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DOI
10.1016/j.landusepol.2019.104168

Publication date
2019

Document Version
Final published version

Published in
Land Use Policy

Land Use Policy 88 (2019) 104168

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

The impact of smallholder farmers' participation in avocado export markets on the labor market, farm yields, sales prices, and incomes in Kenya

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ARTICLE INFO

Keywords:
Avocado
Export markets
Labor Market
Farm yield
Income
Impact
Kenya

ABSTRACT

Smallholder producers in sub-Saharan Africa are often unable integrate into markets and access high-value opportunities by effectively participating in global chains for high-value fresh produce. Using data from a survey of large avocado farmers in Kenya, this study examines the determinants and impacts of smallholder-producer participation in avocado export markets on labor inputs, farm yields, sales prices, and incomes, using a switching regression framework to control for selection effects. We found that farmers who participate in export markets differ significantly from nonparticipating farmers: They are older, have somewhat larger farms, have received more training, and own more avocado trees of the Hass variety, the type favored in export markets. Living near a well-functioning avocado farmers' group is also positively associated with participation in export markets. Participation in avocado export markets will have positive impacts on incomes, revenues, prices, and labor inputs. However, there is an offsetting effect in terms of higher prices and lower volumes, reflecting the stricter quality requirements of export markets. Applying a decomposition analysis, we found that not only differences in endowment sizes, but also differences in returns from endowments in export versus domestic markets, are key to understanding differences in yields, revenues, sales prices, and labor inputs. This suggests that policymakers should not only focus on resource accumulation for farmers, but also pay attention to the inclusiveness of export market participation for smallholder farmers.

1. Introduction

International agricultural markets generally offer higher prices and demand higher quality in comparison with local markets in developing countries. Producing for these markets could raise smallholder farmers' incomes (Yee et al., 1993; Warning and Key, 2002; Minten et al., 2009). But accessing export markets can be hard for smallholders, who need to be linked up with exporting firms, which, in turn, must be able to rely on farmers to supply produce that meets export-market quality standards. Poor infrastructure or insufficient capital can limit the smallholders' ability to meet high production standards and, therefore, to work with export firms (Key and Runsten, 1999). Fresh produce from smallholder farmers in developing countries is often procured through contract farming with farmer groups (Okello and Swinton, 2007) because it reduces monitoring and compliance costs, as farmers' groups can utilize existing social networks that are inaccessible to contracting firms (Barrett et al., 2012; Jack and Cardona-Santos, 2017). As a consequence, farmers need access to a well-functioning farmers' group to access export markets.

Gains from participation in export markets are not a given. If exporting firms have monopoly power over small farmers, the gains for the latter can be minimal (Maertens and Swinnen, 2007; Subervie and Vagneron, 2013). Contract farming can also cause increased concentration of land ownership, social differentiation, and dominance in decision-making by companies over small-scale farmers (Maertens and Swinnen, 2007; Subervie and Vagneron, 2013) because companies prefer to work with larger-scale and more advanced farmers (Barrett et al., 2012; Schuster and Maertens, 2013)

The high costs associated with participation in export markets also limit profitability. Modern agri-food systems exert a strong competitive pressure on all value chain participants, as firms impose stricter requirements for suppliers in terms of quality, timing, handling, and other delivery arrangements (Graffham et al., 2009). This means that smallholder farmers may need to make higher financial and time investments

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https://doi.org/10.1016/j.landusepol.2019.104168
Received 4 June 2018; Received in revised form 11 August 2019; Accepted 14 August 2019
Available online 27 August 2019

to meet stringent standards, thus reducing the benefits of participation (Maertens and Swinnen, 2009). Higher farm-gate prices for exports do not, therefore, necessarily translate into higher profitability or incomes. Although several studies have analyzed the constraints to, and benefits from, participation in agricultural value chains (Schuster and Maertens, 2013; Minot and Ngigi, 2004), there is little empirical evidence regarding the impacts on labor markets, farm yields, sales prices, or incomes of smallholder participation in high-value markets such as avocado exports to the European Union (EU).

This study contributes to the existing literature on export market participation and its impacts by examining the determinants of smallholder farmer participation in export markets and the effects of that participation on sales prices, productivity, labor inputs, and incomes. Specifically, this paper has three objectives: First, it examines the determinants of export market participation by smallholder farmers. We contribute to the literature by considering not only farm household characteristics, but also the availability of well-functioning farmers' groups in Kenya (which we found to be important).[1] This analysis contributes to an enhanced understanding of the policy interventions that can enable or facilitate the participation of small-scale producers in export markets for fresh produce.

Second, this study assesses the impacts on the labor market, farm yields, sales prices, and incomes of the participation of smallholder farmers in export markets. We use hired labor and family labor time inputs as proxies for labor market outcome variables. And we selected a wider range of outcome variables to analyze the impacts of export market participation, compared with most previous studies.

Third, we conduct a decomposition analysis to identify two sources of the observed differences in labor inputs, farm yields, sales prices, and incomes between farmers who participate in export markets and farmers who do not: differences in the sizes of endowments, and differences in the returns to endowments in export versus domestic markets. Through this analysis, we went beyond statistical significance by gauging the extent to which export market participation can explain the observed differences in farmer outcomes.

Kenya is particularly suitable for addressing these issues empirically, as the country is the world's third largest exporter of avocados to Europe, with a 5–6 percent share of total volume in 2010 (Food and Agriculture Organization of the United Nations (FAO), 2017). Furthermore, avocados are one of the pillars of the Kenyan horticultural sector, accounting for 17 percent of total horticultural exports and more than 50 percent of the export value of the fruit subsector. Also, the significant growth seen in the production, volume, and value of avocado exports since the early 2000s may have had implications for smallholder farmers. Nevertheless, previous studies have focused on other countries and/or crops.

We found that farmers who participate in export markets are generally older, have somewhat larger farms, have received more training, and grow more avocado trees of the Hass variety, the favored type in the EU market. Living near a well-functioning avocado farmers' group is also strongly associated with participation in export markets. And we found that participation in export market results in increased labor inputs in terms of both hired and family labor. The cost of hired labor increases by around KSh1, 300 (Kenyan shillings) per year, which is about $13.[2] Family labor inputs per year increase by about 15 days, of which the largest share comes from increases in female labor. Avocado prices increase as well, but the harvested yields are lower, probably due to the more stringent requirements of export firms. The net effect on avocado incomes seems to be positive, on the order of 39 percent, but the estimated effect lacks statistical significance. We found that both the differences in endowment sizes and the differences in returns to endowments in export versus domestic markets are key to understanding the differences in yields, revenues, sales prices, and labor inputs. This suggests that, within the Kenyan context, the effects of export market participation are not only statistically significant (as shown in the econometric analyses), but also economically significant (as shown in the decomposition analysis). Policymakers should thus not only focus on improving farmers' resources, but also on improving their access to export markets.

The rest of this article is structured as follows: Section 2 presents a review of the avocado sector in Kenya, Section 3 discusses the methodological framework of this study, Section 4 presents the data and provides a descriptive analysis, Section 5 discusses the empirical results, and Section 6 offers conclusions and discusses the policy implications based on key findings.

2. Kenya's production and exportation of avocados

Avocados are grown in several agroecological zones in Kenya, mainly by small-scale farmers, who grow them for subsistence and/or to sell in local and export markets. Local varieties dominate Kenyan avocado production, constituting about 70 percent of total production, whereas Fuerte and Hass, improved avocado varieties that are suitable for export markets, comprise approximately 20 percent and 10 percent, respectively (Horticultural Crops Directorate (HCD), 2015). The Hass variety is characterized by a dark green-and-brown skin that is not thick at maturity and is easy to remove from the pulp. It has a small seed with nonfibrous pulp, and is often referred to as a "brown skin." It is vigorous and highly productive, with an oil content of 20 percent. The Fuerte variety is characterized by a smooth, green skin of medium thickness. It has a large seed and a buttery pulp, and is referred to as a "green skin." It has an oil content of 16–18 percent (Saenger et al., 2013). The Hass variety yields a better price than the Fuerte, and this is attributed to the Hass variety's higher resistance to pests and diseases, higher oil content, and ability to conceal bruises. It is also the dominant variety in the large EU export market. For this reason, farmers are increasingly shifting their production away from the Fuerte and toward the Hass variety.

Despite fluctuations in the number of hectares (ha) planted with avocados and in avocado production in recent years, significant growth has occurred in both (Fig. 1). The total area under avocado cultivation in Kenya is about 11,000 ha. The area under avocado cultivation and the volume of avocado production increased during 2005–2014 by 41 percent and 118 percent, respectively (Food and Agriculture Organization of the United Nations (FAO), 2017).[3]

In recent years, avocados have emerged as the leading fruit traded in the Kenyan export market, where it accounts for more than 17 percent of horticultural exports (Horticultural Crops Directorate (HCD), 2015). Kenya is the third largest producer of avocados in the world (behind Mexico and Peru), with production reaching slightly more than 200,000 tons in 2014 (Fig A1). This standing clearly reflects the growing potential and importance of the avocado crop as a contributor to various facets of economic development, such as increased rural household incomes, employment generation, and export diversification.

However, the share of Kenya's total avocado production that is exported is the lowest among the major avocado exporters. Only about 10 percent of its total production is exported, while South Africa exports about 60 percent of its avocado production; and Chile, 55 percent. Moreover, the share of Kenya's total avocado production that is destined for export has been declining (Fig. A2). The difficulty of increasing the export share is often attributed to poor quality; high regulatory standards in export markets; the weak institutional capacity of small-scale producers; and inadequate capacity for, and coordination

[1] Because exporters do not offer contracts to smallholders, the latter can only access avocado export markets as members of a farmers' group.

[2] "$" refers to US dollars in this study.

[3] The fluctuations in avocado yields are attributed to weather shocks, insect pests (such as the fruit fly), and diseases due to fungi or similar organisms (such as anthracnose and Phytophthora-related diseases).

Fig. 1. Trends in avocado land area harvested, production, and yields (ha = hectares).
Sources: Food and Agriculture Organization of the United Nations (FAO), 2017; Horticultural Crops Directorate (HCD), 2015.

of, fruit exportation. The poor quality of Kenyan avocados is mainly due to the inadequate knowledge of modern production practices on the part of small-scale producers, who have traditionally grown their trees for domestic markets or for noncommercial purposes, and to the limited dissemination of market-preferred varieties. Given the weak organization of avocado markets, most smallholder growers market their produce through middlemen, who may be legally certified agents or unofficial brokers. Realizing the underexploited export opportunities offered by the country's sizeable production, the Kenyan government has been supporting smallholder farmers by linking them to exporters through grower schemes. Currently, only a few small-scale producers are linked to exporters, through contract farming; and these producers are mainly found in Murang'a County, in central Kenya.[4]

3. Data and descriptive statistics

3.1. Data

The data used for this study were collected by the Partnership for Economic Policy (PEP), 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 survey was carried out from November to December 2015 and covered 790 avocado-farming households.[5] A multistage sampling procedure was used to select the county, subcounty, villages, and households to be included in the survey. In the first stage, we selected Murang'a County, in Kenya's Central Province, out of the country's 47 counties, as it is one of Kenya's main avocado-producing counties. The county government is actively promoting avocado production, with such measures as the provision of Hass seedlings to farmers who are organized into groups. In addition, the county experienced a substantial expansion in its avocado production between 2005 and 2015, in terms of both volume and exports (Food and Agriculture Organization of the United Nations (FAO), 2017), so it was seen as a potentially interesting case study for an analysis of the implications of government policies for rural development. The second stage involved the selection of Kandara subcounty from among the seven subcounties in Murang'a County. This subcounty was chosen because it is one of the main avocado-producing subcounties in Murang'a. The third stage involved the identification of two main household groups based on the extent of their participation in avocado-marketing contracts.

The first group comprised farm households involved in modern avocado marketing through contract arrangements (via 14 farmers' groups) with one particular, well-established exporting company in Kenya. These groups are hereafter referred to as "export market participating farmers." A list of the farmers in each group was provided by the chair of that group, and all the households on that list were interviewed. The second group consisted of farmers who were involved in traditional avocado marketing arrangements, selling their avocados to middlemen or brokers; this group is hereafter referred to as "export market nonparticipating farmers." For the second group, we identified 7 sublocations (out of 27) that were not linked to any export company. This was followed by a selection of 27 villages that produced similar crops and were in similar geographic locations as the farmers who were linked to exporters. These villages were also similar in terms of several important contextual factors (e.g., size, socioeconomic and agroclimatic conditions, and road and market access). Finally, we randomly selected farmers from each village who were not organized into farmers' groups.

The questionnaire we used covered all the economic activities of households, with a detailed breakdown of avocado production and marketing over the prior 12 months. There are two avocado seasons in the study area, with a long season, running from mid-June to August, and a short season, running from October to December. As we collected the information on avocado activities over the prior 12 months, any intra-year seasonality was taken into account. We also captured the households' demographic composition and various income sources, as well as a variety of contextual household characteristics. The marketed yield was based on farmer reports of the total pieces (i.e., total number) of avocados harvested over the prior year by type, and whether the yield was sold, rejected, or consumed by the household. Only the sold yield was included in the marketed yield. A household's revenue was calculated by multiplying the sold yield by the average price the farmer reported receiving per piece. Income was calculated by subtracting the yearly cost of avocado production from the revenue. The cost estimate was based on reported costs for pesticides/herbicides, fertilizers, seedlings, manure, hired labor, transportation costs, and avocado group membership fees (paid for export market participation).

3.2. Descriptive statistics

Table 1 presents some statistics regarding demographic characteristics and wealth indicators based on the household survey results for the two main sample groups: the export market participating and nonparticipating farmers. The data revealed several differences between the two groups. Household wealth indicators were grouped into different household asset categories: livestock, agricultural assets, nonagricultural assets, and the amount of owned land. Export market participating farmers were richer in terms of assets, livestock, and landholdings. They had more avocado trees, particularly Hass trees, and were more frequently observed/reported to have had some/any training in avocado cultivation. Fuerte yields were lower for the export market participating farmers, while Hass yields were lower for the export market nonparticipating farmers. This pattern probably reflects a selection effect, as farmers with relatively more Hass production have a comparative advantage in export markets vis-à-vis domestic markets.

Farmers participating in export markets earned about 130 percent (exp (0.84)-1 = 1.32) more from avocado farming than did nonparticipating farmers. This is both because the marketed yields were higher (75 percent; exp(0.56)-1 = 0.75) and the prices fetched for

[4] The five major exporters of avocados include Kakuzi, Vegpro, Sunripe, Kenya Horticultural Exporters (KHE), and East African Growers (EAG). Ideal Matunda and Keitt are among the notable upcoming exporters. These exporters obtain avocados in three ways: by placing orders with brokers who supply avocados to their warehouses; by organizing transports to pick up the produce directly from farmers' groups in major growing areas; or by obtaining them from contract farmers, who deliver their avocados directly to them.

[5] We had also noted that 2015 was a normal year in terms of weather and disease-related circumstances.

Table 1
Descriptive statistics, traditional and modern avocado sectors.

	Export market nonparticipating	Export market participating	Difference	Value (diff = 0)
Log income avocado (KSh)	8.77	9.61	0.84	0.000***
Log revenue avocado (KSh)	8.86	9.95	1.09	0.000***
Log total marketed yield avocado (pcs.)	7.96	8.52	0.56	0.000***
Log price avocado (KSh/piece)	1.15	1.58	0.43	0.000***
Share avocado income from Hass	0.47	0.73	0.27	0.000***
Log revenue Hass (KSh)	6.29	9.27	2.98	0.000***
Log revenue Fuerte/local (KSh)	7.22	6.73	−0.49	0.058
Log marketed yield Hass (pcs.)	5.46	7.68	2.22	0.000***
Log marketed yield Fuerte/local (pcs.)	6.61	6.01	−0.60	0.008**
Log price Hass (KSh/piece)	1.31	1.75	0.44	0.000***
Log price Fuerte/local (KSh/piece)	1.00	1.12	0.12	0.004**
Total hired labor cost avocado (KSh person days)	362.2	2688.8	2326.6	0.000***
Family labor (person days)	5.74	7.96	2.22	0.010*
Male family labor (person days)	2.77	4.02	1.25	0.005**
Female family labor (person days)	2.72	3.45	0.73	0.134
Youth family labor (person days)	0.26	0.49	0.23	0.059
Explanatory variables				
Household size (no.)	3.57	3.68	0.11	0.393
HH head (dummy, 1 = male)	0.77	0.83	0.06	0.083
Age of HH head (years)	63.2	64.3	1.12	0.234
Education of HH head (years)	8.19	8.42	0.23	0.425
Log non-agricultural assets	8.24	8.64	0.40	0.003**
Log agricultural assets (KSh)	8.88	9.08	0.20	0.034*
Log land size (acres)	0.98	1.09	0.11	0.001**
Log # Hass trees	1.28	2.27	0.99	0.000***
Log # Fuerte/local trees	1.55	1.57	0.02	0.768
Avocado training 2014/15	0.37	0.77	0.40	0.000***
Instrumental variables				
Log livestock (TLU) end 2014	0.75	0.86	0.11	0.001**
Log non-avocado income (excl. livestock)	10.8	11.0	0.29	0.167
Median distance to nearest market (km)	2.80	2.56	−0.24	0.005**
Average satisfaction with group (scale 1-4)	3.87	3.90	0.03	0.009**
No. of observations	521	263		

Notes: KSh = Kenyan shillings; 100 KSh are equivalent to 1 US dollar. HH = household, km = kilometers, log = logarithm, no. = number, pcs = pieces, TLU = tropical livestock units. * = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$.

avocados were higher (54 percent; exp(0.43)-1 = 0.54). The farmers participating in export markets derived a greater share of income from their sales of Hass avocados than did nonparticipants (73 percent versus 47 percent), reflecting higher yields as well as higher prices. For the Fuerte/local varieties, export market participating farmers tended to have lower revenues, reflecting the much lower yields, albeit with slightly higher prices.[6] Farmers participating in export markets also had a higher cost of hired labor. Export market participating farmers spent about KSh2,300 during the year on hired labor for avocado trees, which amounted to about $23.

4. Conceptual framework and empirical strategies

Integration into global value chains through contract farming is expected to bring multiple benefits to producers: a boost in productivity through specialization in market niches offering comparative advantage and economies of scale; a transfer of modern technologies; and an improvement in the producers' quality standards, further enhancing their access to global markets. However, neither participation in globalized value chains nor the realization of the benefits is guaranteed. Their achievement may depend on several factors, including labor productivity, affordable finance, technological readiness and innovation, a conducive macroeconomic environment, and local institutions involved in production and marketing. This study addresses these issues in multiple dimensions. First, it addresses the determinants of the smallholder avocado farmers' participation in export markets through contract farming. Second, it investigates the impacts of export market participation on the labor market, farm yields, sales prices, and incomes. We measured avocado farm yields and incomes using the marketed yields, revenues, and net incomes generated by the Hass and Fuerte/local varieties. As we were interested in the effects of avocado production on the labor market, we also included hired labor and family labor time inputs as outcome variables. Net income was calculated by subtracting all the recorded costs of avocado production (i.e., the costs of pesticides/herbicides, fertilizer, seedlings, manure, hired labor, transportation costs, and avocado farmers' group membership fees).

4.1. The decision to participate or not in export markets

This paper conceptualizes farmers' decisions about whether to participate in the export market as a technology adoption problem (this approach is adapted from Fuglie and Bosch, 1995). There are two available approaches: selling in the domestic market (through brokers) or selling in the export market (through contract farming). The profit (and utility) of selling in each market depends on the available input and output prices, and on the transaction costs in each market.

Previous studies have revealed that export market participation through agricultural contract farming can benefit productivity (and hence, profits) directly by eliminating entry barriers to input and output markets and by mitigating the transaction costs associated with poor access to market information and transport (e.g., Holloway et al., 2000; Deng et al., 2010). But selling under contract also involves additional transaction costs, such as the costs of harvesting and transport, as well

[6] One possible concern in any comparison between participants and nonparticipants is that the home consumption and rejection rates differ. We did find that the difference between these shares is statistically significant (p-value 0.02), but still rather small at 0.02. Also, the difference in rejection rates (expressed as a share of total yield) is very small: 0.01 (0.03 for the participants and 0.04 for the nonparticipants). We therefore ignored these differences in the further analysis.

as liquidity costs.[7] It also includes farmers' organization transaction costs, such as membership fees and the opportunity costs of time when attending meetings.[8] Risk profiles for selling in each market are also likely to be different. Unlike broker prices, contract prices are fixed; and companies may reject (and not pay for) harvested avocados because of quality problems, while brokers will purchase all the avocados that are harvested.

Let Z indicate a set of exogenous variables that capture the relative performance (utility) of both technologies (selling under contract and selling to brokers), including transaction cost differences. Variables in Z include all the observable factors that influence avocado incomes (such as farm size, ownership of avocado trees, and human capital endowments), as well as indicators of barriers to entry (such as access to the nearest market, inputs, and capital markets) such as non-avocado income (Reardon et al., 2009; Barrett et al., 2012; Holloway et al., 2000; Deng et al., 2010). We did not observe the relative performance of each technology, but what was observable was the choice regarding participation in export markets (i.e., a dummy variable S), which equals one if the utility of export market participation exceeds the utility of selling to brokers, and zero otherwise. Therefore, we model the unobserved preference for participation in export markets for farmer i as:

$$S_i^* = Z_i\gamma + \varepsilon_i \quad (1)$$

where S_i^* is a latent variable, γ is a vector of parameters, and ε_i is an error term with the mean as zero and variance σ^2. A farmer will participate in export markets if $S = 1$ and $S_i^* > 0$; and he/she will sell to the domestic market if $S_i^* \leq 0$ $(S = 0)$.

The choice of export market participation affects various farming outcomes, including labor inputs, prices, productivity, and incomes. We specify an outcome equation using a linear function of a vector of farm and household characteristics:

$$Y_i = X_i^{'}\alpha_s + \mu_i,\ s = 0{,}1 \quad (2)$$

where Y_i represents a vector of outcome variables such as avocado income for farmer i, and X_i is a vector of farm and household characteristics (e.g., the farmer's age, education, wealth indicators such as landholding, agricultural assets and nonagricultural assets, and access to information and markets). Returns to the farm and household characteristics, α, are allowed to vary by sector s, with $s = 1$ if the farmer participates in the export market sector $(S = 1)$ and $s = 0$ if the farmer does not $(S = 0)$; μ_i is a random error term.

4.2. Empirical approach

4.2.1. Identification strategies

Estimating the impacts of smallholder farmer participation in export markets on labor market outcomes, farm yields, sales prices, and incomes is not a trivial exercise, as unobservable factors could arise from various sources. [9] In some cases, a household's participation is determined by self-selection. In other cases, households are systematically selected by contracting firms. And, in still others, these selection methods are combined. Exporters may contract some farmers because doing so serves the exporting firm's interests and objectives. In other words, the treatment of comparison groups may differ systematically, and these differences may manifest themselves in variations in labor market outcomes, farm yields, sales prices, and incomes that could be mistakenly attributed to participation. Potential selection bias arises whenever these unobserved factors (μ in the outcome equation, Eq. 2) are correlated with ε in the selection equation, Eq. 1. This implies that the correlation coefficient of the error terms $\rho = corr(\varepsilon, \mu) \neq 0$. Hence, estimating the outcome equation by ordinary least squares (OLS) tends to yield biased estimates. In a randomized control trial setting, this problem of selection bias is addressed by randomly assigning individuals to the treatment groups (export market participating farmers) and control groups (nonparticipating farmers), so that the only differentiating factor between export market participating and nonparticipating farmers is the presence or absence of export market participation.

However, in a nonrandomized experimental situation like export market participation, selection bias may occur. As in previous studies (e.g., Nkala et al., 2011; Amare et al., 2012; Kassie et al., 2015; Abdulai, 2016), this paper employs endogenous switching regression (ESR) estimates to account for selection bias due to both observable and unobservable factors. In the ESR model framework, there are two stages, which are estimated simultaneously according to the maximum likelihood, assuming normally distributed error terms and correlation between the two error terms. The first stage involves estimating the selection Eq. (1) to determine the factors influencing export market participation through contract farming. In the second stage, the impacts of export market participation on the outcome variables is specified for two regimes estimated by Eq. 2.

For identification purposes, there should be at least one variable in the selection Eq. (1) that is not included in the outcome Eq. (2). In this study, the distance to the nearest market, an assessment of the quality of the avocado farmers' group, non-avocado income (from crops, fruit trees, and other sources of income), and animal assets are used as instruments. (e.g., Kassie et al., 2013; Jaleta et al., 2016).

In order to have valid instruments, we needed to consider their relevance and the exclusion restrictions. The distance to the nearest market plausibly affects market participation, including the avocado market, as longer distances increase the cost of bringing products to the market. The quality of available avocado farmers' groups may also affect the choice to participate in export markets, as farmers are more likely to join well-performing groups. Non-avocado income and animal assets affect the marginal value of income, and so will affect the decision to participate in export markets or in the local avocado market. Hence, each of these four variables likely satisfies the relevance condition.

In terms of exclusion restrictions, the distance to markets can be excluded from the outcome equation, given that we controled for transportation costs in the outcome model whenever possible (specifically, income was calculated *net* of transportation costs).[10] The quality of avocado farmers' groups is constructed as an index of farmers' perceptions regarding the groups. Specifically, member farmers have been asked (i) whether they believe the group will still be in existence in five years; (ii) whether (s)he feels represented by the executives of the group; (iii) whether (s)he feels that (s)he has any influence on the appointment of officials in the group; and (iv) whether (s)he thinks that if an official does not perform well, that official will be replaced. For each avocado farmers' group mentioned in the survey, we calculated the average score of these four dummy variables. It is important to note that we used the score of the most reported group in the sublocation as the explanatory variable, to create an exogenous measure of group quality for each farmer.[11] Finally, the last two instrumental variables were non-avocado income and animal assets. The non-avocado income variable was based on income derived from crops, fruit trees (excluding

[7] Brokers go to the farms to harvest produce and pay for it on the spot. In most cases, contract farmers need to harvest the produce themselves and transport it to collection sheds or company premises, and payment typically arrives after a delay of one to two weeks.

[8] Not all of these costs need to be negative, as farmers can also benefit from farmers' organizations in terms of improved access to information, better access to inputs, and increased social capital.

[9] Unobserved factors could include information about inputs, managerial skills, abilities, and additional characteristics of soil quality.

[10] Also, location dummies are included in the regressions to control for geographical differences.

[11] Each subcounty in Kenya is subdivided into locations, which are further subdivided into sublocations.

avocados), and other income, but excluding livestock income, as animal assets were measured in terms of the tropical livestock unit (TLU) equivalents. These variables can arguably be excluded from the outcome model, as they primarily affect the marginal utility of avocado income (taste shifters) without affecting avocado production directly.

Although we think that our instruments are plausibly exogenous, we acknowledge that identifying a true instrumental variable remains a challenge in many empirical analyses. Therefore, we verify that our findings are robust with regard to any alternative choice of instruments, and with regard to a falsification testing (see section 5.2).

The ESR model can also be used to examine the impacts of participation on labor market outcomes, farm yields, sales prices, and incomes.[12] This is done by comparing the expected labor market outcomes, farm yields, sales prices, and incomes of participating farmers with the expected outcomes of hypothetical cases in which the participating farmers did not participate. The expected values of the outcome Y conditional on participation and nonparticipation can be expressed as:

$$ATT = E(Y_{i1} \mid S = 1) - E(Y_{i0} \mid S = 1) = X_i^{'}\alpha_1 - X_i^{'}\alpha_0 \quad (3)$$

Note that term $E(\mu_i S = 1)$ cancels out of the equation because it is equal across the two expectations. The average treatment effect for the treated and nontreated groups differ because the expectation is calculated on the basis of a different subpopulation.

4.2.2. Labor market, yield, sales price, and income decomposition

After identifying the impacts of participation in the export market, we employed the Blinder-Oaxaca decomposition analysis (Blinder, 1973; Oaxaca, 1973) to analyze the observed differences in labor inputs, farm yields, sales prices, and incomes between farmers who participate and farmers who do not participate in export markets. The expected differences in the outcome variables are decomposed into (1) an effect that can be explained by differences in endowments (farm and household characteristics) and (2) a part that can be explained by differences in returns to the endowments in the two sectors.[13] The expected differences between the outcomes for participants in export markets and for nonparticipants can be written as:

$$\mathrm{E}(Y|S = 1) - \mathrm{E}(Y|S = 0) = E(X_{s=1})^{'}\alpha_1 - E(X_{s=0})^{'}\alpha_0 \quad (4)$$

where $\mathrm{E}(\mathrm{X}_{s=1})^{'}$ denotes a vector with averages for the endowments of farmers who participate, and $\mathrm{E}(\mathrm{X}_{s=0})^{'}$ denotes the same for farmers who do not participate. By rearranging this equation, we can identify the contribution of group differences in predictors to the overall outcome difference:

$$E(X_{s=1})^{'}\alpha_1 - E(X_{s=0})^{'}\alpha_0 \quad (5)$$

$$= \{E(X_{s=1}) - E(X_{s=0})\}^{'}\alpha_{all} + \{E(X_{s=1})^{'}(\alpha_1 - \alpha_{all}) + E(X_{s=0})^{'}(\alpha_{all} - \alpha_0)\}$$

[12] A more flexible version of the model above also allows the distributions of the error terms in the production functions to be independently estimated for both sectors, thus creating a set of three equations (Lokshin and Sajaia, 2004). This version of the model, while offering greater flexibility, turned out to be very unstable. The maximum likelihood routine often failed to converge or proved to be very sensitive to small changes in the specification of the model. For this reason, we dropped this model in favor of a more restrictive one, while still allowing the returns to farm and household characteristics in Equation 2 to vary by sector.

[13] In many applications of the Oaxaca-Blinder decomposition, differences in returns are subsequently interpreted as a proxy for the role of unobserved ("unexplained") factors, such as "discrimination" in the literature on gender and ethnic wage gaps. Here, differences in estimated returns between the avocado export and domestic markets are unlikely to be related to unobserved discrimination, ethnic and/or skill differences (we have no evidence for this, anecdotal or otherwise), but, instead, to differences in pricing, quality requirements, cultivation practices, harvesting, transport, liquidity costs, etc., across these market segments, as discussed in section 4.1 of this paper.

Table 2
Probit estimates for participation in export markets.

Explanatory variables	Estimate	Marginal effect
HH size (no.)	0.078*	0.026*
	(0.035)	(0.012)
HH head (dummy, 1 = male)	−0.193	−0.066
	(0.165)	(0.058)
Age of HH head (years)	0.017**	0.006**
	(0.006)	(0.002)
Education of HH head (years)	0.013	0.004
	(0.020)	(0.007)
Log nonagricultural assets (KSh)	0.017	0.006
	(0.052)	(0.017)
Log agricultural assets (KSh)	−0.011	−0.004
	(0.055)	(0.018)
Log land size (acres)	−0.261	−0.087
	(0.167)	(0.055)
Log no. Hass trees	0.565***	0.188***
	(0.067)	(0.022)
Log no. other avocado trees	0.049	0.016
	(0.072)	(0.024)
Avocado training 2014/15	0.792***	0.258***
	(0.130)	(0.040)
Log TLU	−0.005	−0.002
	(0.144)	(0.048)
Log non-avocado income (excluding livestock)	−0.035	−0.012
	(0.021)	(0.007)
Distance to nearest market	0.047	0.016
	(0.054)	(0.018)
Score avocado group (1-4)	2.166***	0.722***
	(0.527)	(0.178)
No. of observations	766	766

Notes: Regression contains location fixed effects. Standard errors are reported in parentheses. HH = household, KSh = Kenyan shillings, log = logarithm, no. = number, TLU = tropical livestock units. * = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$.

The first term after the equality sign in Eq. 5 indicates the effect of the differences in endowments between farmers who participate and farmers who do not participate in export markets ("endowment effect"). The next term indicates the effect of differences in returns to the endowments, specifically, the direct effect of participation versus nonparticipation in the export market ("export market participation effect"). We estimate α_{all} by estimating Eq. 5 for all farmers together (replacing α_s with α_{all}) by means of a simple regression.

5. Empirical results

A full-information maximum likelihood approach was employed to jointly estimate the selection and outcome equations for all specifications. Appendix Tables A1–A3 present the estimated coefficients of the outcome Eq. (2) for all outcome variables, including the estimated correlation coefficients and variance of the error term of both outcome equations. We also included the maximum and mean of the estimated variance inflation factors (VIF) as a multicollinearity diagnostic in Tables A1–A3; the maximum is typically around 2, suggesting that multicollinearity is not a serious concern.[14] The estimated coefficients for the participation equation, which were estimated jointly, are excluded from the appendix tables, as they are very similar across specifications.[15] Therefore, we report the estimation results of the participation Eq. (1), which were estimated independently of the outcome equations, in Table 2.

[14] The variance inflation factors have been calculated by projecting the control variables onto the instruments before computing VIFs (Stata command ivvif). As a rule of thumb, a VIF exceeding 10 suggests high multicollinearity, although a cutoff of 5 is also commonly used (Sheather, 2009).

[15] The similarity of results is not surprising, given that the estimated ρ is not significantly different from zero for most outcomes. Results are available from the authors on request.

Table 3
Impacts of participation in export markets.

	All ATE/a	Currently in non-export market ATU/a	Currently in export market ATT/a
Yields and prices			
Log total marketed yield avocado (pcs.)	−2.34***	−2.37***	−2.30***
	(0.37)	(0.30)	(0.59)
Log marketed yield Hass (pcs.)	0.36	0.67	−0.24
	(0.89)	(0.96)	(0.80)
Log marketed yield Fuerte/local (pcs.)	−2.98***	−2.86***	−3.20***
	(0.60)	(0.53)	(0.84)
Log price avocado (KSh/ piece)	0.26*	0.24	0.30**
	(0.14)	(0.15)	(0.13)
Log price Hass (KSh)	0.59***	0.61***	0.56***
	(0.16)	(0.17)	(0.16)
Log price Fuerte/local (KSh/piece)	0.06	0.06	0.07
	(0.09)	(0.11)	(0.07)
Revenues and incomes			
Log revenue avocado (KSh)	0.31	0.24	0.46
	(0.67)	(0.72)	(0.59)
Log revenue Hass (KSh)	1.15	1.52	0.44
	(0.94)	(1.02)	(0.84)
Log revenue Fuerte/local (KSh)	−1.77	−1.72	−1.85
	(2.76)	(2.76)	(2.80)
Log income avocado (KSh)	0.33	0.27	0.46
	(0.59)	(0.66)	(0.49)
Share avocado income from Hass	0.10*	0.15**	−0.01
	(0.05)	(0.06)	(0.05)
Hired and family labor			
Total hired labor cost avocado (KSh)	1300.1**	905.6	2,076.9***
	(621.9)	(743.6)	(587.8)
Family labor (person days)	15.22***	15.18***	15.31**
	(5.51)	(5.35)	(6.02)
Male family labor (person days)	0.76	0.52	1.24
	(1.28)	(1.39)	(1.21)
Female family labor (person days)	10.08***	10.32***	9.61***
	(2.37)	(2.40)	(2.47)
Youth family labor (person days)	2.61***	2.22***	3.36***
	(0.55)	(0.37)	(1.04)

Notes: The designation "/a" indicates when participation in the export sector is considered a treatment. The first column covers the average treatment effect (ATE); the second, the average treatment effect on the untreated (ATU); and the third column, the average treatment effect on the treated (ATT). Standard errors are reported in parentheses. KSh = Kenyan shillings, log = logarithm, pcs = pieces. * = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$.

5.1. Determinants of farmers' participation in export markets

The results of the probit contract farming participation model, presented in Table 2, show that household size and the age of the household head positively influenced the probability of participation in export markets. A plausible explanation could be that older farmers have more social connections, giving them better access to information and to farmers' groups. The positive and statistically significant effect of household size is an indication that availability of labor is a crucial factor for participation in export markets. The effects of assets are insignificant; the only asset that seems to matter is the number of Hass trees a farmer has. The quality of the main avocado farmers' group in a sublocation influences participation. Farmers living in areas with better-functioning groups have a higher probability of participation. If a farmer has received training in avocado cultivation, that is also positively associated with participation in export markets. Our results are consistent with those of several studies that have indicated that smallholder farmers with limited access to production technologies and institutional supports like credit and training can be easily excluded from important parts of the value chain (Key and Runsten, 1999; Reardon et al., 2009; Rao and Qaim, 2011; Barrett et al., 2012; Schuster and Maertens, 2013; Weyori et al., 2018).

5.2. Impacts of smallholder farmers' participation in export markets

As explained previously, the impacts of participation in avocado export markets on labor market outcomes, farm yields, sales prices, and incomes were examined using the average treatment effect on the treated (ATT) and the average treatment effect on the untreated (ATU). The estimates regarding different outcomes are reported in Table 3. These estimates are based on the estimated coefficients reported in Tables A1–A3.

The results in Table 3 suggest a 39 percent increase in avocado income with participation in export markets, [16] but the estimated effect is not significant, at only 5 percent. The point estimate is substantially higher for exporters; but, again, the difference is insignificant. It seems that there was an offsetting effect of lower marketed yields and higher prices. Marketed yields dropped substantially as a result of participation. On the other hand, revenues increased (by 11 percent) because most avocados produced in Kenya are of the Hass variety,[17] which fetches higher prices (by 80 percent).[18] On balance, the income effect still seems to have been on the positive side.[19] Our findings support those of earlier studies on

[16] exp(0.33)-1 = 0.39.
[17] exp(0.10)-1 = 0.11.
[18] exp(0.59)-1 = 0.80.
[19] Due to data unavailability, we did not include the costs of harvesting or the opportunity cost of attending farmers' group meetings when calculating net avocado income. Given that the mean net avocado income in the sample equaled over KSh32,000 and the daily wage of a casual agricultural worker was KSh200–300, a 39 percent increase in net income (about KSh12,500) cannot be explained by these omitted costs. While the study focused on mean outcomes, one may also wonder whether export market participating farmers face more risk than nonparticipating farmers. We lack objective risk measures, but export market participating farmers perceived their avocado incomes to be relatively more stable than did nonparticipating farmers.

Table 4
Decomposition of average differences in outcomes observed in modern and traditional sector.

Variables	Predicted difference $(\bar{X}_{s=1})'\alpha_1 - (\bar{X}_{s=0})'\alpha_0$	Endowment effect $(\bar{X}_{s=1} - \bar{X}_{s=0})'\alpha_{all}$		Export market participation effect $(\bar{X}_{s=1})'(\alpha_1 - \alpha_{all}) + (\bar{X}_{s=0})'(\alpha_{all} - \alpha_0)$	
	Estimate	**Estimate**	**Percent**	**Estimate**	**Percent**
Yields and prices					
Log total marketed yield avocado (pcs.)	−0.53**	0.60***	−113	−1.13***	213
	(0.24)	(0.08)		(0.25)	
Log marketed yield Hass (pcs.)	2.26***	2.23***	99	0.03	1
	(0.59)	(0.12)		(0.60)	
Log marketed yield Fuerte/local (pcs.)	−2.07***	−0.51***	25	−1.56***	75
	(0.44)	(0.13)		(0.46)	
Log price avocado (KSh/piece)	0.42***	0.27***	64	0.15	36
	(0.10)	(0.03)		(0.10)	
Log price Hass (KSh)	0.58***	0.24***	41	0.34***	59
	(0.12)	(0.03)		(0.12)	
Log price Fuerte/local (KSh)	0.05	0.05	100	−0.00	0
	(0.08)	(0.03)		(0.08)	
Revenues and incomes					
Log revenue avocado (KSh)	1.12***	0.91***	81	0.21	19
	(0.43)	(0.10)		(0.44)	
Log revenue Hass (KSh)	3.17***	2.75***	87	0.42	13
	(0.63)	(0.15)		(0.65)	
Log revenue Fuerte/local (KSh)	−1.41	−0.47***	33	−0.94	67
	(1.73)	(0.15)		(1.74)	
Log income avocado (KSh)	0.96**	0.80***	83	0.16	17
	(0.40)	(0.12)		(0.42)	
Share avocado income from Hass	0.27***	0.22***	81	0.04	15
	(0.04)	(0.02)		(0.04)	
Hired and family labor					
Total hired labor cost avocado (KSh)	2,552.3***	1,594.0***	62	958.3	38
	(521.6)	(211.9)		(563.0)	
Family labor (person days)	9.16**	1.69**	18	7.47	82
	(3.86)	(0.67)		(3.92)	
Male family labor (person days)	1.16	0.81**	70	0.35	30
	(1.00)	(0.35)		(1.06)	
Female family labor (person days)	5.73***	0.68	12	5.05***	88
	(1.83)	(0.38)		(1.87)	
Youth family labor (person days)	1.40***	0.20	14	1.20***	86
	(0.42)	(0.12)		(0.44)	

Note: The standard errors in indicated in parentheses. Standard errors take into account the variance of the estimated difference/effect. Standard errors are reported in parentheses. KSh = Kenyan shillings, pcs = pieces. * = p < 0.10, ** = p < 0.05, *** = p < 0.01.

farmers' participation in contract farming and export markets (e.g., Dedehouanou et al., 2013; Rao et al., 2012; Rao and Qaim, 2011; Miyata et al., 2009; Minten et al., 2009; Warning and Key, 2002), which show that contract farming helps to increase smallholder farmers' incomes.

Labor inputs increase as well – both hired labor and family labor. The cost of hired labor increased by around KSh1,300 per year, which is about $13. Family labor inputs increase by about 15 days per year, of which the largest share comes from increases in female labor. The supply of male family labor is not affected by participation. Youths also increase their labor inputs, by 2.6 days on a yearly basis.[20] The results in Table 3 reflect the fact that one can sell only good avocados under a contract, so fewer avocados are picked. Farmers who do not participate in export markets generally sell through brokers, who pick most of the avocados themselves, including the good and not so good, leading to a higher marketed yield. But due to the price difference, export market participating farmers still have higher net incomes, despite their lower yields. The positive impacts on labor, both hired and family, could result from the fact that the higher standards of export markets may necessitate the use of modern agricultural practices and modern inputs (including more frequent pruning, more intensive application of fertilizers, weed and pest control measures, as well as record keeping). Market assurance from the export companies may also increase the farmers' ability and willingness to invest in technical innovations, and thereby increase farm productivity (Karafillis and Papanagiotou, 2011).

In section 4.2 we discussed the selection and validity of the instrumental variables used in the above estimations. However, in the absence of a randomized control or natural experiment, any choice of instrumental variables remains open to challenge. We therefore performed two robustness checks on our instrumental estimates. First, we re-estimated the model, omitting all instruments except the quality of the avocado farmers' groups (the only instrument that was consistently significant across the participation models for all outcomes). Table A4 shows that the results

[20] Due to the small effects of labor demand, the increase in labor inputs cannot account for the estimated increase in avocado income (see footnote 15).

remained virtually unchanged (cf. Table 3).[21] Second, we performed a falsification test to check the admissibility of these instruments (Jaleta et al., 2016). A falsification test is a way of checking whether instrumental variables are still valid if they affect decisions regarding participation (Eq. 1), but not the outcome variable (Eq. 2). This can be verified by including the instruments in both the participation and outcome equations. We found that, for most outcome variables, the selected instrumental variables were jointly statistically insignificant in the outcome equation (mean p-value = 0.13), but jointly strongly significant in all the participation equations (mean p-value = 0.0004).[22]

5.3. Decomposition analysis

The regression results discussed above confirm the statistically significant impact of export market participation on labor markets, farm yields, and sales prices, as well as a plausibly positive impact on incomes. Export market participants apparently have higher labor market participation and incomes than nonparticipants. The question now is how economically significant export market participation is when considering the actually observed differences in these outcomes between farmers who participate and farmers who do not participate in export markets.

Following the Blinder-Oaxaca approach (see section 4.2), we broke down these outcome differentials into the "endowment effect" and the "export market participation effect." The results in Table 4 indicate that endowment differences are strongly related to outcome differences, including (log) avocado income (83 percent of the difference explained), (log) revenue (81 percent explained), (log) avocado price (64 percent), and total hired labor cost for avocados (62 percent explained). The importance of endowments for understanding economic outcomes is not surprising, of course, and additional investment in farm household resources will be needed to further improve farm productivity and revenues.

What is especially interesting is our finding that the differences in returns to endowments (in export versus domestic markets) are even more important than the differences in the endowments themselves when it comes to explaining the differences in a number of outcome variables. Specifically, the percentage explained by the export participation effect exceeds the percentage explained by the endowment effect for (log) total marketed yields (213 percent explained); [23] (log) revenues and marketed yields from Fuerte/local varieties (67 percent and 75 percent explained, respectively); (log) Hass sales prices (59 percent explained); and family, female, and youth labor inputs (82, 88, and 86 percent explained, respectively).[24] This finding suggests that, apart from policies for stimulating investment in farm households to strengthen endowments, government interventions to further enable or facilitate the participation of small-scale producers in export markets, so as to increase the returns to existing endowments, will also be needed as a way to further improve productivity and revenues (see below).

6. Conclusions and policy implications

Smallholder producers in sub-Saharan Africa are often unable to capture high-value growth opportunities by effectively participating in global value chains for high-value fresh produce. The existence of strong competition in modern global value chains is often mentioned as a limiting factor, along with the difficulties in meeting quality standards and the lack of access to technology and information about modern farm production and marketing practices. However, modernizing the agricultural value chain by expanding contract farming is one way to overcome barriers and market imperfections, reduce farmer exposure to risk, and thus increase agricultural productivity (Barrett et al., 2012; Okello and Swinton, 2007).

In this study, we analyzed the determinants of participation in modern global value chains for avocado exports and we evaluated the impacts of export market participation on the labor market, farm yields, and incomes. We found that participation of smallholder farmers in the avocado export market is associated with larger incomes and revenues, and with higher prices fetched for avocados. In our model, the impact estimates show that there is an offsetting effect in terms of volume and price. While avocados sold in export markets fetch better prices, the market yield is negatively affected. All in all, the impact of export market participation on avocado incomes seems to be positive, although the effect is insignificant. Also, we found that participation in export markets clearly has positive effects on labor – both hired and family. The effects are small in magnitude, however: about $13 worth of hired labor and 15 days of family labor. The effects on family labor are most visible for women and youth.

The decomposition analysis indicates that differences in incomes, revenues, sales prices, and labor inputs can often be largely explained by differences in the sizes of endowments. However, the differences in returns to endowments in export versus domestic markets explain even more for some outcome variables (i.e., total marketed yields, revenues and marketed yields from Fuerte/local varieties, Hass sales prices, and family/female/youth labor inputs). These findings suggest that existing and future programs should not only focus on resource accumulation for farmers (e.g., increasing productive capacity by improving access to seedlings and building technical knowledge through training programs in avocado cultivation), but also pay attention to the inclusiveness of export market participation for smallholder farmers, so they can increase the returns to their endowments. Our analysis shows that improving the quality of avocado farmers' groups and offering training in avocado cultivation would both be effective means of increasing export market inclusiveness, along with the provision of seedlings to increase the number of avocado trees.

In conclusion, smallholder farmers can benefit from participation in avocado export markets and other supply chain activities. Providing households with access to foreign markets and up-to-date information on farm technology, along with the dissemination of simple and domestically invented technologies, could apparently achieve higher farm incomes, revenues, and sales prices. The question remains, however, as to whether the benefits of export market participation were primarily due to having a contract, which would lower transactions costs and risks. Currently, the two sources of impacts – contract farming and export market participation – are indistinguishable from each other, and impossible to disentangle empirically. However, with the development of the domestic avocado market in Kenya, and the growth of the middle class there, one may expect contract farming to emerge among farmers participating in the domestic market (dealing with large supermarkets, for example). In this case, it would become possible to empirically distinguish between the impacts of contracts and the impacts of participation in export markets.

[21] The only significant difference was that the coefficient for (total) family labor became smaller and was no longer significant. However, the coefficients for the components of family labor (male, female, youth) remained virtually unchanged.

[22] Actually, we performed one additional robustness check. Our instrument non-avocado income includes information on permanent/annual crops and other incomes, while our instrument animal assets includes information on large/small livestock. As suggested by one of the referees, one may argue that instruments using only information on permanent crops and large livestock are possibly more exogenous to current income than our broader measures. Therefore, we have also estimated the model with these more narrowly defined instruments as an additional robustness check. We found, however, that the estimates were virtually the same (results available on request).

[23] If the percentage explained by an Oaxaca-Blinder component exceeds 100 percent, then the change in outcome can be explained only by this component. In this case, the contribution from the other component may even be in the wrong direction (i.e., having the wrong sign).

[24] Endowments are relatively more important for hired labor, however. This difference can be explained by the fact that hired labor is used for work closely associated with the amount of productive assets, and hence production, while family labor is used for other tasks that are less associated with production: for example, marketing, for which the training and monitoring costs are lower than those for hired labor. We thank one of the referees for pointing this out to us.

Acknowledgements

We gratefully acknowledge **Bekele Shiferaw** and three anonymous reviewers for excellent comments on earlier drafts. This research was funded by the Ministry of Foreign Affairs of the Netherlands through the NWO-WOTRO Research for Inclusive Development in Sub-Saharan Africa Call on Productive Employment.

Appendix A

Table A1
Income, revenue, yield, and price effects of avocado farming in the modern and traditional sectors.

Variables	Log avocado income		Log avocado revenue		Log total marketed yield avocado (pieces)		Log avocado price (KSh/piece)		Share of avocado ncome from Hass	
	Non-exp	Exports	Non-exp	Exports	Non-exp	Exports	Non-exp	Exports	Non-exp	Exports
Household size (no.)	−0.012	−0.087	−0.003	−0.082	0.028	−0.004	−0.015	−0.014	−0.002	−0.014
	(0.036)	(0.068)	(0.033)	(0.051)	(0.031)	(0.042)	(0.009)	(0.016)	(0.006)	(0.013)
HH head (1 = male)	0.187	−0.164	0.204	0.043	0.134	−0.054	0.056	−0.095	−0.014	0.067
	(0.202)	(0.354)	(0.188)	(0.325)	(0.165)	(0.226)	(0.043)	(0.082)	(0.023)	(0.043)
Age of HH head (years)	−0.007	−0.005	−0.004	−0.002	0.006	0.004	−0.003	0.003	−0.001	−0.002
	(0.007)	(0.012)	(0.007)	(0.009)	(0.005)	(0.008)	(0.001)	(0.003)	(0.001)	(0.002)
Educ. HH head (years)	−0.039	0.028	−0.044	0.010	−0.021	0.010	−0.010	0.004	−0.003	0.004
	(0.026)	(0.041)	(0.024)	(0.033)	(0.022)	(0.029)	(0.006)	(0.009)	(0.003)	(0.006)
Log nonagric. assets	−0.001	−0.016	0.008	0.095*	0.028	0.046	−0.013	0.040**	−0.002	−0.001
	(0.042)	(0.077)	(0.042)	(0.040)	(0.034)	(0.048)	(0.010)	(0.014)	(0.007)	(0.013)
Log agric. assets (KSh)	0.005	0.058	0.000	−0.002	−0.003	−0.001	0.015	−0.013	0.009	0.019
	(0.085)	(0.102)	(0.083)	(0.071)	(0.063)	(0.063)	(0.020)	(0.022)	(0.010)	(0.011)
Log land size (acres)	0.243	−0.470	0.232	−0.017	0.128	−0.202	0.010	−0.028	0.015	0.099
	(0.278)	(0.387)	(0.278)	(0.221)	(0.218)	(0.214)	(0.087)	(0.079)	(0.027)	(0.069)
Log # Hass trees	0.682***	0.672***	0.699***	0.790***	0.768***	0.997***	0.105***	0.147***	0.257***	0.131***
	(0.089)	(0.181)	(0.095)	(0.155)	(0.087)	(0.111)	(0.020)	(0.036)	(0.011)	(0.025)
Log # other avo. trees	0.662***	0.767***	0.652***	0.461***	0.661***	0.680***	−0.004	−0.089**	−0.203***	−0.201***
	(0.091)	(0.178)	(0.089)	(0.109)	(0.073)	(0.099)	(0.023)	(0.033)	(0.015)	(0.036)
Avo. training 2014/15	0.089	0.909*	0.101	0.845**	0.446***	1.179***	0.050	0.291***	0.040	−0.058
	(0.159)	(0.387)	(0.169)	(0.326)	(0.122)	(0.238)	(0.043)	(0.069)	(0.025)	(0.068)
Rho	−0.101		−0.030		0.844		0.010		0.043	
	(0.176)		(0.231)		(0.085)		(0.162)		(0.078)	
Sigma	1.804		1.582		1.412		0.424		0.259	
	(0.122)		(0.120)		(0.126)		(0.047)		(0.028)	
VIF (max)	1.959		1.961		1.961		1.961		1.957	
VIF (mean)	1.382		1.382		1.382		1.382		1.379	
No. of obs.	762		766		766		766		737	

Notes: All the regressions contain location fixed effects. Standard errors are reported in parentheses. Avo. = avocado, HH = household, KSh = Kenyan shillings, max = maximum, no. = number, Non-exp = non-exports, VIF = variance inflation factors. * = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$.

Table A2
Revenue, yield, and price effects of avocado farming by avocado type, in the modern and traditional sectors.

Variables	Log revenue: Hass		Log revenue: Fuerte/local		Log marketed yield: Hass		Log marketed yield: Fuerte/local		Log price: Hass		Log price: Fuerte/local	
	Non-exp	Export	Non-exp	Export	Non-exp	Export	Non-exp	Export	Non-exp	Export	Non-exp	**Export**
Household size (no.)	−0.089	−0.030	−0.038	0.028	−0.085	0.001	0.028	0.045	−0.021	−0.029	−0.019	0.003
	(0.066)	(0.066)	(0.077)	(0.102)	(0.056)	(0.049)	(0.057)	(0.080)	(0.011)	(0.017)	(0.011)	(0.021)
HH head = male	−0.098	0.153	−0.092	−0.360	−0.120	0.003	−0.050	−0.312	0.067	0.032	0.001	−0.133
	(0.274)	(0.416)	(0.252)	(0.410)	(0.232)	(0.289)	(0.222)	(0.337)	(0.045)	(0.095)	(0.052)	(0.087)
Age of HH	−0.011	0.007	−0.001	0.050**	−0.006	0.001	0.007	0.047***	−0.004*	0.002	−0.003*	0.004
head (years)	(0.010)	(0.011)	(0.014)	(0.018)	(0.009)	(0.009)	(0.008)	(0.013)	(0.002)	(0.003)	(0.002)	(0.004)
Educ. HH head	−0.040	0.035	−0.015	0.036	−0.021	0.028	−0.007	0.042	−0.004	0.009	−0.008	−0.009
(years)	(0.038)	(0.045)	(0.034)	(0.051)	(0.032)	(0.035)	(0.030)	(0.039)	(0.006)	(0.009)	(0.007)	(0.012)
Log nonagric.	0.013	0.017	0.029	0.129	−0.003	−0.024	0.035	0.106	−0.014	0.038*	−0.015	0.050**
Assets	(0.086)	(0.064)	(0.062)	(0.101)	(0.071)	(0.051)	(0.057)	(0.092)	(0.016)	(0.016)	(0.011)	(0.017)
Log agric.	−0.097	0.069	0.045	−0.163	−0.073	0.075	0.067	−0.173	0.011	−0.012	0.022	−0.063*
assets (KSh)	(0.114)	(0.094)	(0.120)	(0.140)	(0.088)	(0.067)	(0.100)	(0.122)	(0.025)	(0.023)	(0.023)	(0.028)

(*continued on next page*)

Table A2 (*continued*)

Variables	Log revenue: Hass		Log revenue: Fuerte/local		Log marketed yield: Hass		Log marketed yield: Fuerte/local		Log price: Hass		Log price: Fuerte/local	
	Non-exp	Export	Non-exp	Export	Non-exp	Export	Non-exp	Export	Non-exp	Export	Non-exp	**Export**
Log land size (acres)	0.186	−0.152	−0.340	−0.684	0.233	−0.218	−0.312	−0.653	−0.021	0.080	−0.007	0.023
	(0.302)	(0.359)	(0.390)	(0.488)	(0.234)	(0.287)	(0.281)	(0.352)	(0.095)	(0.071)	(0.091)	(0.089)
Log nr Hass trees	3.162***	1.691***	−0.099	0.068	2.845***	1.589***	0.013	0.123	0.012	0.019	0.019	0.037
	(0.146)	(0.246)	(0.303)	(0.439)	(0.125)	(0.204)	(0.129)	(0.165)	(0.032)	(0.042)	(0.020)	(0.037)
Log no. other avo trees	−0.339*	−0.010	2.567***	2.880***	−0.339**	0.011	2.381***	2.722***	0.043	−0.016	0.077**	0.115*
	(0.155)	(0.140)	(0.161)	(0.172)	(0.131)	(0.113)	(0.157)	(0.131)	(0.027)	(0.031)	(0.030)	(0.051)
Avo. training 2014/15	0.107	0.546	0.296	0.489	0.028	0.275	0.549*	0.695*	0.094*	0.245**	0.034	0.122
	(0.263)	(0.397)	(0.494)	(0.781)	(0.220)	(0.330)	(0.233)	(0.311)	(0.044)	(0.081)	(0.047)	(0.064)
Rho	−0.081		0.408		−0.014		0.730		−0.312		0.086	
	(0.227)		(0.597)		(0.269)		(0.118)		(0.193)		(0.065)	
Sigma	2.349		2.400		1.886		2.132		0.447		0.466	
	(0.100)		(0.231)		(0.089)		(0.118)		(0.039)		(0.053)	
VIF (max)	1.961		1.961		1.961		1.961		1.915		1.961	
VIF (mean)	1.382		1.382		1.382		1.382		1.383		1.373	
# of obs.	766		766		766		766		630		671	

Note: all regressions contain location fixed effects. Standard errors are reported in parentheses. Avo. = avocado, HH = household, KSh = Kenyan shillings, max = maxumum, no. = number, non-exp = non-exports, VIF = variance inflation factors. * = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$.

Table A3
Hired labor cost and family labor effects of avocado farming by avocado type, in the modern and traditional sectors.

Variables	Total labor cost avocado		Family labor (person days)		Male family labor		Female family labor		Youth family labor	
	Trad.	Modern	Trad.	Modern	Trad.	Modern	Trad.	Modern	Trad.	**Modern**
Household size (no.)	−42.58	−22.72	0.592	−0.430	0.317	−0.487*	0.204	−0.053	0.073	0.167
	(30.88)	(131.0)	(0.393)	(0.398)	(0.168)	(0.231)	(0.242)	(0.211)	(0.039)	(0.089)
HH head (1 = male)	28.86	311.2	0.740	1.541	1.576***	2.737**	−0.820	−1.502	0.011	0.236
	(106.1)	(545.7)	(1.078)	(2.192)	(0.451)	(1.023)	(0.718)	(1.225)	(0.150)	(0.448)
Age of HH head (years)	4.815	25.955	−0.034	−0.279***	−0.006	−0.109**	−0.005	−0.138***	−0.016*	−0.026
	(4.909)	(23.6)	(0.037)	(0.071)	(0.018)	(0.037)	(0.019)	(0.041)	(0.007)	(0.014)
Educ. HH head (years)	14.21	−36.22	−0.044	−0.363	−0.067	−0.180	0.076	−0.181	−0.038	−0.023
	(16.11)	(74.95)	(0.155)	(0.214)	(0.074)	(0.111)	(0.099)	(0.116)	(0.024)	(0.054)
Log nonagricul. assets	9.77	524.6**	0.466	−0.057	0.228	0.055	0.209	−0.097	0.035	−0.018
	(36.451)	(170.5)	(0.279)	(0.423)	(0.152)	(0.187)	(0.148)	(0.234)	(0.041)	(0.066)
Log agricul. assets (KSh)	18.47	−447.4*	0.028	−0.457	−0.043	−0.085	−0.006	−0.174	0.034	−0.133
	(42.85)	(186.7)	(0.382)	(0.613)	(0.195)	(0.348)	(0.222)	(0.295)	(0.051)	(0.116)
Log land size (acres)	−35.55	2093.8**	1.732	6.120**	0.791	1.389	0.554	4.153**	0.330*	0.307
	(144.3)	(811.3)	(1.114)	(2.200)	(0.562)	(1.233)	(0.652)	(1.306)	(0.137)	(0.329)
Log # Hass trees	250.3**	1319.3***	0.274	−1.116	1.011***	0.839	−0.378	−1.520*	−0.189**	−0.211
	(94.8)	(368.3)	(0.837)	(1.166)	(0.287)	(0.712)	(0.437)	(0.732)	(0.062)	(0.142)
Log # other avo. trees	107.0	−346.3	0.098	2.747**	0.624	1.383**	−0.447	1.185**	−0.088	0.313
	(63.9)	(303.6)	(0.508)	(0.869)	(0.320)	(0.497)	(0.285)	(0.419)	(0.074)	(0.171)
Avo. training 2014/15	7.922	1643.1***	−1.291	−6.163**	0.091	−1.520	−0.753	−2.876***	−0.497**	−0.967**
	(125.5)	(489.7)	(1.133)	(1.985)	(0.540)	(0.905)	(0.518)	(0.795)	(0.186)	(0.308)
Rho	−0.088		−0.658		0.020		−0.805		−0.805	
	(0.068)		(0.241)		(0.092)		(0.127)		(0.106)	
Sigma	2503.8		11.651		5.442		7.040		1.708	
	(259.5)		(1.675)		(0.441)		(1.340		(0.235)	
VIF (max)	1.961		1.965		1.965		1.965)		1.965	
VIF (mean)	1.382		1.383		1.383		1.383		1.383	
# of obs	766		765		765		765		765	

Notes: All regressions contain location-fixed effects. Parentheses around numbers indicate… Avo. = avocado, HH = household, KSh = Kenyan shilling, max = maximum, no. = number, Trad. = traditional, VIF = variance inflation factors. * = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.01$.

Table A4
Impacts of participation in export markets: one instrument only.

	All ATE/a	Currently in non-export market ATU/a	Currently in export marketATT/a
Log income avocado (KSh)	0.46	0.40	0.59
	(0.56)	(0.63)	(0.45)
Log revenue avocado (KSh)	0.48	0.41	0.62
	(0.44)	(0.49)	(0.36)
Log total marketed yield avocado (pcs.)	−2.35***	−2.36***	−2.33***
	(0.38)	(0.29)	(0.62)
Log price avocado (KSh/piece)	0.70**	0.69**	0.72**
	(0.30)	(0.30)	(0.29)
Share avocado income from Hass	0.10**	0.15**	−0.01
	(0.05)	(0.06)	(0.05)
Log revenue Hass (KSh)	1.29	1.66*	0.55
	(0.87)	(0.95)	(0.78)
Log revenue Fuerte/local (KSh)	−1.88	−1.83	−1.98
	(2.60)	(2.59)	(2.67)
Log marketed yield Hass (pcs.)	0.45	0.76	−0.16
	(0.80)	(0.85)	(0.72)
Log marketed yield Fuerte/local (pcs.)	−2.97***	−2.85***	−3.21***
	(0.58)	(0.52)	(0.82)
Log price Hass (KSh)	0.61***	0.63***	0.57***
	(0.15)	(0.16)	(0.14)
Log price Fuerte/local (KSh/piece)	0.09	0.08	0.09
	(0.09)	(0.11)	(0.08)
Total hired labor cost avocado (KSh)	1300.7**	915.2	2062.8***
	(594.3)	(715.4)	(568.2)
Family labor (person days)	2.10	1.93	2.42
	(5.56)	(5.75)	(5.29)
Male family labor (person days)	0.78	0.56	1.22
	(1.10)	(1.22)	(1.06)
Female family labor (person days)	9.94***	10.11***	9.59***
	(2.44)	(2.43)	(2.62)
Youth family labor (person days)	2.60***	2.20***	3.39***
	(0.55)	(0.36)	(1.03)

Notes: The designation "/a" indicates when participation in the export sector is considered a treatment. The first column covers the average treatment effect (ATE); the second, the average treatment effect on the untreated (ATU); and the third column, the average treatment effect on the treated (ATT). Parentheses around numbers indicate… KSh = Kenyan shillings, log = logarithm, pcs = pieces. * = p < 0.10, ** = p < 0.05, *** = p < 0.01.

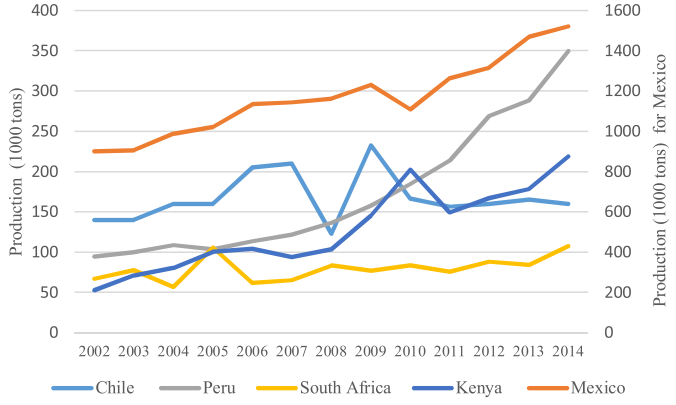

Fig. A1. Trends in avocado production for major producing countries.
Source: Food and Agriculture Organization of the United Nations (FAO), 2017.

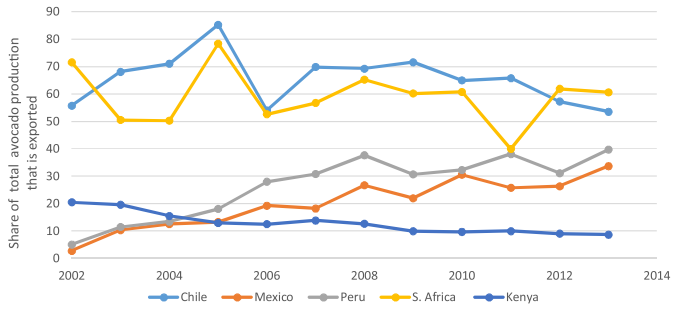

Fig. A2. Trends in the share of total avocado production handled by major exporters (ha = hectares).
Sources: Food and Agriculture Organization of the United Nations (FAO), 2017; Horticultural Crops Directorate (HCD), 2015.

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