17 (0.08)***	[0.01, 0.33]	294 (83)
Sold Fuerte avocado to company	**0.16 (0.06)***	[0.04, 0.28]	308 (73)
Fraction Hass of total sales	0.05 (0.04)	[-0.03, 0.12]	437 (111)
Fraction Fuerte of total sales	-0.03 (0.03)	[-0.10, 0.04]	437 (111)
Activities: GAP and Training			
Received GAP certification (individual)	**0.19 (0.05)****	[0.10, 0.29]	458 (113)
Received GAP certification	**0.44 (0.05)****	[0.33, 0.55]	458 (113)
Received training	**0.19 (0.08)***	[0.04, 0.34]	458 (113)
Production			
Number planted Hass trees	**3.09 (1.50)***	[0.16, 6.03]	458 (113)
Total family labor (avo, labor days), ihs	**-0.54 (0.20)****	[-0.94, -0.14]	457 (112)
Total family labor (non-avo, labor days), ihs	**-0.44 (0.17)****	[-0.77, -0.11]	457 (112)
Cost hired labor (avo, KSh), ihs	**-1.09 (0.61)**$^{+}$	[-2.28, 0.10]	458 (113)
Cost hired labor (non-avo, KSh), ihs	0.12 (0.47)	[-0.81, 1.05]	458 (113)
Knowledge index	-0.23 (0.37)	[-0.95, 0.50]	458 (113)
Marketing: Hass			
Share high quality, Hass	-0.11 (0.11)	[-0.32, 0.10]	293 (83)
Avg. Hass price (KSh per unit)	0.54 (0.38)	[-0.20, 1.29]	293 (81)
Quantity Hass sold (units), ihs	0.31 (0.38)	[-0.44, 1.07]	458 (113)
Income (incl. consumption) from Hass (KSh), ihs	-0.04 (0.46)	[-0.94, 0.86]	458 (113)
Welfare			
Subjective satisfaction	0.00 (0.06)	[-0.12, 0.13]	458 (113)
Subjective stability	0.10 (0.07)	[-0.03, 0.23]	458 (113)
Food INsecurity index	**1.29 (0.76)**$^{+}$	[-0.19, 2.77]	458 (113)
Total income (KSh), ihs	0.09 (0.28)	[-0.45, 0.63]	458 (113)

Note: Significance levels: 0.1 ($^{+}$), 0.05 (*), 0.01 (**)

Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. 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.11: The effect of being a member of the targeted farmer organizations at baseline, compared to the existing contract group, doubly-robust ATT estimates.

Outcome	ATT	95% CI	n
Activity: Selling			
Fraction avocado sold to company	**0.13 (0.07)***	[0.00, 0.27]	352 (110)
Fraction Hass sold to company	**0.24 (0.09)****	[0.07, 0.41]	312 (83)
Fraction Fuerte sold to company	-0.01 (0.08)	[-0.17, 0.16]	234 (73)
Sold (any avo) to company	**0.32 (0.08)****	[0.17, 0.48]	352 (110)
Sold Hass avocado to company	**0.34 (0.08)****	[0.19, 0.50]	312 (83)
Sold Fuerte avocado to company	-0.01 (0.09)	[-0.17, 0.16]	234 (73)
Fraction Hass of total sales	-0.02 (0.04)	[-0.09, 0.06]	349 (111)
Fraction Fuerte of total sales	0.01 (0.03)	[-0.05, 0.08]	349 (111)
Activities: GAP and Training			
Received GAP certification (individual)	0.02 (0.06)	[-0.11, 0.15]	357 (113)
Received GAP certification	**0.57 (0.05)****	[0.48, 0.67]	357 (113)
Received training	**0.39 (0.10)****	[0.19, 0.58]	356 (113)
Production			
Number planted Hass trees	0.09 (1.72)	[-3.28, 3.46]	357 (113)
Total family labor (avo, labor days), ihs	-0.24 (0.21)	[-0.64, 0.16]	356 (112)
Total family labor (non-avo, labor days), ihs	-0.13 (0.18)	[-0.47, 0.22]	356 (112)
Cost hired labor (avo, KSh), ihs	**1.10 (0.66)**$^{+}$	[-0.19, 2.40]	357 (113)
Cost hired labor (non-avo, KSh), ihs	0.19 (0.47)	[-0.74, 1.11]	357 (113)
Knowledge index	0.31 (0.44)	[-0.55, 1.17]	357 (113)
Marketing: Hass			
Share high quality, Hass	-0.05 (0.10)	[-0.26, 0.16]	311 (83)
Avg. Hass price (KSh per unit)	**1.18 (0.46)***	[0.28, 2.08]	309 (81)
Quantity Hass sold (units), ihs	-0.38 (0.34)	[-1.03, 0.28]	357 (113)
Income (incl. consumption) from Hass (KSh), ihs	**-0.79 (0.45)**$^{+}$	[-1.68, 0.10]	357 (113)
Welfare			
Subjective satisfaction	0.00 (0.06)	[-0.12, 0.12]	357 (113)
Subjective stability	0.09 (0.05)	[-0.02, 0.20]	357 (113)
Food INsecurity index	-1.00 (0.74)	[-2.45, 0.45]	356 (113)
Total income (KSh), ihs	0.12 (0.32)	[-0.49, 0.74]	357 (113)

Note: Significance levels: 0.1 ($^{+}$), 0.05 (*), 0.01 (**)
Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. 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.12: The impacts of contracts for different avocado types, doubly-robust ATT estimates.

Contract Type	Contract			Contract Hass			Contract Fuerte		
	ATT	95% CI	n	ATT	95% CI	n	ATT	95% CI	n
Fraction avocado sold to company	**0.41 (0.04)****	[0.32, 0.49]	395 (119)	**0.42 (0.04)****	[0.33, 0.51]	403 (116)	**0.39 (0.04)****	[0.31, 0.47]	624 (175)
Fraction Hass sold to company	**0.49 (0.06)****	[0.38, 0.60]	259 (95)	**0.52 (0.05)****	[0.41, 0.63]	262 (93)	**0.31 (0.06)****	[0.20, 0.42]	478 (150)
Fraction Fuerte sold to company	**0.25 (0.05)****	[0.16, 0.35]	273 (86)	**0.26 (0.05)****	[0.15, 0.36]	280 (83)	**0.41 (0.05)****	[0.32, 0.51]	418 (134)
Sold (any avo) to company	**0.51 (0.05)****	[0.41, 0.61]	395 (119)	**0.52 (0.05)****	[0.42, 0.62]	403 (116)	**0.38 (0.05)****	[0.28, 0.47]	624 (175)
Sold Hass avocado to company	**0.51 (0.06)****	[0.40, 0.63]	259 (95)	**0.54 (0.06)****	[0.44, 0.65]	262 (93)	**0.36 (0.06)****	[0.25, 0.47]	478 (150)
Sold Fuerte avocado to company	**0.27 (0.05)****	[0.16, 0.37]	273 (86)	**0.28 (0.06)****	[0.16, 0.39]	280 (83)	**0.43 (0.05)****	[0.34, 0.53]	418 (134)
Fraction Hass of total sales	0.05 (0.04)	[-0.03, 0.13]	395 (119)	0.03 (0.04)	[-0.04, 0.11]	404 (116)	**0.05 (0.03)**$^{+}$	[0.00, 0.11]	621 (172)
Fraction Fuerte of total sales	-0.03 (0.03)	[-0.09, 0.04]	395 (119)	-0.01 (0.03)	[-0.08, 0.06]	404 (116)	-0.02 (0.03)	[-0.07, 0.03]	621 (172)

Note: Significance levels: 0.1 ($^{+}$), 0.05 (*), 0.01 (**)

Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. Outcomes with the ihs suffix are transformed using the inverse hyperbolic sine transformation and ATT estimates show semi-elasticities, calculated as $\frac{P}{100} \approx \exp(\hat{\beta}) - 1$ following Bellemare, Wichman 2020 equation 11. Transformed standard errors and CIs are calculated using delta method (multiplying old se with exp(beta)). Column 1: The treatment is having a contract (to sell any type of avocado), as indicated by belonging to a farmer organization or selling (any type of avocado) under contract. In 2015, farmers in newly created farmer organizations were not treated, because the farmer organizations were formed immediately preceding the survey and the contracts were only effective for the coming harvest period. Column 2: The treatment is having a contract to sell hass avocado, as indicated by belonging to a farmer organization or selling hass avocado under contract. In 2015, farmers in newly created farmer organizations were not treated, because the farmer organizations were formed immediately preceding the survey and the contracts were only effective for the coming harvest period. Column 3: The treatment is having a contract to sell fuerte avocado, as indicated by belonging to a newly created farmer organization or selling fuerte avocado under contract. In 2015, farmers in newly created farmer organizations were not treated, because the farmer organizations were formed immediately preceding the survey and the contracts were only effective for the coming harvest period. Farmers in farmer organizations connected to the established company are not classified as having a contract for fuerte avocado, because the established company buys only Hass avocado under contract . In our data only 13 farmers (out of 236) reported having sold fuerte avocado under contract to the established company. The other companies connected to the newly-created farmer organizations (presumably) buy Hass and Fuerte (according to information by Michael Murigi), so are treated as providing contracts for Hass and Fuerte avocado. Households in the treatment group are adopters (no treatment in 2015, treatment in 2017), households in the control group are never-treated (no treatment in 2015 and 2017). 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.13: The impacts of contracts, comparing competing definitions of contract treatment, doubly-robust ATT estimates.

'Contract Group' is not based on sales	Contract			Contract Group		
	ATT	95% CI	n	ATT	95% CI	n
Activities: GAP and Training						
Received GAP certification	**0.73 (0.04)****	[0.65, 0.80]	416 (124)	**0.82 (0.03)****	[0.76, 0.89]	458 (129)
Received GAP certification (individual)	**0.29 (0.04)****	[0.21, 0.37]	416 (124)	**0.32 (0.04)****	[0.23, 0.40]	458 (129)
Received training	**0.50 (0.06)****	[0.37, 0.62]	416 (124)	**0.54 (0.06)****	[0.42, 0.66]	458 (129)
Activity: Selling						
Fraction avocado sold to company	**0.41 (0.04)****	[0.32, 0.49]	395 (119)	**0.40 (0.05)****	[0.31, 0.48]	436 (124)
Fraction Hass sold to company	**0.49 (0.06)****	[0.38, 0.60]	259 (95)	**0.44 (0.06)****	[0.32, 0.56]	294 (101)
Fraction Fuerte sold to company	**0.25 (0.05)****	[0.16, 0.35]	273 (86)	**0.32 (0.05)****	[0.21, 0.42]	308 (90)
Sold (any avo) to company	**0.51 (0.05)****	[0.41, 0.61]	395 (119)	**0.44 (0.05)****	[0.33, 0.55]	436 (124)
Sold Hass avocado to company	**0.51 (0.06)****	[0.40, 0.63]	259 (95)	**0.46 (0.06)****	[0.34, 0.58]	294 (101)
Sold Fuerte avocado to company	**0.27 (0.05)****	[0.16, 0.37]	273 (86)	**0.33 (0.06)****	[0.22, 0.44]	308 (90)

Note: Significance levels: 0.1 ($^+$), 0.05 (*), 0.01 (**)

Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. Column 1: The treatment is having a contract (to sell any type of avocado), as indicated by belonging to a farmer organization or selling (any type of avocado) under contract. In 2015, farmers in newly created farmer organizations were not treated, because the farmer organizations were formed immediately preceding the survey and the contracts were only effective for the coming harvest period. Column 2: Contract Group defines contract treatment only based on membership in farmer organizations, to avoid the circular definition that farmers with contract sales by definition sale to companies. Households in the treatment group are adopters (no treatment in 2015, treatment in 2017), households in the control group are never-treated (no treatment in 2015 and 2017). 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.

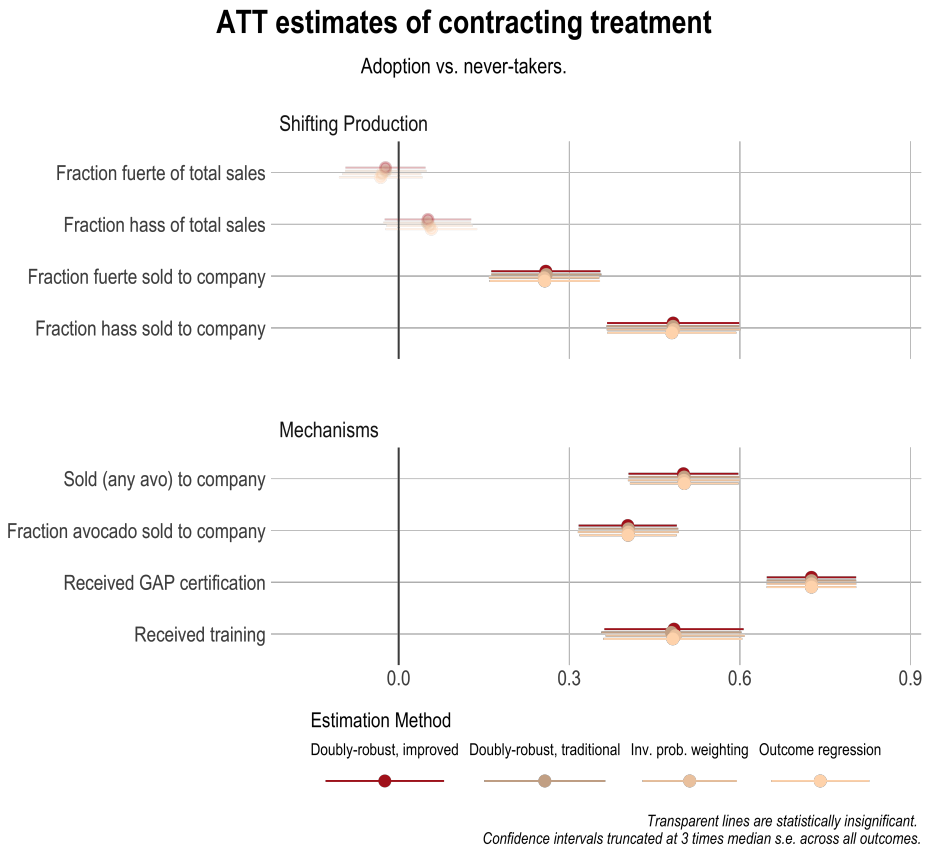
Table D.14: The immediate impacts of contracting, ATTs of other estimation methods.

Estimation Method	Doubly-robust, traditional			Inv. prob. weighting			Outcome regression		
	ATT	95% CI	n	ATT	95% CI	n	ATT	95% CI	n
Activity: Selling									
Fraction avocado sold to company	**0.41 (0.04)****	[0.32, 0.49]	395 (119)	**0.41 (0.04)****	[0.32, 0.49]	395 (119)	**0.40 (0.04)****	[0.32, 0.49]	395 (119)
Fraction Hass sold to company	**0.49 (0.06)****	[0.38, 0.60]	259 (95)	**0.49 (0.06)****	[0.37, 0.60]	259 (95)	**0.48 (0.06)****	[0.37, 0.60]	259 (95)
Fraction Fuerte sold to company	**0.25 (0.05)****	[0.15, 0.35]	273 (86)	**0.25 (0.05)****	[0.15, 0.35]	273 (86)	**0.25 (0.05)****	[0.15, 0.35]	273 (86)
Sold (any avo) to company	**0.51 (0.05)****	[0.41, 0.60]	395 (119)	**0.51 (0.05)****	[0.41, 0.60]	395 (119)	**0.50 (0.05)****	[0.41, 0.60]	395 (119)
Sold Hass avocado to company	**0.52 (0.06)****	[0.40, 0.63]	259 (95)	**0.51 (0.06)****	[0.40, 0.63]	259 (95)	**0.51 (0.06)****	[0.40, 0.62]	259 (95)
Sold Fuerte avocado to company	**0.27 (0.05)****	[0.16, 0.37]	273 (86)	**0.26 (0.06)****	[0.15, 0.37]	273 (86)	**0.27 (0.05)****	[0.16, 0.37]	273 (86)
Fraction Hass of total sales	0.05 (0.04)	[-0.03, 0.13]	395 (119)	0.06 (0.04)	[-0.02, 0.13]	395 (119)	0.05 (0.04)	[-0.03, 0.13]	395 (119)
Fraction Fuerte of total sales	-0.03 (0.03)	[-0.10, 0.04]	395 (119)	-0.03 (0.03)	[-0.10, 0.03]	395 (119)	-0.02 (0.04)	[-0.10, 0.05]	395 (119)
Activities: GAP and Training									
Received GAP certification	**0.73 (0.04)****	[0.65, 0.80]	416 (124)	**0.73 (0.04)****	[0.65, 0.80]	416 (124)	**0.73 (0.04)****	[0.65, 0.80]	416 (124)
Received training	**0.50 (0.06)****	[0.37, 0.62]	416 (124)	**0.50 (0.06)****	[0.37, 0.62]	416 (124)	**0.48 (0.07)****	[0.35, 0.61]	416 (124)

Note: Significance levels: 0.1 ($^{+}$), 0.05 (*), 0.01 (**)

Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. The treatment is having a contract (to sell any type of avocado), as indicated by belonging to a farmer organization or selling (any type of avocado) under contract. In 2015, farmers in newly created farmer organizations were not treated, because the farmer organizations were formed immediately preceding the survey and the contracts were only effective for the coming harvest period. Households in the treatment group are adopters (no treatment in 2015, treatment in 2017), households in the control group are never-treated (no treatment in 2015 and 2017). 'Doubly-robust, traditional' refers to Sant'Anna, Zhao (2020). The propensity scores are estimated using maximum likelihood and the outcome regression coefficients are estimated using ordinary least squares. Estimation via inverse probability weighting follows Abadie (2005) and using weights normalized to one. Estimation via outcome regression follows Heckman, Ichimura, Todd (1997) assuming a linear (parametric) regression model.

Figure D.13: Alternative estimation methods for first results.



Appendix D.3. Corresponding to second results presented in Section 5.2

Figure D.14: Joint significance test for shift from family to hired labor.

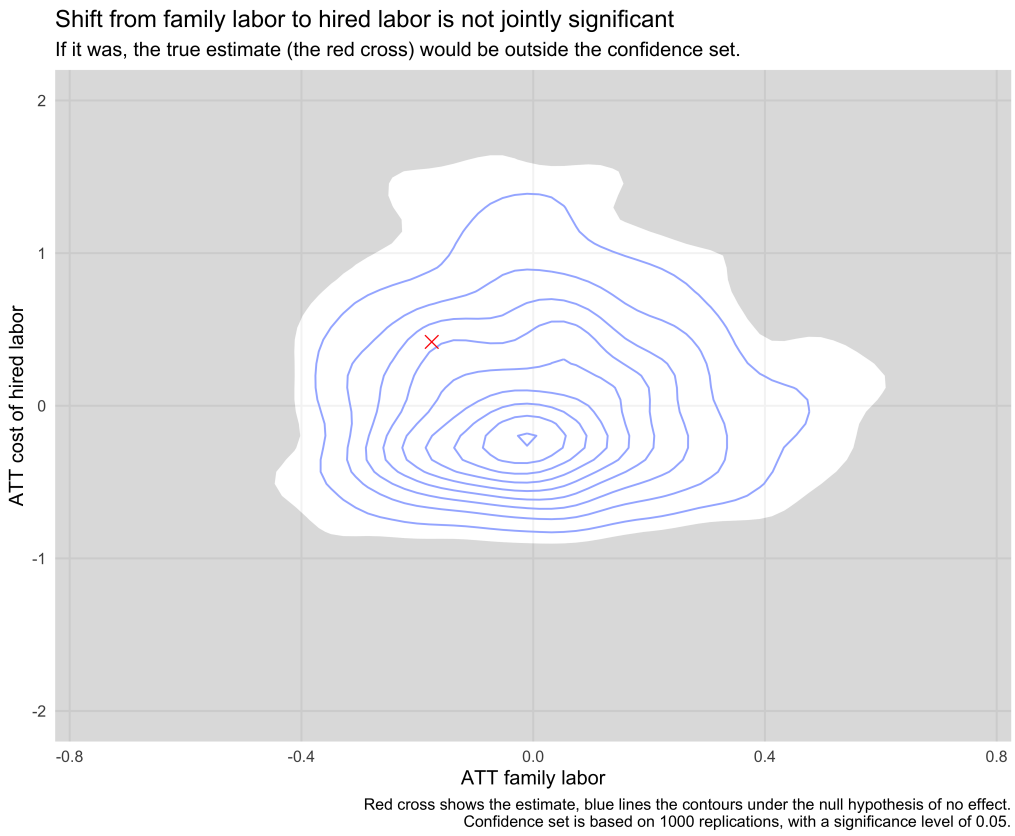


Table D.15: Marketing outcomes for different avocado types, doubly-robust ATT estimates.

Outcome	ATT	95% CI	n
Outcome: Production			
Number planted avo trees	4.58 (3.62)	[-2.51, 11.67]	416 (124)
Number planted Hass trees	4.27 (3.59)	[-2.76, 11.29]	416 (124)
Number planted Fuerte trees	-0.10 (0.14)	[-0.37, 0.17]	416 (124)
Number planted local trees	0.42 (0.50)	[-0.56, 1.40]	416 (124)
Outcome: Marketing			
Share high quality, avo	0.07 (0.08)	[-0.08, 0.23]	395 (119)
Share high quality, Hass	0.12 (0.10)	[-0.08, 0.33]	259 (95)
Share high quality, Fuerte	0.01 (0.09)	[-0.16, 0.19]	272 (86)
Avg. avo price (KSh per unit)	**0.93 (0.23)****	[0.49, 1.38]	389 (116)
Avg. Hass price (KSh per unit)	**1.25 (0.32)****	[0.63, 1.88]	258 (91)
Avg. Fuerte price (KSh per unit)	**0.34 (0.19)**$^{+}$	[-0.04, 0.71]	273 (83)
Quantity avo sold (units), ihs	**-0.35 (0.19)**$^{+}$	[-0.72, 0.01]	416 (124)
Quantity Hass sold (units), ihs	0.02 (0.40)	[-0.77, 0.80]	416 (124)
Quantity Fuerte sold (units), ihs	-0.22 (0.34)	[-0.89, 0.45]	416 (124)
Quantity local sold (units), ihs	-0.42 (0.27)	[-0.95, 0.10]	416 (124)
Income (incl. consumption) from avo (KSh), ihs	-0.17 (0.28)	[-0.72, 0.37]	416 (124)
Income (incl. consumption) from Hass (KSh), ihs	0.21 (0.56)	[-0.88, 1.31]	416 (124)
Income (incl. consumption) from Fuerte (KSh), ihs	-0.10 (0.46)	[-1.00, 0.80]	416 (124)
Income (incl. consumption) from local (KSh), ihs	0.00 (0.48)	[-0.95, 0.94]	416 (124)

Note: Significance levels: 0.1 ($^{+}$), 0.05 (*), 0.01 (**)

Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. Outcomes with the ihs suffix are transformed using the inverse hyperbolic sine transformation and ATT estimates show semi-elasticities, calculated as $\frac{P}{100} \approx \exp(\hat{\beta}) - 1$ following Bellemare, Wichman 2020 equation 11. Transformed standard errors and CIs are calculated using delta method (multiplying old se with exp(beta)). The treatment is having a contract (to sell any type of avocado), as indicated by belonging to a farmer organization or selling (any type of avocado) under contract. In 2015, farmers in newly created farmer organizations were not treated, because the farmer organizations were formed immediately preceding the survey and the contracts were only effective for the coming harvest period. 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.

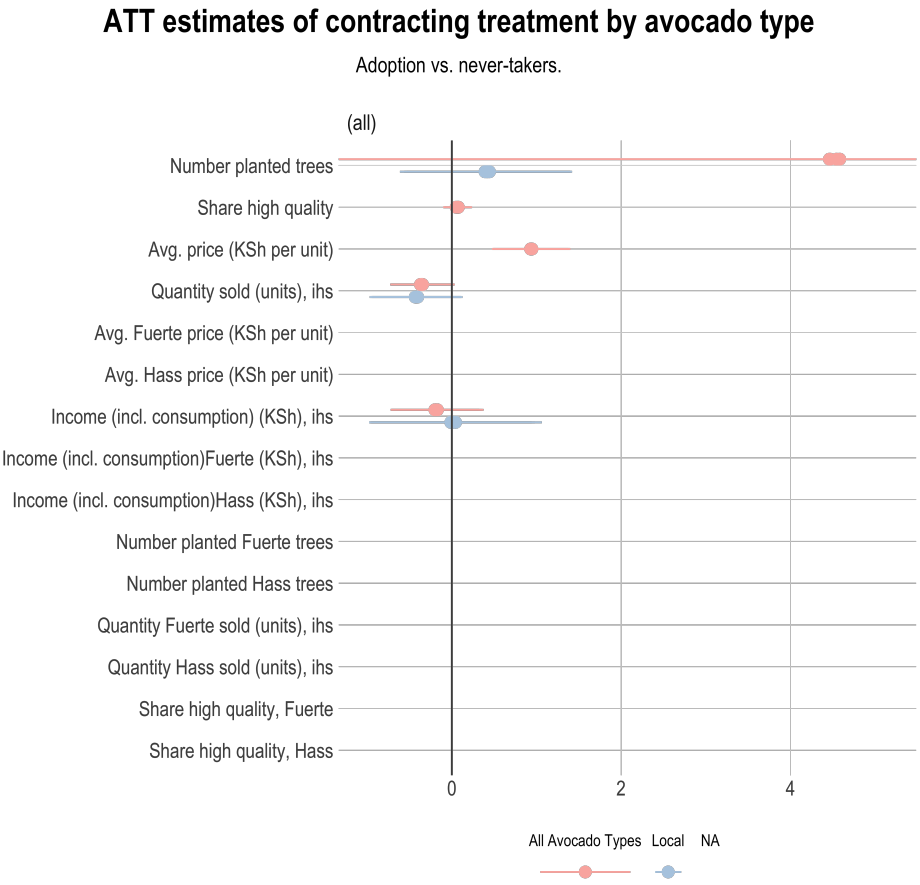

ATT estimates of contracting treatment by avocado type
Adoption vs. never-takers.
(all)
Number planted trees
Share high quality
Avg. price (KSh per unit)
Quantity sold (units), ihs
Avg. Fuerte price (KSh per unit)
Avg. Hass price (KSh per unit)
Income (incl. consumption) (KSh), ihs
Income (incl. consumption)Fuerte (KSh), ihs
Income (incl. consumption)Hass (KSh), ihs
Number planted Fuerte trees
Number planted Hass trees
Quantity Fuerte sold (units), ihs
Quantity Hass sold (units), ihs
Share high quality, Fuerte
Share high quality, Hass
0
2
4
All Avocado Types
Local
NA
Solid line is estimate from improved doubly-robust estimation, transparent lines are estimates from other estimations (trad. DR, IPW and OR).
Confidence intervals truncated at 2 times median s.e. across outcomes

Table D.16: The impacts of contracts for different avocado types, doubly-robust ATT estimates.

Contract Type	Contract			Contract Hass			Contract Fuerte		
	ATT	95% CI	n	ATT	95% CI	n	ATT	95% CI	n
Production									
Number planted avo trees	4.58 (3.62)	[-2.51, 11.67]	416 (124)	4.92 (3.69)	[-2.32, 12.16]	425 (121)	1.13 (2.36)	[-3.50, 5.76]	648 (179)
Number planted Hass trees	4.27 (3.59)	[-2.76, 11.29]	416 (124)	4.62 (3.66)	[-2.56, 11.79]	425 (121)	0.66 (2.33)	[-3.90, 5.22]	648 (179)
Number planted Fuerte trees	-0.10 (0.14)	[-0.37, 0.17]	416 (124)	-0.11 (0.14)	[-0.38, 0.17]	425 (121)	-0.03 (0.11)	[-0.25, 0.18]	648 (179)
Total family labor (avo, labor days), ihs	-0.12 (0.17)	[-0.45, 0.20]	415 (123)	-0.19 (0.16)	[-0.50, 0.13]	424 (120)	-0.03 (0.14)	[-0.30, 0.25]	647 (178)
Total family labor (non-avo, labor days), ihs	0.05 (0.16)	[-0.27, 0.37]	415 (123)	0.00 (0.15)	[-0.30, 0.29]	424 (120)	0.15 (0.16)	[-0.16, 0.47]	647 (178)
Cost hired labor (avo, KSh), ihs	0.03 (0.56)	[-1.07, 1.14]	416 (124)	0.10 (0.61)	[-1.11, 1.30]	425 (121)	1.69 (2.47)	[-3.16, 6.54]	648 (179)
Cost hired labor (non-avo, KSh), ihs	0.28 (0.62)	[-0.94, 1.50]	416 (124)	0.26 (0.62)	[-0.95, 1.47]	425 (121)	0.70 (0.73)	[-0.73, 2.14]	648 (179)
Knowledge index	**0.70 (0.33)***	[0.05, 1.34]	416 (124)	**0.61 (0.34)**$^{+}$	[-0.06, 1.27]	425 (121)	0.15 (0.27)	[-0.38, 0.68]	648 (179)
Marketing									
Share high quality, avo	0.07 (0.08)	[-0.08, 0.23]	395 (119)	0.08 (0.08)	[-0.08, 0.25]	403 (116)	0.08 (0.06)	[-0.05, 0.20]	624 (175)
Share high quality, Hass	0.12 (0.10)	[-0.08, 0.33]	259 (95)	0.13 (0.11)	[-0.08, 0.34]	262 (93)	0.09 (0.08)	[-0.06, 0.23]	477 (149)
Share high quality, Fuerte	0.01 (0.09)	[-0.16, 0.19]	272 (86)	0.02 (0.10)	[-0.17, 0.20]	279 (83)	0.09 (0.08)	[-0.06, 0.24]	417 (134)
Avg. avo price (KSh per unit)	**0.93 (0.23)****	[0.49, 1.38]	389 (116)	**0.88 (0.23)****	[0.42, 1.33]	396 (113)	**0.99 (0.23)****	[0.53, 1.44]	611 (167)
Avg. Hass price (KSh per unit)	**1.25 (0.32)****	[0.63, 1.88]	258 (91)	**1.21 (0.33)****	[0.56, 1.87]	262 (89)	**0.79 (0.33)***	[0.14, 1.43]	475 (142)
Avg. Fuerte price (KSh per unit)	**0.34 (0.19)**$^{+}$	[-0.04, 0.71]	273 (83)	**0.35 (0.19)**$^{+}$	[-0.03, 0.72]	279 (81)	**0.76 (0.21)****	[0.34, 1.18]	412 (127)
Quantity avo sold (units), ihs	**-0.35 (0.19)**$^{+}$	[-0.72, 0.01]	416 (124)	**-0.35 (0.19)**$^{+}$	[-0.73, 0.02]	425 (121)	**-0.48 (0.13)****	[-0.74, -0.22]	648 (179)
Quantity Hass sold (units), ihs	0.02 (0.40)	[-0.77, 0.80]	416 (124)	-0.17 (0.33)	[-0.82, 0.48]	425 (121)	-0.33 (0.20)	[-0.72, 0.07]	648 (179)
Quantity Fuerte sold (units), ihs	-0.22 (0.34)	[-0.89, 0.45]	416 (124)	-0.11 (0.39)	[-0.87, 0.65]	425 (121)	-0.34 (0.22)	[-0.76, 0.09]	648 (179)
Income (incl. consumption) from avo (KSh), ihs	-0.17 (0.28)	[-0.72, 0.37]	416 (124)	-0.17 (0.28)	[-0.73, 0.38]	425 (121)	**-0.36 (0.19)**$^{+}$	[-0.73, 0.00]	648 (179)
Income (incl. consumption) from Hass (KSh), ihs	0.21 (0.56)	[-0.88, 1.31]	416 (124)	-0.03 (0.43)	[-0.87, 0.81]	425 (121)	-0.24 (0.26)	[-0.75, 0.27]	648 (179)
Income (incl. consumption) from Fuerte (KSh), ihs	-0.10 (0.46)	[-1.00, 0.80]	416 (124)	-0.03 (0.49)	[-0.99, 0.94]	425 (121)	-0.01 (0.35)	[-0.70, 0.67]	648 (179)
Welfare									
Subjective satisfaction	0.01 (0.06)	[-0.11, 0.14]	416 (124)	-0.02 (0.06)	[-0.15, 0.10]	425 (121)	0.05 (0.05)	[-0.04, 0.15]	648 (179)
Subjective stability	0.03 (0.06)	[-0.09, 0.15]	416 (124)	0.01 (0.06)	[-0.12, 0.13]	425 (121)	**0.07 (0.04)**$^{+}$	[-0.01, 0.16]	648 (179)
Food INsecurity index	1.17 (0.76)	[-0.32, 2.66]	416 (124)	1.15 (0.79)	[-0.41, 2.70]	425 (121)	0.67 (0.56)	[-0.42, 1.76]	647 (179)
Total income (KSh), ihs	0.27 (0.44)	[-0.60, 1.14]	416 (124)	0.34 (0.48)	[-0.59, 1.27]	425 (121)	-0.01 (0.24)	[-0.48, 0.45]	648 (179)

Note: Significance levels: 0.1 ($^{+}$), 0.05 (*), 0.01 (**)

Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. Outcomes with the ihs suffix are transformed using the inverse hyperbolic sine transformation and ATT estimates show semi-elasticities, calculated as $\frac{P}{100} \approx \exp(\hat{\beta}) - 1$ following Bellemare, Wichman 2020 equation 11. Transformed standard errors and CIs are calculated using delta method (multiplying old se with exp(beta)). Column 1: The treatment is having a contract (to sell any type of avocado), as indicated by belonging to a farmer organization or selling (any type of avocado) under contract. In 2015, farmers in newly created farmer organizations were not treated, because the farmer organizations were formed immediately preceding the survey and the contracts were only effective for the coming harvest period. Column 2: The treatment is having a contract to sell hass avocado, as indicated by belonging to a farmer organization or selling hass avocado under contract. In 2015, farmers in newly created farmer organizations were not treated, because the farmer organizations were formed immediately preceding the survey and the contracts were only effective for the coming harvest period. Column 3: The treatment is having a contract to sell fuerte avocado, as indicated by belonging to a newly created farmer organization or selling fuerte avocado under contract. In 2015, farmers in newly created farmer organizations were not treated, because the farmer organizations were formed immediately preceding the survey and the contracts were only effective for the coming harvest period. Farmers in farmer organizations connected to the established company are not classified as having a contract for fuerte avocado, because the established company buys only Hass avocado under contract . In our data only 13 farmers (out of 236) reported having sold fuerte avocado under contract to the established company. The other companies connected to the newly-created farmer organizations (presumably) buy Hass and Fuerte (according to information by Michael Murigi), so are treated as providing contracts for Hass and Fuerte avocado. Households in the treatment group are adopters (no treatment in 2015, treatment in 2017), households in the control group are never-treated (no treatment in 2015 and 2017). 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.

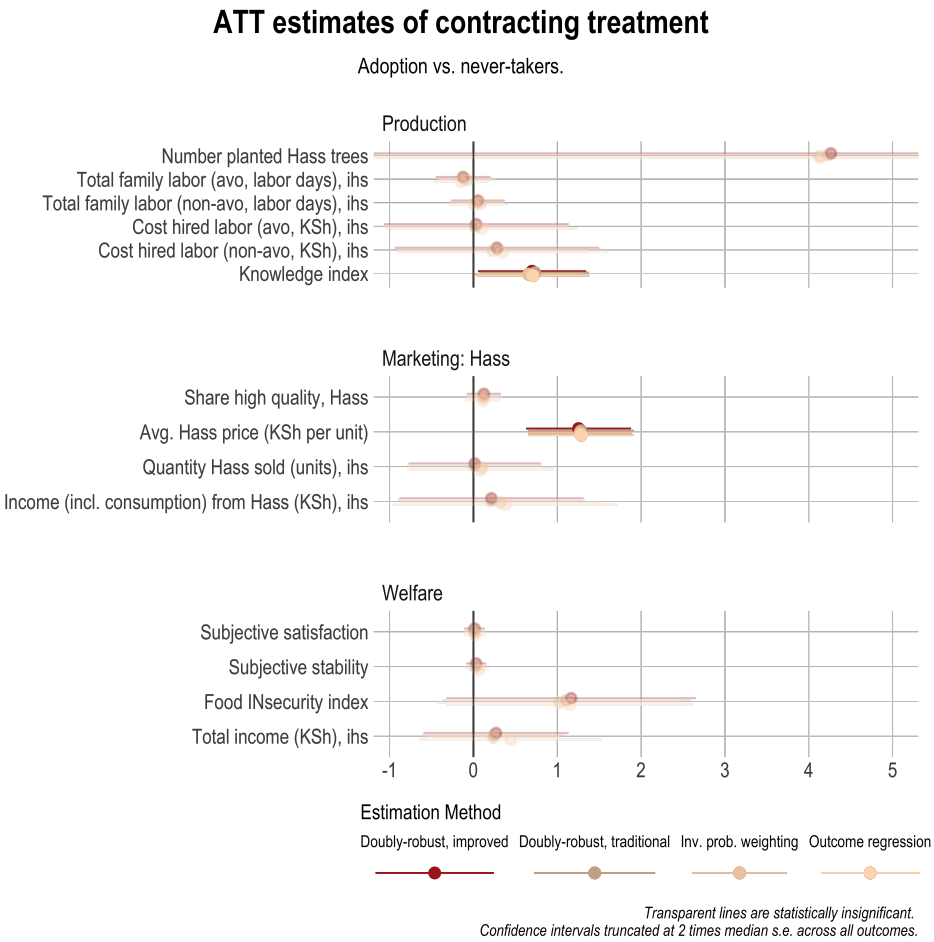
Table D.17: Outcomes for contracting, ATTs of other estimation methods.

Estimation Method	Doubly-robust, traditional			Inv. prob. weighting			Outcome regression		
	ATT	95% CI	n	ATT	95% CI	n	ATT	95% CI	n
Production									
Number planted Hass trees	4.23 (3.59)	[-2.81, 11.27]	416 (124)	4.13 (3.60)	[-2.92, 11.19]	416 (124)	4.14 (3.62)	[-2.95, 11.23]	416 (124)
Total family labor (avo, labor days), ihs	-0.11 (0.17)	[-0.45, 0.22]	415 (123)	-0.08 (0.17)	[-0.42, 0.26]	415 (123)	-0.15 (0.17)	[-0.47, 0.18]	415 (123)
Total family labor (non-avo, labor days), ihs	0.04 (0.16)	[-0.28, 0.36]	415 (123)	0.08 (0.17)	[-0.24, 0.41]	415 (123)	0.01 (0.16)	[-0.30, 0.32]	415 (123)
Cost hired labor (avo, KSh), ihs	0.02 (0.56)	[-1.07, 1.12]	416 (124)	0.03 (0.56)	[-1.08, 1.13]	416 (124)	0.10 (0.58)	[-1.03, 1.24]	416 (124)
Cost hired labor (non-avo, KSh), ihs	0.29 (0.63)	[-0.95, 1.52]	416 (124)	0.23 (0.58)	[-0.91, 1.37]	416 (124)	0.34 (0.64)	[-0.91, 1.60]	416 (124)
Knowledge index	**0.73 (0.33)***	[0.09, 1.38]	416 (124)	**0.66 (0.32)***	[0.02, 1.29]	416 (124)	**0.71 (0.34)***	[0.04, 1.38]	416 (124)
Marketing: Hass									
Share high quality, Hass	0.12 (0.10)	[-0.08, 0.32]	259 (95)	0.12 (0.11)	[-0.09, 0.33]	259 (95)	0.11 (0.10)	[-0.09, 0.31]	259 (95)
Avg. Hass price (KSh per unit)	**1.28 (0.32)****	[0.65, 1.91]	258 (91)	**1.27 (0.32)****	[0.65, 1.89]	258 (91)	**1.28 (0.32)****	[0.65, 1.92]	258 (91)
Quantity Hass sold (units), ihs	0.01 (0.41)	[-0.79, 0.81]	416 (124)	0.10 (0.43)	[-0.75, 0.95]	416 (124)	0.08 (0.44)	[-0.79, 0.95]	416 (124)
Income (incl. consumption) from Hass (KSh), ihs	0.21 (0.57)	[-0.90, 1.33]	416 (124)	0.32 (0.61)	[-0.88, 1.51]	416 (124)	0.38 (0.69)	[-0.97, 1.72]	416 (124)
Welfare									
Subjective satisfaction	0.01 (0.06)	[-0.12, 0.14]	416 (124)	0.02 (0.06)	[-0.11, 0.14]	416 (124)	0.02 (0.07)	[-0.11, 0.15]	416 (124)
Subjective stability	0.04 (0.06)	[-0.09, 0.16]	416 (124)	0.02 (0.06)	[-0.10, 0.14]	416 (124)	0.06 (0.06)	[-0.06, 0.18]	416 (124)
Food INsecurity index	1.11 (0.76)	[-0.37, 2.59]	416 (124)	1.03 (0.74)	[-0.43, 2.48]	416 (124)	1.15 (0.75)	[-0.33, 2.62]	416 (124)
Total income (KSh), ihs	0.24 (0.43)	[-0.61, 1.09]	416 (124)	0.23 (0.41)	[-0.57, 1.04]	416 (124)	0.44 (0.56)	[-0.64, 1.53]	416 (124)

Note: Significance levels: 0.1 ($^+$), 0.05 (*), 0.01 (**)

Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. Outcomes with the ihs suffix are transformed using the inverse hyperbolic sine transformation and ATT estimates show semi-elasticities, calculated as $\frac{P}{100} \approx \exp(\hat{\beta}) - 1$ following Bellemare, Wichman 2020 equation 11. Transformed standard errors and CIs are calculated using delta method (multiplying old se with exp(beta)). The treatment is having a contract (to sell any type of avocado), as indicated by belonging to a farmer organization or selling (any type of avocado) under contract. In 2015, farmers in newly created farmer organizations were not treated, because the farmer organizations were formed immediately preceding the survey and the contracts were only effective for the coming harvest period. Households in the treatment group are adopters (no treatment in 2015, treatment in 2017), households in the control group are never-treated (no treatment in 2015 and 2017). 'Doubly-robust, traditional' refers to Sant'Anna, Zhao (2020). The propensity scores are estimated using maximum likelihood and the outcome regression coefficients are estimated using ordinary least squares. Estimation via inverse probability weighting follows Abadie (2005) and using weights normalized to one. Estimation via outcome regression follows Heckman, Ichimura, Todd (1997) assuming a linear (parametric) regression model.

Figure D.15: Alternative estimation methods for second results.



Appendix D.4. Corresponding to third results presented in Section 5.3

Table D.18: Reduced form outcomes for different aspects of contract farming, other estimations (here Doubly-robust, traditional).

Treatment Type	Sell			Certification			Training		
	ATT	95% CI	n	ATT	95% CI	n	ATT	95% CI	n
Production									
Number planted Hass trees	2.25 (1.86)	[-1.40, 5.90]	377 (62)	**3.51 (1.54)***	[0.48, 6.54]	377 (76)	1.55 (1.41)	[-1.22, 4.31]	377 (107)
Total family labor (avo, labor days), ihs	-0.05 (0.22)	[-0.48, 0.38]	377 (62)	0.00 (0.25)	[-0.49, 0.48]	377 (76)	0.01 (0.19)	[-0.37, 0.39]	377 (107)
Total family labor (non-avo, labor days), ihs	-0.07 (0.15)	[-0.38, 0.23]	377 (62)	-0.21 (0.15)	[-0.51, 0.09]	377 (76)	0.05 (0.15)	[-0.25, 0.36]	377 (107)
Cost hired labor (avo, KSh), ihs	0.74 (1.42)	[-2.05, 3.53]	377 (62)	-0.32 (0.44)	[-1.19, 0.55]	377 (76)	-0.45 (0.31)	[-1.06, 0.17]	377 (107)
Cost hired labor (non-avo, KSh), ihs	2.97 (11.35)	[-19.28, 25.21]	377 (62)	0.06 (0.59)	[-1.10, 1.22]	377 (76)	0.16 (0.52)	[-0.86, 1.18]	377 (107)
Knowledge index	0.19 (0.40)	[-0.59, 0.97]	377 (62)	**0.72 (0.40)**$^{+}$	[-0.06, 1.50]	377 (76)	0.40 (0.34)	[-0.26, 1.07]	377 (107)
Marketing: Hass									
Share high quality, Hass	0.12 (0.12)	[-0.12, 0.35]	246 (53)	0.08 (0.13)	[-0.17, 0.33]	246 (58)	0.10 (0.10)	[-0.09, 0.30]	246 (82)
Avg. Hass price (KSh per unit)	**2.46 (0.37)****	[1.73, 3.19]	246 (50)	**1.10 (0.38)****	[0.36, 1.85]	246 (53)	**1.04 (0.32)****	[0.40, 1.67]	246 (78)
Quantity Hass sold (units), ihs	0.18 (0.54)	[-0.88, 1.23]	377 (62)	0.00 (0.49)	[-0.97, 0.97]	377 (76)	0.17 (0.44)	[-0.69, 1.03]	377 (107)
Income (incl. consumption) from Hass (KSh), ihs	1.15 (1.59)	[-1.96, 4.26]	377 (62)	0.00 (0.56)	[-1.11, 1.10]	377 (76)	0.36 (0.61)	[-0.83, 1.55]	377 (107)
Welfare									
Subjective satisfaction	0.06 (0.08)	[-0.10, 0.22]	377 (62)	0.03 (0.08)	[-0.12, 0.18]	377 (76)	0.00 (0.07)	[-0.15, 0.14]	377 (107)
Subjective stability	0.03 (0.06)	[-0.10, 0.15]	377 (62)	0.08 (0.08)	[-0.08, 0.24]	377 (76)	0.07 (0.06)	[-0.05, 0.20]	377 (107)
Food INsecurity index	-0.33 (0.91)	[-2.11, 1.45]	377 (62)	0.51 (0.87)	[-1.19, 2.22]	377 (76)	-0.30 (0.70)	[-1.67, 1.07]	377 (107)
Total income (KSh), ihs	-0.09 (0.33)	[-0.75, 0.56]	377 (62)	0.07 (0.45)	[-0.81, 0.95]	377 (76)	0.31 (0.45)	[-0.58, 1.20]	377 (107)

Note: Significance levels: 0.1 ($^{+}$), 0.05 (*), 0.01 (**)

Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. Across the three contract farming activities, the panel has been balanced to only include households with non-missing treatment status in all three treatment types. Outcomes with the ihs suffix are transformed using the inverse hyperbolic sine transformation and ATT estimates show semi-elasticities, calculated as $\frac{P}{100} \approx \exp(\hat{\beta}) - 1$ following Bellemare, Wichman 2020 equation 11. Transformed standard errors and CIs are calculated using delta method (multiplying old se with exp(beta)). Activity 1: The treatment is selling (any avocado type) to a company as opposed to selling only to brokers. Activity 2: The treatment is having group-level GAP certification (inferred via survey response and farmer organization membership). Activity 3: The treatment is having been trained in the last two years (inferred via survey response). Households in the treatment group are adopters (no treatment in 2015, treatment in 2017), households in the control group are never-treated (no treatment in 2015 and 2017). 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. 'Doubly-robust, traditional' refers to Sant'Anna, Zhao (2020). The propensity scores are estimated using maximum likelihood and the outcome regression coefficients are estimated using ordinary least squares.

Table D.19: Reduced form outcomes for different aspects of contract farming, other estimations (here Inv. prob. weighting).

Treatment Type	Sell			Certification			Training		
	ATT	95% CI	n	ATT	95% CI	n	ATT	95% CI	n
Production									
Number planted Hass trees	2.36 (1.88)	[-1.32, 6.04]	377 (62)	**3.50 (1.55)***	[0.47, 6.53]	377 (76)	1.57 (1.41)	[-1.19, 4.33]	377 (107)
Total family labor (avo, labor days), ihs	-0.06 (0.22)	[-0.49, 0.36]	377 (62)	-0.04 (0.23)	[-0.49, 0.41]	377 (76)	-0.01 (0.19)	[-0.38, 0.36]	377 (107)
Total family labor (non-avo, labor days), ihs	-0.09 (0.15)	[-0.38, 0.20]	377 (62)	-0.22 (0.15)	[-0.51, 0.08]	377 (76)	0.04 (0.15)	[-0.26, 0.34]	377 (107)
Cost hired labor (avo, KSh), ihs	0.76 (1.49)	[-2.16, 3.69]	377 (62)	-0.26 (0.47)	[-1.17, 0.65]	377 (76)	-0.43 (0.32)	[-1.07, 0.20]	377 (107)
Cost hired labor (non-avo, KSh), ihs	3.02 (12.14)	[-20.77, 26.81]	377 (62)	0.08 (0.59)	[-1.08, 1.23]	377 (76)	0.18 (0.53)	[-0.86, 1.23]	377 (107)
Knowledge index	0.20 (0.40)	[-0.59, 1.00]	377 (62)	**0.70 (0.39)**$^{+}$	[-0.07, 1.47]	377 (76)	0.40 (0.34)	[-0.27, 1.06]	377 (107)
Marketing: Hass									
Share high quality, Hass	0.11 (0.12)	[-0.13, 0.35]	246 (53)	0.08 (0.12)	[-0.16, 0.32]	246 (58)	0.10 (0.10)	[-0.09, 0.30]	246 (82)
Avg. Hass price (KSh per unit)	**2.47 (0.37)****	[1.74, 3.20]	246 (50)	**1.08 (0.38)****	[0.34, 1.82]	246 (53)	**1.05 (0.32)****	[0.42, 1.68]	246 (78)
Quantity Hass sold (units), ihs	0.22 (0.55)	[-0.86, 1.30]	377 (62)	0.05 (0.52)	[-0.97, 1.07]	377 (76)	0.19 (0.45)	[-0.69, 1.07]	377 (107)
Income (incl. consumption) from Hass (KSh), ihs	1.23 (1.69)	[-2.08, 4.55]	377 (62)	0.08 (0.60)	[-1.11, 1.27]	377 (76)	0.40 (0.63)	[-0.83, 1.63]	377 (107)
Welfare									
Subjective satisfaction	0.07 (0.08)	[-0.09, 0.23]	377 (62)	0.03 (0.07)	[-0.12, 0.17]	377 (76)	0.00 (0.07)	[-0.15, 0.14]	377 (107)
Subjective stability	0.03 (0.07)	[-0.10, 0.16]	377 (62)	0.07 (0.08)	[-0.09, 0.22]	377 (76)	0.07 (0.06)	[-0.05, 0.19]	377 (107)
Food INsecurity index	-0.35 (0.92)	[-2.15, 1.45]	377 (62)	0.41 (0.85)	[-1.25, 2.07]	377 (76)	-0.36 (0.70)	[-1.72, 1.01]	377 (107)
Total income (KSh), ihs	-0.05 (0.34)	[-0.73, 0.62]	377 (62)	0.01 (0.41)	[-0.79, 0.81]	377 (76)	0.33 (0.45)	[-0.56, 1.22]	377 (107)

Note: Significance levels: 0.1 ($^{+}$), 0.05 (*), 0.01 (**)

Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. Across the three contract farming activities, the panel has been balanced to only include households with non-missing treatment status in all three treatment types. Outcomes with the ihs suffix are transformed using the inverse hyperbolic sine transformation and ATT estimates show semi-elasticities, calculated as $\frac{P}{100} \approx \exp(\hat{\beta}) - 1$ following Bellemare, Wichman 2020 equation 11. Transformed standard errors and CIs are calculated using delta method (multiplying old se with exp(beta)). Activity 1: The treatment is selling (any avocado type) to a company as opposed to selling only to brokers. Activity 2: The treatment is having group-level GAP certification (inferred via survey response and farmer organization membership). Activity 3: The treatment is having been trained in the last two years (inferred via survey response). Households in the treatment group are adopters (no treatment in 2015, treatment in 2017), households in the control group are never-treated (no treatment in 2015 and 2017). 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. Estimation via inverse probability weighting follows Abadie (2005) and using weights normalized to one.

Table D.20: Reduced form outcomes for different aspects of contract farming, other estimations (here Outcome regression).

Treatment Type	Sell			Certification			Training		
	ATT	95% CI	n	ATT	95% CI	n	ATT	95% CI	n
Production									
Number planted Hass trees	1.78 (1.74)	[-1.63, 5.19]	377 (62)	**3.14 (1.68)**$^{+}$	[-0.15, 6.42]	377 (76)	1.49 (1.41)	[-1.28, 4.26]	377 (107)
Total family labor (avo, labor days), ihs	-0.10 (0.21)	[-0.51, 0.31]	377 (62)	-0.06 (0.23)	[-0.51, 0.39]	377 (76)	0.01 (0.19)	[-0.37, 0.39]	377 (107)
Total family labor (non-avo, labor days), ihs	-0.08 (0.15)	[-0.39, 0.22]	377 (62)	**-0.25 (0.14)**$^{+}$	[-0.53, 0.03]	377 (76)	0.06 (0.15)	[-0.25, 0.36]	377 (107)
Cost hired labor (avo, KSh), ihs	0.64 (1.27)	[-1.86, 3.13]	377 (62)	-0.16 (0.52)	[-1.17, 0.86]	377 (76)	-0.43 (0.32)	[-1.06, 0.19]	377 (107)
Cost hired labor (non-avo, KSh), ihs	2.63 (7.89)	[-12.85, 18.10]	377 (62)	0.21 (0.68)	[-1.12, 1.54]	377 (76)	0.17 (0.51)	[-0.84, 1.17]	377 (107)
Knowledge index	0.22 (0.39)	[-0.54, 0.98]	377 (62)	**0.85 (0.41)***	[0.03, 1.66]	377 (76)	0.38 (0.34)	[-0.29, 1.05]	377 (107)
Marketing: Hass									
Share high quality, Hass	0.11 (0.12)	[-0.12, 0.35]	246 (53)	0.11 (0.12)	[-0.13, 0.34]	246 (58)	0.11 (0.10)	[-0.08, 0.31]	246 (82)
Avg. Hass price (KSh per unit)	**2.46 (0.38)****	[1.72, 3.20]	246 (50)	**1.06 (0.39)****	[0.30, 1.82]	246 (53)	**1.06 (0.33)****	[0.41, 1.71]	246 (78)
Quantity Hass sold (units), ihs	0.40 (0.66)	[-0.90, 1.70]	377 (62)	-0.01 (0.49)	[-0.98, 0.95]	377 (76)	0.20 (0.45)	[-0.69, 1.09]	377 (107)
Income (incl. consumption) from Hass (KSh), ihs	1.65 (2.60)	[-3.44, 6.75]	377 (62)	0.03 (0.58)	[-1.11, 1.17]	377 (76)	0.43 (0.66)	[-0.86, 1.72]	377 (107)
Welfare									
Subjective satisfaction	0.06 (0.08)	[-0.10, 0.22]	377 (62)	0.02 (0.08)	[-0.13, 0.17]	377 (76)	0.01 (0.07)	[-0.13, 0.15]	377 (107)
Subjective stability	0.04 (0.07)	[-0.09, 0.17]	377 (62)	0.11 (0.07)	[-0.03, 0.26]	377 (76)	0.09 (0.06)	[-0.03, 0.21]	377 (107)
Food INsecurity index	-0.12 (0.86)	[-1.80, 1.56]	377 (62)	0.73 (0.83)	[-0.90, 2.35]	377 (76)	-0.35 (0.71)	[-1.75, 1.05]	377 (107)
Total income (KSh), ihs	-0.07 (0.35)	[-0.75, 0.61]	377 (62)	0.31 (0.58)	[-0.83, 1.44]	377 (76)	0.40 (0.51)	[-0.60, 1.40]	377 (107)

Note: Significance levels: 0.1 ($^{+}$), 0.05 (*), 0.01 (**)

Numbers of treated observations in parentheses. Outcomes have a varying number of observations because households with missing responses in baseline or endline are dropped. Across the three contract farming activities, the panel has been balanced to only include households with non-missing treatment status in all three treatment types. Outcomes with the ihs suffix are transformed using the inverse hyperbolic sine transformation and ATT estimates show semi-elasticities, calculated as $\frac{P}{100} \approx \exp(\hat{\beta}) - 1$ following Bellemare, Wichman 2020 equation 11. Transformed standard errors and CIs are calculated using delta method (multiplying old se with exp(beta)). Activity 1: The treatment is selling (any avocado type) to a company as opposed to selling only to brokers. Activity 2: The treatment is having group-level GAP certification (inferred via survey response and farmer organization membership). Activity 3: The treatment is having been trained in the last two years (inferred via survey response). Households in the treatment group are adopters (no treatment in 2015, treatment in 2017), households in the control group are never-treated (no treatment in 2015 and 2017). 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. Estimation via outcome regression follows Heckman, Ichimura, Todd (1997) assuming a linear (parametric) regression model.

Appendix E. Cross-Sectional Appendix

Appendix E.1. Comparing DiD results with cross-sectional results but same treatment definition and same households

Table E.21: The impacts of contracting, comparing doubly-robust difference-in-differences with cross-sectional endline-only ATT estimates.

Comparison	Adopters vs. never-treated (doubly-robust DiD)			Adopters vs. never-treated (endline only)		
	ATT	95% CI	n	ATT	95% CI	n
Activity: Selling						
Fraction avocado sold to company	**0.41 (0.04)****	[0.32, 0.49]	395 (119)	**0.41 (0.04)****	[0.32, 0.49]	395 (119)
Fraction Hass sold to company	**0.49 (0.06)****	[0.38, 0.60]	259 (95)	**0.50 (0.05)****	[0.39, 0.60]	259 (95)
Fraction Fuerte sold to company	**0.25 (0.05)****	[0.16, 0.35]	273 (86)	**0.26 (0.05)****	[0.16, 0.37]	273 (86)
Sold (any avo) to company	**0.51 (0.05)****	[0.41, 0.61]	395 (119)	**0.51 (0.05)****	[0.42, 0.60]	395 (119)
Sold Hass avocado to company	**0.51 (0.06)****	[0.40, 0.63]	259 (95)	**0.52 (0.05)****	[0.42, 0.62]	259 (95)
Sold Fuerte avocado to company	**0.27 (0.05)****	[0.16, 0.37]	273 (86)	**0.27 (0.05)****	[0.17, 0.38]	273 (86)
Fraction Hass of total sales	0.05 (0.04)	[-0.03, 0.13]	395 (119)	0.04 (0.04)	[-0.03, 0.11]	395 (119)
Fraction Fuerte of total sales	-0.03 (0.03)	[-0.09, 0.04]	395 (119)	0.00 (0.03)	[-0.07, 0.07]	395 (119)
Activities: GAP and Training						
Received GAP certification	**0.73 (0.04)****	[0.65, 0.80]	416 (124)	**0.72 (0.04)****	[0.65, 0.80]	416 (124)
Received training	**0.50 (0.06)****	[0.37, 0.62]	416 (124)	**0.56 (0.05)****	[0.46, 0.65]	416 (124)

Note: Significance levels: 0.1 ($^+$), 0.05 (*), 0.01 (**)

Table E.22: Outcomes for contracting, comparing doubly-robust difference-in-differences with cross-sectional endline-only ATT estimates.

Comparison	Adopters vs. never-treated (doubly-robust DiD)			Adopters vs. never-treated (endline only)		
	ATT	95% CI	n	ATT	95% CI	n
Production						
Number planted Hass trees	4.27 (3.59)	[-2.76, 11.29]	416 (124)	4.52 (3.78)	[-2.91, 11.96]	416 (124)
Total family labor (avo, labor days), ihs	-0.12 (0.17)	[-0.45, 0.20]	415 (123)	-0.04 (0.12)	[-0.28, 0.20]	415 (123)
Total family labor (non-avo, labor days), ihs	0.05 (0.16)	[-0.27, 0.37]	415 (123)	0.13 (0.13)	[-0.13, 0.38]	415 (123)
Cost hired labor (avo, KSh), ihs	0.03 (0.56)	[-1.07, 1.14]	416 (124)	0.09 (0.39)	[-0.66, 0.85]	416 (124)
Cost hired labor (non-avo, KSh), ihs	0.28 (0.62)	[-0.94, 1.50]	416 (124)	1.31 (1.28)	[-1.21, 3.83]	416 (124)
Knowledge index	**0.70 (0.33)***	[0.05, 1.34]	416 (124)	**0.61 (0.23)****	[0.17, 1.06]	416 (124)
Marketing: Hass						
Share high quality, Hass	0.12 (0.10)	[-0.08, 0.33]	259 (95)	0.03 (0.07)	[-0.10, 0.17]	259 (95)
Avg. Hass price (KSh per unit)	**1.25 (0.32)****	[0.63, 1.88]	258 (91)	**1.59 (0.27)****	[1.07, 2.12]	258 (91)
Quantity Hass sold (units), ihs	0.02 (0.40)	[-0.77, 0.80]	416 (124)	0.33 (0.39)	[-0.44, 1.10]	416 (124)
Income (incl. consumption) from Hass (KSh), ihs	0.21 (0.56)	[-0.88, 1.31]	416 (124)	0.76 (0.72)	[-0.64, 2.16]	416 (124)
Welfare						
Subjective satisfaction	0.01 (0.06)	[-0.11, 0.14]	416 (124)	0.05 (0.04)	[-0.03, 0.14]	416 (124)
Subjective stability	0.03 (0.06)	[-0.09, 0.15]	416 (124)	**0.09 (0.04)***	[0.01, 0.17]	416 (124)
Food INsecurity index	1.17 (0.76)	[-0.32, 2.66]	416 (124)	**1.01 (0.56)**$^{+}$	[-0.10, 2.12]	416 (124)
Total income (KSh), ihs	0.27 (0.44)	[-0.60, 1.14]	416 (124)	1.65 (1.80)	[-1.87, 5.17]	416 (124)

Note: Significance levels: 0.1 ($^{+}$), 0.05 (*), 0.01 (**)