Technology Training, Buyer-Supplier Relationship, and Quality Upgrading in an Agricultural Supply Chain

Sangyoon Park   Zhaoneng Yuan   Hongsong Zhang*

Abstract

This paper examines the impacts of technology training and buyer-supplier relationship on technology adoption and quality upgrading. We randomly varied subjects of each training group across farmer–exporter clusters—farmers, exporters, both, or none-—and provided training on Good Agricultural Practices (GAP). We find that offering training to farmers enhances technology adoption and quality upgrading. Yet, the effects are much stronger when farmers and exporters are trained together. We document a plausible mechanism to explain this finding: joint training improves buyer-supplier relationship, which facilitates contract trade between farmers and exporters. We find no effect of GAP certification eligibility on technology adoption.

Keywords: quality upgrading, technology training, buyer-supplier relationship, certification eligibility, agricultural supply chain
JEL codes: O12, O13, Q12, Q16, L15

*HKU Business School, University of Hong Kong. Corresponding author: Sangyoon Park (email: sangyoon@hku.hk). We thank Binh Thuan Dragon Fruit Development and Research Center for providing support and cooperation in this project and Nguyen Phuong Thanh and Nguyen Vu Anh Tram for excellent research assistance. We are thankful to Emmanuel Jimenez and Prashant Bharadwaj and participants at the KDI-3ie Impact Evaluation Workshop for providing insightful suggestions during the early stage of this project. We are also grateful to Jie Bai, Hyuncheol Kim, Ryan Kim, Jin Li, Albert Park, Sujata Visaria and conference and seminar participants at BREAD (NYU), Hong Kong University of Science and Technology, Jinan University, Korea University, Monash University, NEUDC (Dartmouth), Seoul National University, Sogang University, University of Hong Kong, and Yonsei University. This study was registered in the AEA RCT registry as AEARCTR-0003237 and partly funded by a research grant from Hong Kong's Research Grants Council (ECS27501618).

1 Introduction

Quality upgrading is imperative for producers to export to high-income markets (Verhoogen 2008) and a pathway to growth for developing economies (Hausmann, Hwang, & Rodrik 2007). Yet in many developing countries, the transition from production of low- to high-quality goods is painfully slow (Verhoogen 2021; World Bank 2007). To stimulate quality upgrading, government policies typically focus on reducing producers' costs of technology adoption and quality upgrading (a supply-side constraint) through technology training, R&D subsidies, and input subsidies. However, asymmetric information on quality between producers and downstream buyers and the resulting market friction (a demand-side constraint) may dampen the effects of supply-side interventions.[1] For example, subsidizing farmers to produce high-quality dragon fruit may fail if buyers are unwilling to pay a price premium due to lack of trust in the product's quality. This problem may be especially severe in supply chains where quality verification (e.g., safety of food products) is difficult or costly, and when contract enforcement is weak.

This paper examines the impact of technology training and buyer-supplier relationship on technology adoption and quality upgrading through a field experiment in an agricultural supply chain in Vietnam. As the main intervention, we provide training on agricultural technologies designed to increase food safety, which is a key determinant of quality for agricultural products, yet difficult for downstream buyers to observe or verify. We experiment with farmers and exporting intermediaries (henceforth, exporters) and randomize the subjects of training groups across matched farmer-exporter clusters: farmer-only training, exporter-only training, farmer-exporter joint training, or no training, serving as our control group. The content of the training program was developed based on Good Agricultural Practices (GAP) and was identical across all training groups. As the second intervention, we randomly offer eligibility for GAP certification to farmers in half of the clusters within each training treatment arm. The certificate can convey information about product quality to buyers, and thus being eligible for certification may incentivize farmers to adopt GAP in farm production.

[1] Bai (2021) and Björkman Nyqvist, Svensson, and Yanagizawa-Drott (2022) examine the impact of asymmetric information and reputation between retailers and final consumers. We take this information problem in the final transaction stage as given and focus on potential approaches to mitigating the information problem between producers and downstream intermediaries in the supply chain.

The main finding is that training farmers and exporters together generates much larger effects on technology adoption and quality upgrading than when only farmers are trained. Moreover, training exporters only or certification eligibility has no significant effect on farmers' technology adoption or quality upgrading. We exploit detailed survey data on farmer knowledge, farm-gate transactions, and measures of trust between farmers and exporters obtained from a lab-in-the-field experiment to document potential mechanisms. On the one hand, training farmers increases their knowledge of GAP, relaxing a supply-side constraint to quality upgrading. On the other hand, the intensive interaction between farmers and exporters in joint training improves their mutual trust and buyer-supplier relationship, leading to more contract trade and higher incentives for farmers to upgrade quality. We also explore other potential explanations.

As introduced in Section 2, the dragon fruit supply chain is characterized by many smallholder farmers and medium- to large-scale intermediaries specializing in export or domestic markets. Farmers and intermediaries mostly engage in spot trade at the farm gate, lacking a stable buyer-supplier relationship and contract trade is rarely used. Mostly grown as a cash crop, quality and food safety have been a major obstacle for Vietnam in exporting dragon fruit to high-price countries. Accordingly, the Vietnamese government has been encouraging agricultural producers to adopt GAP through policy interventions, such as GAP training and state-operated GAP certification programs.

Section 3 describes the experimental design and introduces our main measures of technology adoption and product quality. The experiment features a 4×2 factorial design with two randomized interventions—training and certification eligibility. We formed farmer-exporter clusters by matching randomly sampled farmer groups and exporters from the same commune. As our first intervention, we offered training on Good Agricultural Practices (GAP), which is a set of agricultural management practices designed to improve food safety and product quality (Food and Agriculture Organization 2016). Each cluster was randomly assigned to one of four training treatment arms: (1) farmer-only training, (2) exporter-only training, (3) farmer-exporter joint training, and (4) no training which serves as our control group. Within each training treatment arm, we then randomly provide certification eligibility to farmers in half of the clusters. Eligible farmers who met the requirements would be awarded a GAP certificate after the end of our study. In total, our sample consists of 88 farmer-exporter clusters with 1,141 farmers and 228 exporters participating in the experiment.

To increase the accuracy of the measurement of technology adoption, we hired agronomists specializing in dragon fruit to conduct field audits on each participating farmer's GAP compliance twice, 6 and 12 months after the training respectively. The product quality measure is based on a pesticide residue analysis of 18 different types of pesticides conducted by an ISO-certified laboratory. Based on the test results, we constructed a standardized quality index for dragon fruit at the farm level. The audit and pesticide residue testing are mandatory for GAP certification. In addition, we conducted assessments on several observable quality attributes, such as sweetness, skin color, and size of the fruit, to provide measures on other dimensions of product quality.

We present the empirical analysis in Section 4. First, we find that farmer-only training improves technology adoption. It increases a farmer's GAP compliance by 0.46 standard deviation, commensurate with a 6.4 percent increase in compliance relative to the control group. Second, joint training generates a significantly larger effect, increasing GAP compliance by 0.68 standard deviation (a 9.4 percent increase). Accordingly, product quality increased substantially. Farmer-only training reduces the average pesticide residue by 30 percent relative to the control group. Yet, again, farmer-exporter joint training has a significantly larger impact. Pesticide residue falls by 48 percent relative to the average level found in the control group. Third, exporter training and certification eligibility has no significant impact on technology adoption and quality upgrading. As corroborating evidence, we find that training effectively increases farmers' GAP knowledge and expenditures on crucial inputs required for adopting technology. This finding is consistent with the interpretation that our training intervention increased farmers' knowledge on GAP and induced them to upgrade their farming practices.

Do training and quality upgrading improve farmer performance at the farm gate? Studies have shown positive (often limited) training effects on farmers' profit and income (Davis et al. 2012; Fafchamps, Islam, Malek, & Pakrashi 2020). We find that 12 months after the intervention, farmers in the joint training group receive higher farm-gate prices (by 11.5 percent), revenue (by 20 percent), and profits (by 30 percent). However, there is no significant effect on farm performance in the farmer-only training group, although they improved product quality. The differential price and profitability performance of the joint training and farmer-only training groups emphasize the importance of demand-side constraint as a barrier for quality upgrading.

Section 5 provides potential explanations for the major findings. We provide suggestive evidence that improved buyer-supplier relationship may have contributed to the larger effects of joint training. A lab-in-the-field experiment shows that joint training substantially increases mutual trust between farmers and exporters, which is arguably a proxy for buyer-supplier relationship, potentially due to their intensive interaction during the training. As predicted by the model in Section 4.1, a better buyer-supplier relationship can increase contract trade and quality upgrading by reducing monitoring costs. This is confirmed using detailed survey data on contract formation and trade partners. Joint training substantially increases within-cluster trade between farmers and exporters by 31 percent (from 7 percent in the baseline). A large portion of the increase is arranged through informal contracts, which were associated with higher farm-gate price and product quality. This finding is in line with previous studies on contract trade and quality provision (Deutschmann, Bernard, & Yameogo 2021; Macchiavello & Miquel-Florensa 2019; Magnan, Hoffmann, Garrido, Kanyam, & Opoku 2021). By contrast, we find no economically or statistically significant increase in contract trade in clusters with farmer-only or exporter-only training. Compared to other studies, our joint treatment is cost-effective in helping establish buyer-supplier relationship and improving business performance–the return is about 6.9 dollars for each dollar spent. We also explore other potential explanations including knowledge complementarity, lowered monitoring costs, complementarity in quality production, and changes in market structure.

Next, regarding the lack of effect of GAP certification eligibility, our data show that farmers with GAP certificates previously issued by the government do not receive higher prices at the farm-gate. This result holds regardless of whether we control for the farm's GAP compliance or product quality. A plausible explanation is that although GAP compliance is valued by intermediaries in the local dragon fruit supply chain, the government-issued GAP certificate is not considered as a credible device that can mitigate asymmetric information. As a result, providing eligibility has no impact on farmers' incentives to adopt GAP technology. This result is related to the literature on quality disclosure and certification (see Dranove & Jin 2010, for a review). Although a number of studies suggest that the distortions caused by asymmetric information on quality may be "solved" by disclosure of private information through certification (Jin & Leslie 2003; Saenger, Torero, & Qaim 2014), Bai (2021) shows that the credibility of the certificate matters. Our no-effect result of certification eligibility echoes her finding.

This paper is related to the growing empirical literature on the role of relationships and contracts in technology adoption and quality upgrading. While Cai and Szeidl (2018) find that general inter-firm relationships can enhance firm performance[2], we show that buyer-supplier relationships in the supply chain can induce quality upgrading and improve business performance. Moreover, the literature has shown that the lack of enforceable contracts makes producers subject to the holdup problem (Krishna & Sheveleva 2017) and curtails incentives to provide high-quality products (Bai 2021; Macchiavello & Miquel-Florensa 2019) when quality is unobservable to buyers.[3] In this case, randomly providing contracts to producers may incentivize them to upgrade quality.[4] We contribute to this literature in two ways. First, in contrast to randomly assigned orders, we create an opportunity for farmers and downstream exporting intermediaries to meet and potentially establish business linkages. Second, we show that establishing buyer-supplier relationship could be a particularly effective way of facilitating contract formation.

This paper also contributes to the literature evaluating agricultural training programs in two ways.[5] First, we examine how training effects depend on who receives the training in the supply

[2]McMillan and Woodruff (1999) provide evidence that prior information or experience can increase trust and relational contracts between firms in Vietnam. Banerjee and Duflo (2000) show the importance of reputation in contract choice in the Indian software industry. Macchiavello and Morjaria (2015) provides evidence on the role of reputation and relationships where enforcement is lacking.

[3]In such settings, producers may have to establish their reputations through repeated transactions with buyers (Bai 2021; Bai, Gazze, & Wang 2021; Björkman Nyqvist et al. 2022; Zhao 2020). These papers highlight the dynamic feature of learning and reputation-building during the final transaction stage, as a device to replace the role of contracts. By contrast, our paper emphasizes the role of mutual understanding and trust between farmers and exporters in increasing contract trade and incentivizing quality upgrading.

[4]Bold et al. (2022); Deutschmann et al. (2021); Magnan et al. (2021) examine the effect of market access on quality upgrading by randomly assigning contractual arrangement to farmers. In the manufacturing industry, Atkin, Khandelwal, and Osman (2017) show that exporting contracts randomly assigned to rug producers in Egypt improve producer skills and (largely observable) product quality. Mitra, Mookherjee, Torero, and Visaria (2018b) examine the effect of accessing information on wholesale prices in an Indian potato supply chain where farmers have no access to wholesale markets and have to trade through middlemen.

[5]Prior experiments has established field schools (Davis et al. 2012; Feder, Murgai, & Quizon 2004) or offered training (Ashraf, Giné, & Karlan 2009; Grimm & Luck 2020; Kondylis, Mueller, & Zhu 2017) to educate farmers on certain cultivation techniques. Others used information and communications technology to provide agricultural advice to farmers (Casaburi, Kremer, Mullainathan, & Ramrattan 2019; Cole & Fernando 2021).

chain. Beaman, BenYishay, Magruder, and Mobarak (2021) show that targeting centrally connected farmers is important for technology adoption.[6] To our best knowledge, our paper is the first to study the effect of jointly training both buyers and producers. Second, we focus on a quality-enhancing technology rather than yield- or productivity-improving technologies as discussed in the literature. When output quality is unobservable to buyers, training farmers alone may not be effective in promoting quality upgrading. Our study shows that, compared to farmer-only training, farmer-exporter joint training on quality-enhancing technology results in much higher technology adoption, quality upgrading, and profits at the farm-gate.

2 Study Setting

2.1 Good Agricultural Practices (GAP)

Food safety and quality have become a primary concern for consumers. In response to rising demand for safe agricultural products, governments and agribusinesses have been working to promote the use of Good Agricultural Practices (GAP) in the production of fresh fruits and vegetables. GAP is a farm management system consisting of rules and procedures that guide producers to grow, harvest, and process agricultural products in accordance with international requirements on food safety and environmental protection (Food and Agriculture Organization 2016). In 2008, Vietnam's Ministry of Agricultural and Rural Development (MARD) developed VietGAP based on the EurepGAP program.[7] Due to mounting concerns on food safety and quality of Vietnamese products, in 2017 the government amended VietGAP to enhance regulations on pesticide and chemical use.

From an exporter's perspective, procuring products compliant with GAP is imperative for selling to foreign buyers. For instance, European importers and retailers increasingly demand GAP certification for Vietnamese agricultural products, as recent inspections in Europe and the United States have revealed violations of pesticide residue levels in fresh fruits and vegetables imported from Vietnam. In the case of dragon fruit, the European Commission's Rapid Alert

[6] Banerjee, Chandrasekhar, Duflo, and Jackson (2013) and Banerjee, Chandrasekhar, Duflo, and Jackson (2019) also find similar results in the context of microfinance and immunization. Both papers demonstrate the importance of central agents in diffusing knowledge. Suri (2011) provides evidence that heterogeneous returns to technology is a crucial determinant of farmers' adoption of hybrid maize.

[7] In 2007, EurepGAP was re-named GlobalGAP to reflect its growing use by countries outside Europe.

System for Food and Feed (RASFF) reported 19 cases of rejections of shipments from Vietnam at the border due to detection of pesticide residue levels exceeding limits set by the EU (European Commission 2014-2019). In a 2017 inspection report, the California Department of Pesticide Regulation found illegal pesticide residue levels in 100 percent of samples of Vietnamese dragon fruit (California Department of Pesticide Regulation 2017).

Yet adoption of GAP remains low among Vietnamese farmers. Several factors may have hindered GAP adoption. First, although farmers are aware of GAP standards, transfer of technology for implementing GAP may have been limited due to inexplicit guidelines and difficulty in self-learning GAP procedures. Second, if intermediaries, or buyers at the farm gate, cannot verify GAP compliance and safety of dragon fruit, then this may severely undermine farmers' incentives to comply with GAP standards due to low expectations of quality premium. Finally, other factors such as financial constraints may also prevent farmers from adopting GAP.

2.2 Dragon Fruit Supply Chain

Dragon fruit (better known as *pitaya* in South America and *thanh long* in Vietnam) is a cactus species grown in tropical regions as an ornamental plant or fruit crop (see Online Appendix Figure A-1 for a picture of dragon fruit). As a perennial crop, the fruit is harvested twice a year in southern Vietnam, once during the dry season (October - February) and once during the wet season (March - September). In 2018, dragon fruit accounted for one-third of the total export value of Vietnamese vegetables and fruits (General Office of Customs 2018). The largest export market is China, which accounts for more than 90 percent of export volume in 2015 and about 80 percent of national output (Binh Thuan Dragon Fruit Center 2019). The fact that it is hard for Vietnamese dragon fruit to enter other high-price markets (e.g., Canada, Japan, South Korea, Netherlands, and US) reflects its quality problem.[8] Agricultural experts point out that inappropriate use of chemical pesticides and growth regulations during the on-farm production stage is a major factor hindering the production of high-quality dragon fruit (Trinh et al. 2018).

Figure 1 illustrates the dragon fruit supply chain in Binh Thuan province, where our experiment

[8] General Office of Customs data show that the average unit price of dragon fruit exports to several countries (Canada, Japan, South Korea, Netherlands, and United States) are 3-7 times higher than those to China.

was implemented. There are three main layers in the supply chain: farmers, intermediaries, and buyers from foreign or domestic markets. Most farmers operate on small plots, cultivating less than one hectare of land. Intermediaries can be exporters or domestic retailers. Exporters operate packing facilities at which fruits are cleaned, packed, and prepared for shipping to overseas markets. Domestic retailers supply to the regional or national domestic market. In the supply chain that we study, the share of products sold to the domestic market is only 3 percent. As a result, our study focuses on intermediaries in the export supply chain.

Exporters receive orders from overseas markets and decide the price, volume, and quality required to meet buyer demand (e.g., GAP compliance). They may purchase fruits directly from farmers or indirectly through small-scale local collectors, who can be considered middlemen in the supply chain, searching for farms that are ready for harvesting and purchasing fruits on behalf of exporters.[9] Contract trade, including informal verbal arrangements and formal written contracts, is rare in the local supply chain. Typically, farmers engage in spot trade with local collectors or exporters, in which both sides bargain at the farm gate before harvest. Price offers are based on grading criteria that largely depend on certain exterior features of the fruit, such as size and skin condition. One farmer may be approached by multiple buyers who compete to offer the highest price. Buyer-supplier relationship varies across seasons due to competition among buyers and lack of contract trade in the supply chain.

Food safety is difficult to observe and verify at the farm gate. Moreover, testing food safety in a laboratory is not only costly but also time consuming, which can be highly problematic for a perishable fruit. Hence, food safety tests are rarely conducted in local trade of perishable fruits such as dragon fruit. This creates information asymmetry on quality between farmers and intermediaries: the farmer possesses information on quality but intermediaries do not. This information asymmetry on product quality further discourages farmers from investing in quality-upgrading technologies. In this paper, we exploit a randomized field experiment to explore whether and how GAP training, buyer-supplier relationship, and certification eligibility affect farmers' GAP adoption and quality upgrading in the Vietnamese dragon fruit industry.

[9] Exporters purchase through local collectors to save transaction costs associated with searching for farmers.

3 Experiment, Data, and Quality Measurements

The experiment was implemented across multiple districts in Binh Thuan province, which accounts for 55 percent of national production of dragon fruit in Vietnam (Binh Thuan Dragon Fruit Center 2019). We formed farmer-exporter clusters as our unit of randomization at the cluster level. The experiment is designed with two cross-randomized interventions. First, we randomly assigned each cluster to one of the four GAP training treatment arms in equal proportion; then within each assigned treatment arm half of the clusters were randomly assigned to be eligible for VietGAP certification and the other half were ineligible. Below we provide details of the sample selection process and the experimental design.

3.1 Sample Selection Details

Farmer group selection The unit of sample selection for farmers is a farmer group, consisting of around 15 farmers per group. Several reasons make the farmer group ideal as our unit of treatment group. First, farmer groups are self-organized and composed of farmers located in the same town.[10] By assigning treatment at the level of farmer groups, we allow for intra-group learning of a technology, which may increase technology adoption and reduce potential treatment spillovers across groups, given the group organization and geographic characteristics. Second, in the context of Vietnamese agriculture, government support and policy interventions have been previously provided at the farmer group level. We follow this convention by assigning treatment at that same (farmer group) level. Finally, according to government regulations, farmer groups have to be registered with their provincial agriculture agency before they can receive any assistance from the government. Therefore, by partnering with a government agency we were able to use the list of registered farmer groups as the pool for random sampling in two major districts, namely, Ham Thuan Bac and Ham Thuan Nam.[11] We randomly selected 88 farmer groups out of 406 registered ones and sent out letter invitations asking farmers to participate in our experiment. In total, 1,141 farmers from 88 farmer groups participated in the

[10]There may be more than one farmer group in a town. We limit our sample to one farmer group from each town to prevent treatment spillover across different groups.

[11]Figure A-2 presents a map of Binh Thuan province with the two districts highlighted.

baseline survey and were offered training and certification eligibility treatments.[12]

Exporter (exporting intermediary) selection We also recruited exporters to participate in the GAP training program. However, unlike farmer groups, the list of exporters was not readily available. To create a list of exporters, we carried out a search and recruitment drive in the two districts in August 2017. In total, we found 325 dragon fruit exporters operating in the area, of which 228 eventually participated in our study.[13] Using geographic information on the exporters and farmer groups, we matched each farmer group to on average 3 of the closest exporters to form a farmer-exporter cluster.

3.2 Experimental Design and Implementation

Figure 2 illustrates the experiment design. Treatments were randomized within 11 geographical strata, where each stratum is either a single commune or a coalition of multiple communes. Our main sample consists of 88 farmer-exporter clusters, which is our unit of randomization. We randomly assign the 88 clusters in equal proportion (22 clusters in each treatment arm) to one of the four training treatment arms: (i) farmer-only training, in which only farmers in the cluster were invited to receive GAP training; (ii) exporter-only training, in which only exporters in the cluster were invited to receive GAP training; (iii) joint training, in which farmers and exporters in the cluster were both invited to receive GAP training in the same classes; and (iv) no training, which is our control group.

Then within each training treatment arm we randomly assign half of the clusters to be eligible for VietGAP certification. Farmers in the *eligible* group could receive VietGAP certification at the end of our study if they meet requirements on GAP standards assessed through a field audit and pesticide residue testing, while farmers in the *ineligible* group could not be certified. All farmers were notified of their eligibility at the start of the training program by our partner, the agricultural extension center in charge of VietGAP certification.[14] Review of the assessment

[12]Some farmers in the selected farmer groups did not participate in the baseline survey and, therefore, are not included in our analysis.

[13]To incentivize exporter participation, Binh Thuan Dragon Fruit Research and Development Center offered to support the registration of exporters in the supply chain database that was planned to be launched in 2020 by the Vietnamese government.

[14]Due to financial constraints, in the VietGAP program the agricultural extension center each year selects a few farmer groups and conducts fully subsidized training and certification evaluation with them as a regular practice.

results took place after the end of our second follow-up survey. Therefore, our study examines the effect of *eligibility for certification* rather than the effect of being certified. All administrative cost for certification, including auditing and testing fees, was fully subsidized. A summary of the certification process is presented in Table A-1.

The experimental design allows us to investigate three main questions in this paper. First, how and to what extent does training on quality-enhancing technology affect farmers' decisions to upgrade their farming practices and product quality? Second, compared with the approach of the conventional extension program to train farmers only, can training exporters, or training them together with farmers generate larger effects? Third, how does certification eligibility on agricultural technology affect decisions on technology adoption and quality upgrading? If certification can credibly signal farming quality, then certification eligibility may provide incentives for farmers to adopt this technology.

To implement the interventions, we partnered with Binh Thuan Dragon Fruit Research and Development Center (BTDC), a provincial agricultural extension service agency. BTDC was an ideal partner for collaboration, as it conducts research on dragon fruit production, provides extension services to farmers, and is designated by the central government as the VietGAP certifier for dragon fruit. Agronomists at BTDC developed GAP training materials and conducted field audits for VietGAP certification.[15] In collaboration with BTDC, our project provided GAP training programs and conducted surveys and audits with farmers and exporters.

Farmers and exporters were invited to attend GAP training sessions, which were instructed by BTDC staff. The training materials were designed specifically for implementing GAP in dragon fruit farming, covering five on-farm management sectors for implementing GAP: (1) Pesticides; (2) Production Area and Tools; (3) Hygiene and Work Safety; (4) Soil, Water, and Waste; and (5) Fertilizers. Our training material laid out a practical step-by-step guide for implementing and monitoring GAP in the field along these five sectors. Figure A-3 shows several agricultural

Our experiment follows closely the regular procedure of the VietGAP program. All of the administrative, training, and testing costs were subsidized as part our study yet only eligible farmers, which were randomly selected by our research team, could be certified.

[15]BTDC had been providing VietGAP training for several years before our study. However, our study was the first to provide training on an updated version of VietGAP (TCVN 11892-1: 2017 - Good Agricultural Practices for cultivation). Accordingly, agronomists developed new training materials and guidelines for this study.

technologies – irrigation methods, pest control devices, and water management – introduced through our GAP training program. In addition, all farmers and exporters who participated in training were provided with a GAP checklist that was later used for auditing compliance with GAP. The English version of the checklist is provided in Table B-1.

Participants went through an intensive three-day training program, which included lectures, focus group discussions, and a field demonstration by experts on the last day of training. They were required to attend all sessions and daily attendance was recorded by BTDC staff.[16] After concluding the training program, BTDC organized a one-time group meeting between farmers and exporters assigned to the same cluster for all treatment and control groups. The meeting was intended to promote cooperation and partnership between farmers and exporters.

3.3 Surveys and Summary Statistics

Figure 3 provides an overview of the timeline of the study. In total, we conducted three rounds of interviews with farmers and exporters, including a baseline survey and two follow-up surveys.[17] The baseline survey was performed in the winter of 2018, immediately before the training intervention. Farmers were asked questions on (a) demographic and farm characteristics, (b) farm production and transactions, (c) expenses on farm inputs, (d) self-reported compliance with GAP, and (e) cognitive and non-cognitive abilities. The exporter survey was administered to the representative of each firm, who was often the owner or office manager of the firm. We asked questions on (a) firm characteristics, (b) trading and export activities, and (c) business expenses.

The two follow-up surveys were administered approximately 6 and 12 months after the training intervention, respectively, corresponding to the two harvest seasons after the training. Extension staff at BTDC visited farmers and exporters to conduct individual interviews. Each round of follow-up survey with farmers included a basic module that asked farmers to report on-farm production and transactions, an on-farm GAP audit module, and a product assessment module.

[16] After the last training session, participants with full attendance received a small payment in the amount of 100,000 Vietnamese Dong (VND; approximately 4.3 US Dollars).

[17] All interviews were conducted in person, except the second follow-up survey with exporters which was conducted via phone due to the outbreak of COVID-19.

Given the importance of obtaining a consistent measure of product characteristics across farms with different crop cycles, BTDC staff phoned each farmer in advance to check the production stage and expected harvest day to schedule the follow-up survey around the day of harvest.

Table 1 reports the basic summary statistics from the baseline survey with farmers and exporters. Panel A shows farmer demographics and farm characteristics. The average farmer has around 11 years of experience in growing dragon fruit and cultivates a dragon fruit farm with a size of 0.75 hectares and around 750 dragon fruit trees. The balance check regarding farmer characteristics in Online Appendix Table A-2 suggests that the farmer sample seems well balanced across treatment and control groups and the attrition has been low in all surveys.

Panel B presents the summary statistics of farm-gate trade characteristics based on farmer reports of sales in the season prior to the intervention. The median farmer sold to a buyer whom they have known for approximately four years.[18] Only 1 percent of farmers had a formal written contract with a buyer. The vast majority of farm-gate purchases are made by local collectors (90 percent); only 6 percent are purchased directly by exporters and 3 percent by domestic retailers. The high level of transaction between farmers and local collectors is not surprising, since local collectors receive orders from exporters and visit farms to collect and transport dragon fruit to exporters' packing facilities, behaving like agents representing the exporters.[19] Consistent with the customs data, 90 percent of transactions were for exports to China, 5 percent were for high-price Asian markets(excluding China), and 2 percent were exported to EU and US markets.[20] The remaining 3 percent of sales were for the domestic market.

Panel C shows summary statistics on the characteristics of exporters. The average exporter had been in operation for almost nine years, and traded roughly 420 tons of dragon fruit during the past six months, or one season. The median exporter purchased dragon fruit at a price of 13,000 VND per kilogram and sold it at 15,000 VND per kilogram.The balance check in Table

[18]This does not necessarily mean that they have traded for four years. Although we did not ask whether the farmer had continuously or exclusively traded with the same buyer throughout this period, based on conversations with farmers and exporters, we believe that farmers trade with multiple buyers across different seasons.

[19]During the pilot stage of this study, we discussed the possibility of including local collectors in our study with BTDC. In the end, BTDC recommended working with exporters because of logistical issues and for ensuring the efficacy of the program. Nevertheless, we are aware that leaving out local collectors is a limitation of our study. We discuss how this potentially affects our study findings in Section 5.1.2.

[20]In most Asian countries outside China, the exporting prices of dragon price are much higher than those in China. These countries are all high-price Asian markets.

A-3 shows that exporter characteristics are not systematically different across treatment groups. Importantly, attrition rates of exporters are not significantly different between treatment and control groups, although they (26 percent) are higher than that of the farmers' (3 percent).

3.4 Measurements on Technology Adoption and Product Quality

We measure technology adoption using GAP compliance, which is constructed as the standardized score of an on-site audit of farmers' compliance with GAP standards. It is a comprehensive measure of farm production quality evaluated along five on-farm management sectors as listed in Section 3.2. The GAP audit was conducted twice (once in each survey round) by BTDC staff for all farmers in our study.[21] The auditors filled out the 32-item GAP checklist in which each item was marked as either pass or fail. GAP compliance is based on the number of items that a farmer passed in the audit.

We use pesticide residue as our main measure of product quality, which captures a key component of food safety and is typically unobserved by buyers. Pesticide residue tests were conducted at a private ISO-certified chemical testing laboratory. The test reports residue levels (mg/kg) for 18 pesticides on fruit samples collected from 264 randomly sampled farmers.[22] Safety regulations by governments and agricultural businesses mandate that a pesticide residue in food products cannot exceed a Maximum Residue Limit (MRL), which is the maximum concentration of a pesticide residue (expressed as mg/kg) that is legally tolerated in or on a food. We construct two indicators of product quality based on pesticide residue tests: (1) the mean level of pesticide residue; and (2) compliance to MRLs in each of the four countries - China, Japan, EU and US.

We incorporated an on-farm product assessment module in the follow-up surveys to measure observable product attributes along four main dimensions: sweetness, appearance (skin color and bract color), size (length and width), and weight. Details on measurement methods are provided in Online Appendix Section D. These product attributes were chosen to represent

[21] For logistical and data quality reasons, farmers in the same stratum were audited by the same auditor. In our estimation, auditor-specific factors in audit scores, if any, are subsumed by strata fixed effects.

[22] Due to a limited budget, we were only able to conduct tests using three farmers from each cluster, including the two control clusters outside the study area. Farmers were randomly chosen using a random number generator. In Online Appendix Section C, we provide detailed information on the field logistics for sample collection, the list of pesticides and their MRLs set by the EU, US, Japan, and China, and a sample report showing results from pesticide residue testing.

product quality that can be directly observed and evaluated by buyers at the farm gate.

4 Technology Training, Adoption, and Quality Upgrading

This section presents experimental evidence on the impact of GAP training and certification eligibility on farmers' technology adoption, quality upgrading and sales performance. We first provide predictions derived from a theoretical model built to resemble several features of the supply chain of interest. Next, we present visual evidence of treatment effects on farmers' adoption and quality upgrading followed by the econometric specification and main empirical results.[23]

4.1 Theoretical Predictions

We propose a stylized model that delivers testable predictions of the impact of technology training, buyer-supplier relationship, and certification eligibility on technology adoption and quality upgrading. The full model is provided in Online Appendix section E. The model features information asymmetry between exporters and farmers concerning the latter's GAP compliance at the production stage and product quality at the transaction stage. Such information friction depresses the farmer's incentive to adopt technology and improve product quality. Farmers and exporters can trade on spot or through contracts. Having a contract could be beneficial to both sides as it insures the farmer a price premium for quality; it can also procure the desired product for the exporter. However, implementing contracts incurs high compliance cost to the farmer and high monitoring cost for the exporter.

The model makes several predictions for our interventions. First, increasing farmers' GAP knowledge (e.g., through farmer training) may induce technology adoption and quality upgrading, as it lowers the production cost of quality and thus increases the production efficiency. Second, increasing exporter knowledge (e.g., through exporter training) alone may be ineffective as the low production efficiency on the supply side still prevents the farmer from providing high quality. Third, increasing both farmer and exporter knowledge or establishing a buyer-supplier

[23] We adhere to the empirical analysis outlined in the pre-analysis plan of this study registered at the AEA RCT Registry for the main empirical specification and outcome variables.

relationship (e.g., through joint training) induces an increase in contract trade, resulting in improved technology adoption, quality upgrading and sales performance by lowering monitoring costs. The effect is stronger than the farmer only group because it relaxes the constraints on both demand and supply sides. Finally, providing certification improves technology adoption and quality upgrading, as (credible) certification mitigates asymmetric information on product quality and strengthens farmers' incentive to upgrade quality.

4.2 Graphic Evidence

Figure 4 presents bar graphs of the average outcome across the eight treatment groups, including the control group. Given that treatments are randomly assigned in our experiment as supported by the balance check, the differences among these groups can be interpreted as preliminary evidence of the effect of the treatments on technology adoption and quality upgrading.

Panel (a) shows the difference in farmers' GAP compliance rate across treatment groups. The left side of the panel shows the average GAP compliance, standardized by the control group's mean and standard deviation, of different training groups without certification eligibility and the right side shows that for training groups with certification eligibility. The main finding is that, while both the farmer training and joint training groups show significant increases in GAP compliance compared to the control group, the effect from joint training is much larger. By contrast, exporter training has an insignificant effect: farmers in the exporter training group had similar GAP compliance relative to those in the control group. Interestingly, certificate eligibility shows almost no difference in average GAP compliance between farmers with and without certificate eligibility, given that they receive the same training treatment.

In Panel (b), we compare the mean pesticide residue level across the treatment groups. The results are similar to Panel (a). Overall, the graphic evidence suggests that farmer-only and joint training produce visible impacts on technology adoption and quality upgrading with joint training producing much larger effects, whereas the effects of other treatments (i.e. exporter training or certificate eligibility) are small and insignificant statistically. In the rest of this section, we utilize our experimental data to estimate the causal impacts of technology training and certificate eligibility on farmers' technology adoption, product quality, and farm-gate trade.

4.3 Empirical Strategy

Our main empirical specification includes a linear specification with indicators for each of the three training treatments, certification eligibility treatment, and the interactions between them. The estimation equation is as follows:

$$
\begin{aligned}
Y_{icst} \;=\;& \alpha_0 + \Sigma_G \beta_G \text{Training}^G_{cs} + \gamma_0 \text{Eligible}_{cs} + \Sigma_G \gamma_G \text{Training}^G_{cs} \times \text{Eligible}_{cs} \\
& + X_{ics} + \xi_s + \theta_t + \epsilon_{icst}, \qquad (1)
\end{aligned}
$$

where Y_{icst} is a measure of quality or other performance measures for farmer i in farmer-exporter cluster c and stratum s in round t. $Training^G_{cs}$ is an indicator that takes the value 1 if cluster c is assigned to training treatment $G = \{\text{Farmer, Exporter, Joint}\}$; otherwise, the value is 0. $Eligible_{cs}$ is equal to 1 if cluster c is eligible for VietGAP certification and 0 otherwise. X_{ics} is a vector of farmer and exporter characteristics collected from the baseline survey immediately before training. ξ_s is a vector of strata fixed effects that picks up variations arising from geographical differences. θ_t is a fixed effect for the survey round that picks up any survey round fixed effect or seasonal effect. ϵ_{icst} is the idiosyncratic error term.

Our coefficients of interest for evaluating the effects of different training interventions are elements of vector $\beta_G = \{\beta_{Farmer}, \beta_{Exporter}, \beta_{Joint}\}$: β_{Farmer} measures the impact of providing GAP training to farmers only, $\beta_{Exporter}$ measures the impact of providing GAP training to exporters only, and β_{Joint} measures the impact of providing GAP training to both farmers and exporters through joint training sessions. By comparing the estimates of different training treatments, we can test the relative effectiveness of each training program on technology adoption, product quality, and farm-gate performance. The coefficient γ_0 is interpreted as the difference in farmer outcomes between groups eligible and ineligible for VietGAP certification. Finally, the set of coefficients on Training × Eligible terms, $\gamma_G = \{\gamma_{Farmer}, \gamma_{Exporter}, \gamma_{Joint}\}$, estimate the differential effects of certificate eligibility with regard to different training treatments. The theoretical framework in Section 4.1 predicts that the coefficient β_{Farmer} should be positive because GAP training increases farmer knowledge and thus improve their production efficiency. We also expect $\beta_{Exporter}$ to be insignificant because training exporters alone may not be effective when the supply-side constraint is not relaxed. The model also predicts that β_{Joint} should be larger than β_{Farmer} because joint training facilitates contract formation and incentivize technology adoption and quality upgrading. Finally, if the certificate is a credible signal of quality and therefore provides stronger incentive for quality upgrading, both γ_0 alone and the sum of γ_0 and any one of the γ_G should be positive.

The key identification assumption for causal interpretation of our coefficients is that farmers in treatment groups did not have systematically different outcomes from those in the control group for reasons other than the treatment itself. This assumption will be violated if, for instance, farmers self-selected into the GAP training program or were eligible for certification based on unobserved dimensions of farmers' abilities. As treatments were randomized across groups within geographic strata, we believe that a farmer's treatment status is unrelated to the unobserved error term. Nonetheless, we cannot completely rule out the presence of some factors that may arise as part of the training treatment (e.g. building a personal relationship with extension service staff during the training sessions), which may pose a potential threat to our causal interpretation. We provide corroborating evidence to show that these factors are unlikely to drive our main results.

We estimate specification (1) by using ordinary least squares estimation. In the main analysis, if the outcome is measured in both survey rounds, then we pool both rounds and estimate the average treatment effect. In the event we believe that treatment effects are expected to evolve across rounds or if seasonal or temporal factors may potentially influence the result, we show the estimates separately for each round. For estimating the effects of training and certification eligibility on farm-gate outcomes (e.g., price and profits) we follow McKenzie (2012) and use the ANCOVA specification by including lagged outcomes from the baseline survey as controls.

In light of recent studies that document proper inference techniques with randomized experiments (e.g., Young 2019), we further conduct randomization inference tests and report p-values based on 5,000 permutations. The test is implemented by re-randomizing the assignment of treatment separately for each training or certification treatment without altering the other treatments within each stratum. Specifically, since there are three training treatments in our study, one permutation involves three independent trials of randomization, where we re-randomize only one of the three training treatments while holding the other two treatment assignments and certification eligibility assignment unchanged. Then in a separate trial we fix the training assignments and re-randomize the assignment to certification eligibility. In addition, to account for multiple hypothesis testing, we follow Anderson (2008) and adopt the two-stage false discovery rate (FDR) control approach when interpreting the statistical significance of the results.

4.4 Impact on GAP Technology Adoption

We first present the results on the impact of training and certificate eligibility on GAP compliance in Table 2. Column 1 reports the estimates from equation (1) using the standardized total score on the GAP audit as the outcome variable. We find four main results. First, consistent with the theoretical predictions in Section 4.1, when farmers receive technology training, they substantially improve their GAP compliance. As shown in the table, farmer-only training increases GAP compliance by 0.459 standard deviation. When focusing on compliance with pesticide management (Column 2) we find a similar result. Farmer-only training increases compliance with GAP pesticide management by 0.352 standard deviation. Both estimates in Columns 1 and 2 are statistically significant at the 1% level. We also find a significant increase in GAP compliance in other areas, including production area and equipment (Column 3) and soil, water, and waste management (Column 5).

Second, compared with farmer-only training, joint training has a substantially larger effect on technology adoption. It increases farmers' GAP compliance by 0.676 standard deviation and GAP compliance of pesticide management in particular by 0.556 standard deviation. Both of them are substantially larger than and statistically different from the effects of farmer-only training at the 10% and 1% significance levels.[24] The stronger effect of joint training relative to farmer-only training may arise from some special advantages of joint training, such as improved buyer-supplier relationship or knowledge complementarity, as to be discussed in Section 5.

Third, exporter-only training has no significant effect on farmers' GAP compliance. If farmers' GAP knowledge can enhance quality upgrading, as to be shown below, then the no-effect result

[24] The p-values on test of equivalence between estimated treatment coefficients are provided in the table.

suggests that there is no knowledge transmission from exporting intermediaries to farmers in the exporter-only training group. This could be due to the market structure: without a formal contract, small farmers can freely choose buyers at harvest, exporters have no incentive to invest their time in training farmers. Alternatively, according to the model in Section 4.1, this no-effect of exporter training may arise if exporter knowledge mitigates asymmetric information only in contract trade, which is rare at the baseline.

Finally, we find no significant impact of eligibility for VietGAP certification on GAP compliance. Across six columns, none of the coefficients are statistically significant at conventional levels after adjusting for multiple hypothesis testing. Coefficients on interaction terms are also statistically insignificant, suggesting that being eligible for certification creates no additional effects of training on technology adoption. The insignificant effect of certification eligibility seems surprising and contradicts with our theoretical prediction, indicating that the certificate may not effectively solve the information asymmetry in the Vietnam dragon fruit supply chain. We will explore the reasons for this outcome in greater detail in Section 5.2.

Table A-4 reports estimates on GAP compliance by survey round to examine its temporal patterns. The results between the two rounds are quantitatively and qualitatively similar. Table A-5 reports the heterogeneous treatment effect with respect to farmer characteristics.[25] Across all 10 columns, the coefficient estimates of farmer training and joint training are quantitatively similar to those reported in Table 2. Interestingly, we find that farmers who received secondary education, have savings at a bank, and are present biased are likely to exhibit larger impacts of joint training on quality upgrading. Additionally, for farmer-only training, high level of entrepreneurship and having bank savings are positively associated with quality upgrading. Table A-6 shows no heterogeneous impacts of training with respect to exporters' characteristics, including age, facility size, and export volume to high-price markets.

In order to document how training drives farmers to comply with GAP, we provide two pieces of corroborating evidence: knowledge acquisition and investment in farm management practices.

[25] We restrict the set of farmer characteristics used in this analysis to those specified for heterogeneity analysis in our pre-analysis plan: gender, secondary education, farming experience, size of farm, savings at bank, business attitude, entrepreneurship, present bias, risk attitude, and raven's test score.

Corroborating evidence: Knowledge acquisition from training

As shown in the literature, the lack of knowledge on proper technology may be a barrier to quality upgrading (Jack 2013; Magruder 2018). We first examine the treatment effect on the GAP knowledge of farmers exporters by exploiting post-training test scores on GAP. We measure their GAP knowledge based on the answers to 10 relevant multiple-choice questions in the first follow-up survey round after the training (see Table B-2 for the list of questions). The standardized score of the 10 answers is used as a measure of knowledge of GAP technology. In the second follow-up survey round, we asked farmers five questions on food safety awareness (see Table B-3 for question list). In addition, our surveyors also conducted inspections at collection facilities of exporters to assess their compliance with Good Handling Practices (GHP), which is the intermediary counterpart to GAP providing standards for intermediaries in the food supply chain (see Table B-4 for question list).[26] These measures allow us to better understand potential mechanisms that drive the impact of training on technology adoption.

Table A-7 shows that technology training substantially improves farmers' and exporters' knowledge on GAP. First, when only farmers (or exporters) are trained there are no improvements in the exporters' (or farmers') knowledge, suggesting no knowledge spillover from one group to the other. Second, jointly training farmers and exporters does not improve the farmers' knowledge of GAP more than when only the farmer is trained. This suggests that there was, if any, little knowledge transfer of GAP from exporters to farmers in joint training. Finally, we find no significant difference in exporters' compliance with GHP between treated and control groups as shown in column 4. This makes sense as the training focuses on farmers' GAP compliance rather than intermediaries' GHP compliance.

Corroborating evidence: Changes in input expenditure

We next document evidence on farmers' input expenditure in support of farmers' investment in upgrading farm management practices in accordance with GAP standards. Table A-8 presents the results. Column 1 shows that, consistent with evidence on GAP compliance, farmer-only training and joint training both increased production costs; yet this can be only observed during the first season (Panel A) but not in the second (Panel B). One possible explanation for the

[26] Our treatments did not provide information or training on GHP.

difference across seasons is that farmers need to make some investments to implement GAP, but once invested, reinvestment is not needed or is much smaller in the second season. Columns 2-8 show estimates for specific input categories. Spending on the facility increases by almost 200 percent during the first six months after training but is near zero in the latter six months. This finding is consistent with farmers incurring a fixed cost for upgrading farm facilities to adopt GAP. Also, spending on pesticides, utilities, and hours worked during the second season is significantly higher for farmer and joint training, which is possibly indicative of increased usage of high-quality pesticides and variable inputs, such as electricity and farm work, into agricultural production. Finally, VietGAP certificate eligibility does not significantly change farmers' input costs, consistent with the previous result on GAP compliance.

4.5 Impact on Quality Upgrading

Table 3 presents estimates of equation (1) using pesticide residue as the measure for product quality. Column 1 uses the average of 18 pesticide residue levels, where each residue level is normalized by EU's Maximum Residue Limit (MRL). The results show that farmer-only training reduces the average pesticide residue by 0.43 MRL units, which reflects a 31 percent drop from the control group's average residue level (1.4 MRL units). Joint training has a much larger effect, reducing the average pesticide residue by 0.67 MRL units, or about a 50 percent reduction relative to the control group's mean. Columns 2-5 examine treatment effects on compliance to MRLs of China, Japan, EU, and US, respectively. The dependent variable is an indicator variable equal to one if all 18 tested pesticides comply to the respective country's MRL. We find that joint training increases compliance to Japan's MRL by 0.24 from a base compliance rate of 0.55. We do not find any effect on compliance with other countries' MRLs.[27] Consistent with Table 2, exporter-only training or certificate eligibility has no effect on pesticide residue levels.

Table A-9 presents treatment effects on observable product attributes. Each column is a separate regression with a different measure of product attribute standardized by the control group's mean and standard deviation. Because there are six observed attributes, we calculate the

[27]The county-differential effect may be due to large differences in MRLs across countries (for comparison, refer to Table C-1 in the Online Appendix). The result implies that VietGAP may be particularly effective for qualifying for exports to Japan.

average z-score across six attributes as an index of overall product attribute (Column 1). The estimates suggest that overall neither GAP training treatments nor certificate eligibility led to a significant change in observable product attributes. The only exception is that certification eligibility has a marginally significant negative effect on fruit weight by 0.29 standard deviation (Column 6).

4.6 Impact on Farm Sales Performance

To what extent do farmers benefit from such improvements in product quality? This question is important for understanding whether farmers have incentives to invest in quality-upgrading technologies. In this section, we focus on presenting findings on the effects of GAP training on farmers' business outcomes. The certification eligibility treatment is unlikely to directly affect farm sales performance through the VietGAP certificate because the certificate was awarded after the second followup survey and therefore farmers did not have the certificate nor did they know about the certification result at the time they sold their products.

Table 4 reports results from estimating (1) for each survey round with various farm business outcomes: farm-gate prices, revenue, and profit. To account for potential spurious outliers, we winsorize the sample at the top and bottom one percentile for each outcome variable and survey round. Price and volume are log-transformed while revenue and profit are in levels because of zero or negative values (for profits). Panel A shows that training has no economically meaningful impact on farmers' business outcomes in the first season. However, in Panel B (second season), farmers in the joint training group sold dragon fruit at significantly higher prices (10.6 percent) and earned higher revenues (23 percent) and profits (27 percent) relative to the control group. By contrast, farmer-only training has no economically significant effect on farm sales performance. This may seem surprising since farmers were making costly investment to upgrade quality when the profit gains turned out to be zero. Interviews with farmers suggest that this may be due to their high expectation of the training program initially.[28]

[28] Our GAP training program was advertised to participants as "Technology training for dragon fruit export supply chain". Interviews with farmers at baseline indicate that farmers were eager to participate in order to join export supply chains for high-price Asian and European markets. Thus, participation in the training program may have raised their expectations about the returns to quality upgrading, which incentivized them to invest more.

Table A-10 reports the treatment effects on product market destinations using farmer-exporter trade data.[29] Joint training significantly and substantially increases sales to high-price Asian markets, accompanied by a decline in sales to China. As there are no significant changes in total volume, these results suggest that training induced export reallocation from the low quality-low price Chinese market to other proximate markets that require higher quality and pay higher prices. We find no such effect in the farmer-only or exporter-only training groups.

Next, we present results on the effects of training on exporters' business performances. Table A-13 reports effects of training on various sales outcomes – price paid to suppliers (farmers or local collectors), price sold to buyers, trade volume, revenue, cost and profit. Across the two seasons, there is no significant training effects on exporters' sales. Admittedly, we may not be able to detect training effects on exporters' businesses given the larger scale of exporters compared to individual farmers. Table A-14 shows estimates of training on exporters' sales to different markets. Consistent with our previous finding using farmers' sales data, the estimate on joint training in Column 2 of Panel B suggests that exporters increased sales to high-price Asia market (most Asian countries outside China) by 22.5 percent although it is estimated without precision.

Finally, one potential concern is the presence of treatment spillovers across farmer-exporter clusters, which could bias our estimates. To address this issue, at the start of this project we sampled four farmer groups outside our two study districts as spillover-proof control groups. They are within the same province but located sufficiently distant from our experiment regions. As with control groups in the treated districts, we did not provide any training or certification eligibility to the spillover-proof groups but conducted the same baseline and follow-up surveys, including GAP audit and product assessment modules. The idea is to test for spillovers by comparing key outcomes between control groups in treated districts and the spillover-proof control group.[30] Table F-1 presents the results of this empirical exercise. Overall, we do not find evidence to suggest that our estimates are systematically biased due to treatment spillovers.

[29] In Tables A-11 and A-12, we also report estimates on certification eligibility and on its interaction terms with training treatment for farm-gate sales. The insignificant, close-to-zero estimates are not surprising since eligibility has no meaningful impact on farm quality and the evaluation for the VietGAP certificate was still ongoing at the time of the survey.

[30] Online Appendix F provides more details on the design and methodology to test local treatment spillovers.

To summarize, we find that GAP training to farmers is substantially effective in inducing GAP adoption and promoting quality. However, the effect is even stronger when farmers and exporters are trained together. Yet, offering eligibility for VietGAP certification has no significant impact. Understanding the mechanisms driving these results is important for generating policy implications, as we do in the next section.

5 Discussion on Experimental Findings and Potential Mechanisms

5.1 Why Does Joint Training Have Larger Effects?

The larger impact of joint training on technology adoption, quality upgrading, and farm sales performance may arise from some special advantages associated with joint training, compared with farmer-only and exporter-only training. For instance, joint training may enhance the buyer-supplier relationship between the associated farmers and exporters; it may also generate knowledge complementarity or change the market structure. This subsection discusses several potential mechanisms that may contribute to the larger effect of joint training.

5.1.1 Buyer-Supplier Relationship

The intensive interaction between farmers and exporters in joint training offers an opportunity for them to improve mutual understanding and trust, which help improve their relationship. As predicted by our model in Section 4.1, a better buyer-supplier relationship can increase contract trade by reducing monitoring costs.[31] And the contract, which may formally or informally guarantee producers a quality premium, can promote technology adoption and quality upgrading (Deutschmann et al. 2021; Macchiavello & Miquel-Florensa 2019; Magnan et al. 2021). Although the design of the experiment does not allow us to separately identify the effect of buyer-supplier relationship, measures on trust obtained from a lab-in-the-field experiment and the observed outcome of trade types convey suggestive evidence that joint training improved the relationship between the associated farmers and exporters, which may have played an important role in

[31] This is in line with Cai and Szeidl (2018), who find a positive impact of a broadly defined inter-firm relationship (not necessarily buyer-supplier relationship) on firm performance.

promoting technology adoption and quality upgrading.[32] We discuss this in detail below.

Joint training improves mutual trust

In the baseline survey, 44 percent of farmers indicated distrust towards exporters as the main reason for not contracting with them. From the farmer's perspective, the lack of trust in an exporter may cause the fear of holdup by exporters, especially when contract enforcement is weak (Krishna & Sheveleva 2017). From the exporter's perspective, there is a fear of farmers reneging on contracts and selling to other buyers, which is of concern when exporters are constrained by contracts with foreign buyers.

We conduct a post-training lab-in-the-field trust game with all participants in our study to provide evidence on the impact of joint training on mutual trust between farmers and exporters. Right after concluding the training sessions in our experiment, we invited farmers and exporters to participate in a lab-in-the-field experiment in which participants played two games: a trust game and a dictator game. Both games were designed similar to Ashraf, Bohnet, and Piankov (2006), in which the trust game is designed to measure the level of trust a player (farmer or exporter) has toward her game partner, while the dictator game is designed to measure the level of kindness a player has toward her game partner. In Online Appendix section G we provide more detail on the design of the games.

As shown in Table 5, we find strong evidence that joint training increases farmers' (exporters') trust in their exporter (farmer) partner. We do not find significant increase in trust in other training groups. Because the games were conducted just several days after training and long before the first harvest season, changes in trust should reflect the impact of the treatment and not the effect of farm-gate transactions between farmers and exporters in subsequent seasons. This suggests that the intensive interaction between farmers and exporters improved trust in the buyer-supplier relationship, which may be responsible for the larger effect of joint training on technology adoption, quality upgrading, and farm performance.

[32] One might imagine that farmers and exporters can establish relationship through repeated interactions, and a grim trigger type strategy can help support good farming practices. But such reputation mechanism fails at the baseline in our context. This could be due the high cost of lab-testing and acquiring quality information at the farm-gate, or the exporters' inability of punishing precisely the non-complying farmers, given that product from multiple farmers are pooled at the sale to final buyers.

Joint training increases contract trade

If the intensive interaction in joint training improves buyer-supplier relationship, we should observe an increase in contract trade between the jointly trained farmers and exporters as predicted by our model in Section 4.1. Using detailed data on the use of formal and informal contracts in trade and trade partners recorded in our experiment, this subsection documents experimental evidence suggesting the increased use of informal contracts between farmers and exporters following joint training. Table 6 reports the estimated effect of training and certification eligibility on farmer trade outcomes. Column 1 shows that joint training substantially increases the probability of trade of all types between farmers and exporters in the same cluster, which we term as within-cluster, by 30.9 percentage points, from a baseline of 7 percentage points in the control group. This is much larger than that for farmer-only training at 7.8 percent and exporter-only training whose effect is insignificant. As anticipated by the timing of the receipt of the certificate occurring after our second follow-up survey, we find no effect of certification eligibility on farm-gate trade.

Columns 2-5 explore the treatment effects on who and how farmers do trade at the farm-gate. Based on farmer reports in follow-up surveys, we categorize trade into spot trade and contract trade. Columns 2 and 3 demonstrate that joint training substantially increases spot trade with exporters in the same cluster, but reduces spot trade with exporters outside the cluster. Column 4 shows an economically and statistically significant increase in contract trade with exporters in the same cluster for joint training. Compared to the control group, where contract trade within the cluster consists of only 1 percent of all trade, farmers in joint training are 14 percentage points more likely to engage in contract trade with exporters in the same cluster. In contrast, there is no significant change in contract trade with buyers outside the experiment cluster, as shown in Column 5.

Figure 5 further reports the dynamic formation of contract trade after training. It shows that the difference in dynamics of contract trade between joint training and other groups is partly because some of the spot trade established in the first harvest season for joint training developed to contract trade in the second harvest season. Interestingly, the increase in within-cluster trade roughly offsets the decline in outside-cluster trade after training. Likewise, the increase in within-cluster contract trade roughly offsets the decline in spot trade in the second season. This suggests that farmers are not adding more buyers, but rather are replacing former buyers and trade types with new ones. The detailed discussion is included in Online Appendix H.

To explore the association between trust and contract trade, we regress contract trade on the level of farmer's trust toward the exporter measured in the experiment. Table A-16 shows that trust is indeed a significantly positive predictor of contract trade within a cluster. However, although joint training increases farmer's kindness toward the jointly trained exporters as shown in the dictator game, kindness does not predict contract trade. Thus, although we do not have direct evidence on the causal mechanism behind the increase in contract trade after joint training, the results from the lab-in-the-field experiment and contract trade provide suggestive evidence that joint training may have facilitated formation of contract trade through enhancing trust in buyer-supplier relationships (Otsuka, Nakano, & Takahashi 2016). Moreover, the literature has documented a positive effect of contracting on prices, technology adoption, quality upgrading, and farm performance (Deutschmann et al. 2021; Macchiavello & Miquel-Florensa 2019; Magnan et al. 2021), as confirmed in our experiment in Online Appendix Figure A-4. Therefore contracting and the resulting higher prices provide incentives for farmers to adopt new technologies and upgrade quality.

5.1.2 Alternative Explanations

This subsection discusses several alternative explanations to the larger effects of joint training.

More effective farmer learning in the presence of potential buyers

One possibility is that farmers may have a stronger incentive to learn GAP technology when they are trained together with potential buyers (exporters), or they can learn more effectively through knowledge transfer from jointly trained exporters. This may increase farmers' technology adoption and quality upgrading in joint training. However, we find that joint training with exporting intermediaries does not improve farmers' motivation or effectiveness in learning GAP technology. As shown in Table A-7, joint training increases a farmer's knowledge by 0.228 standard deviation, which is not statistically different from the effect of farmer-only training

(0.279 standard deviation). So more effective learning in the presence of potential buyers is unlikely to be the main factor contributing to the larger effect of joint training.

Knowledge complementarity and lowered monitoring cost

Joint training increased knowledge for both farmers and exporters. If farmer knowledge and exporter knowledge act as complements in driving quality upgrading, then it may explain the larger effect of joint training. One potential mechanism of knowledge complementarity is that it may lower the costs for exporters to monitor farmers, as they are now more familiar with good production practices. As in the model in Section 4.1, decrease in monitoring cost induces more contract trade, which may in turn provide stronger incentives for farmers to adopt GAP. To test this possibility, ideally we need a measure of monitoring costs. Without such a measure in our experiment, we use exporters' knowledge on GAP collected through a paper-based test as a (potentially noisy) measure of monitoring cost. We estimate an extended model of the baseline specification (1) by controlling for farmer knowledge, average knowledge of exporters in the cluster, and their interaction. We find that the coefficients of the interaction term are neither economically nor statistically significant at any conventional level as shown in Table A-17. This provides suggestive evidence that knowledge complementarity and lowered monitoring cost may not be a key driver of the larger effect of joint training. Of course, considering the potential bias of the Baron and Kenny (1986) type regression and the noisy measure of monitoring costs, we interpret this as suggestive evidence and cannot completely rule out it as a potential mechanism.

Complementarity in quality production

Another possibility is that exporters may improve practices in the processing and packaging stage and perform better quality control/sorting after training, due to reasons such as improved exporter knowledge. The exporters' quality upgrading may complement farmers' production, providing stronger incentives for farmers to upgrade quality especially in joint training groups. While we admit that production complementarity may be important for quality upgrading in supply chains, it is unlikely to be the main driver of the larger effects of joint training in our case. Six months after the training, we conducted quality control audits at exporters' processing facilities and evaluated each exporter's handling of dragon fruit samples and quality control process based on the standards of Good Handling Practices (GHP), an intermediary version of

Good Agricultural Practices (GAP). Column 4 of Table A-7 shows no difference in exporters' handling practices between the control and any of the treatment groups. This result indicates that GAP training with exporters did not lead to quality upgrading in exporters' production processes.

Cutting off the middleman (local collectors) and changes in market structure

In the dragon fruit supply chain we study, 90 percent of the transactions occur between farmers and small local collectors, who act as another layer of "intermediation". The buyer-supplier relationship established in joint training may cut off the middlemen or change the market structure and competition in the local supply chain. This gives jointly trained farmers more bargaining power, because now they can use transactions with exporters as an "outside option". Cutting off middlemen also avoids double marginalization. The avoidance of double marginalization and stronger bargaining power ex-post can incentivize farmers to improve quality ex-ante (Krishna & Sheveleva 2017; Mitra et al. 2018b).[33] However, our data suggests that high-quality, high-price transactions mostly occurred in contract trade. Thus, while the shift in market structure could have influenced farmers' incentives to upgrade quality we believe that this cannot fully explain the increased use of contracts as well as the high-quality, high-price transactions associated with them. Unfortunately, without detailed data on local collectors we are unable to empirically test this hypothesis. We acknowledge this as a limitation of our study.

Reduction of search friction

Another possibility is that joint training may mitigate the search friction between farmers and exporters.[34] However, it is unlikely to be the main mechanism for three reasons. First, the cost of travel to search for high-quality product should be relatively small given the proximity between farmers and exporters, as shown in Section 2. Second, we organized a one-time meeting for farmers and exporters in the same cluster for all treatment and control groups. Such meeting may have allowed exporters to know better about farmers and reduced the search cost. Hence, the comparison of joint training against other groups already removes the effect of reduced search friction, if any. Third, we also sample a spillover-proof control group of untreated farmers

[33] We thank an anonymous referee for this comment.
[34] We thank Jie Bai for an insightful comment, which led to this discussion.

within the same province. As no meeting or other treatments are provided, we would expect that this group might underperform our control group if reduced search friction does induce quality upgrading. But Table F-1 shows no significant differences between these two groups, suggesting search friction is unlikely to be a major barrier for quality upgrading.

5.1.3 Cost-Benefit Analysis

Through helping establish buyer-supplier relationship, our joint training intervention increases farmer profits by around 370 USD (8.6 Million Vietnamese Dong) after two seasons as shown in Table 4. But how do these gains compare to the costs? The total expense of the project, including instructor fee, cost of materials, transportation, rental rate for classroom, is around 37 USD (or 870,000 Vietnamese Dong) per trainee. Given Vietnam's 2019 minimum wage rate (5.6 USD per day), we assume that the forgone wages from participating in the three-day program is 16.8 USD, which gives a total cost of 53.8 USD per trainee. From the perspective of farmer's welfare, that is a return of 6.9 dollars for each dollar spent on the joint training intervention.

This cost-effectiveness is comparable to other programs documented in the literature, if not better. For example, Cai and Szeidl (2018) show that the average annual profit margin from holding meetings to improve inter-firm relationship is more than twice of the estimated cost of hold these meetings. In the agricultural context, Bold et al. (2022) evaluate the importance of access to high-quality maize market. Their intervention can increase farmer profit by around 63-98 USD in one year, 4-6 times of its cost (15 USD). Cole and Fernando (2021) examines the impact of providing voice-based ICT agricultural advice for farmers and shows that such services, which cost 9.87 USD, increase the farmers profit by about 77 USD in a year. In Kondylis et al. (2017), farmers who receive training on a new agricultural technology earn yield and labor benefits of 150 USD, about twice of the training cost of 74 USD. These comparisons suggest that our joint intervention is quite cost-effective in improving farmers' business performance.

5.2 Why Does Certification Eligibility have an Insignificant Effect?

The main empirical findings strongly indicate that certification eligibility has no effect on improving farming practices or product quality. It could be the case that farmers do not adopt

GAP technology because the certificate has no value on the market (i.e., zero price premium). To explore this possibility, we estimate the price difference between VietGAP certified and non-certified farmers controlling for farmer characteristics and various measures of product quality. This price difference would indicate to some extent the price premium associated with VietGAP certification. Specifically, we regress the farm-gate price from the first and second follow-up surveys on VietGAP certification, which equals to 1 if a farmer received a VietGAP certificate within the past two years and 0 otherwise.[35] Note that we refrain from interpreting the price premium estimate as causal because there may be confounding factors (e.g., farmers with a VietGAP certificate or high-quality fruit may be better negotiators or have better connections with buyers). Nevertheless, we do control for an individual farmer's baseline characteristics and use price and quality information from two rounds of follow-up surveys in the regression.

Table A-20 presents the estimates of the price premium associated with the VietGAP certificate. We find no significant relationship between the VietGAP certificate and farm-gate prices. This result is robust after controlling observed fruit attributes and GAP compliance (as a proxy for unobserved quality). This may explain the lack of additional incentives in the certificate eligibility treatment. As expected, we do find a robust positive price premium of output quality and observed fruit attributes, as shown in Column 2-4.[36] This, although speculative, suggests that exporters value compliance with GAP technology and, moreover, food safety.[37]

The positive demand for quality from exporters, yet a zero price premium on quality certification, may seem puzzling. However, studies suggest that credibility of certification is a critical factor for obtaining a positive price premium (Abate, Bernard, de Janvry, Sadoulet, & Trachtman 2021; Bai 2021).[38] Examining the credibility of VietGAP certification lies beyond the scope of

[35] We use past certificates because the certificate from our experiment was awarded only after our final follow-up survey. We only use certificates in the past two years (2017, 2018) as the VietGAP certificate has to be renewed every two years. Table A-19 presents predictors of farmer characteristics associated with VietGAP certification. VietGAP-certified farmers are more likely to be male and better educated. We find no observable difference in other dimensions such as farm experience, farm size, measures of trust, and business attitude.

[36] In Figure A-5, we present price premium estimates for low-price and high-price markets, separately. GAP compliance shows a positive price premium only for the high-price market.

[37] Of course, the underlying assumption is that exporters can obtain some information on product quality by observing or inspecting farms' GAP compliance. To the best of our knowledge, it is standard practice for exporters to visit farms to inspect farming practices and product quality before making price offers.

[38] Bai (2021) provides experimental evidence from a watermelon market that sticker labeling certification technology (possible for contaminated quality signal) does not induce higher prices than when no certification is provided, whereas laser-cut labeling increased profits by 30-40%. Abate et al. (2021) offers four conditions for

this study and we plan to explore this question in a follow-up study.

6 Conclusion

This paper contributes to the literature and policy practices to promote technology adoption and quality upgrading, especially in agricultural sectors in developing countries. By randomly providing training on quality-enhancing agricultural technologies to farmer-only, exporter-only, or farmer-exporter joint groups in a dragon fruit supply chain in Vietnam, we examine the effect of technology training and buyer-supplier relationship on quality upgrading. The main finding is that while training encourages farmers to upgrade quality, joint training has a much larger effect. However, exporter-only training or certificate eligibility have no significant effect on technology adoption and quality upgrading.

We explore the potential mechanisms using detailed survey data on GAP knowledge, farm-gate transactions, and measures of mutual trust between farmers and exporters obtained from a lab-in-the-field experiment. On the one hand, training farmers increases their GAP knowledge, relaxing a supply-side constraint to quality upgrading. On the other hand, improvements in buyer-supplier relationship may have contributed to the larger effect of joint training. This is supported by the higher level of mutual trust and the increase in contract trade between jointly trained farmers and exporters. Finally, we find that the VietGAP certificate has no price premium in farm-gate transactions which may explain why farmers eligible for certification were no more likely to adopt GAP technology.

Our findings have important policy implications. In particular, the findings suggest that training programs, widely adopted by many governments in developing countries, can be more effective if—in addition to transferring knowledge—they can help trainees to establish buyer-seller relationships and form contracts. The results also suggest that policy evaluations need to take into account the relationship between buyers and producers in supply chains to accurately assess the impact of training programs on technology adoption decisions and business performance.

quality certification to be successful, using the example of staple food markets in Sub-Saharan Africa.

References

Abate, G., Bernard, T., de Janvry, A., Sadoulet, E., & Trachtman, C. (2021). Introducing quality certification in staple food markets in sub-saharan africa: Four conditions for successful implemention. *Food Policy*, *105*, 102173.

Anderson, M. L. (2008). Multiple Inference and Gender Differences in the Effects of Early Intervention: A Reevaluation of the Abecedarian, Perry Preschool, and Early Training projects. *Journal of the American Statistical Association*, *103*(484), 1481-1495.

Ashraf, N., Bohnet, I., & Piankov, N. (2006). Decomposing trust and trustworthiness. *Experimental Economics*, *9*, 193-208.

Ashraf, N., Giné, X., & Karlan, D. (2009). Finding missing markets (and a disturbing epilogue): Evidence from an export crop adoption and marketing intervention in kenya. *American Journal of Agricultural Economics*, *91*(4), 973–990.

Atkin, D., Khandelwal, A. K., & Osman, A. (2017). Exporting and firm performance: Evidence from a randomized experiment. *The Quarterly Journal of Economics*, *132*(2), 551–615.

Bai, J. (2021). Melons as lemons: Asymmetric information, consumer learning and quality provision. *Working Paper*.

Bai, J., Gazze, L., & Wang, Y. (2021). Collective reputation in trade: Evidence from the chinese dairy industry. *The Review of Economics and Statistics*, Accepted.

Banerjee, A., Chandrasekhar, A. G., Duflo, E., & Jackson, M. O. (2013). The diffusion of microfinance. *Science*, *341*(6144).

Banerjee, A., Chandrasekhar, A. G., Duflo, E., & Jackson, M. O. (2019). Using gossips to spread information: Theory and evidence from two randomized controlled trials. *The Review of Economic Studies*, *86*(6), 2453–2490.

Banerjee, A., & Duflo, E. (2000). Reputation Effects and the Limits of Contracting: A Study of the Indian Software Industry. *Quarterly Journal of Economics*, *115*(3), 989-1017.

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of personality and social psychology*, *51*(6), 1173.

Beaman, L., BenYishay, A., Magruder, J., & Mobarak, A. M. (2021). Can network theory-based targeting increase technology adoption? *American Economic Review*, *111*(6), 1918–43.

Binh Thuan Dragon Fruit Center. (2019). *Report on the status of dragon fruit consumption, production and market opening in Binh Thuan* (Tech. Rep.). Binh Thuan Dragon Fruit Research and Development Center, Vietnam.

Björkman Nyqvist, M., Svensson, J., & Yanagizawa-Drott, D. (2022). Can good products drive out bad? a randomized intervention in the antimalarial medicine market in uganda. *Journal of the European Economic Association*, *20*(3), 957–1000.

Bold, T., Ghisolfi, S., Nsonzi, F., & Svensson, J. (2022). Market access and quality upgrading: Evidence from three field experiments. *American Economic Review*, Forthcoming.

Cai, J., & Szeidl, A. (2018). Interfirm relationships and business performance. *The Quarterly Journal of Economics*, *133*(3), 1229–1282.

California Department of Pesticide Regulation. (2017). *2017 pesticide residues in fresh produce.* Retrieved from https://www.cdpr.ca.gov/docs/enforce/residue/resi2017/

rsfr2017.htm.

Casaburi, L., Kremer, M., Mullainathan, S., & Ramrattan, R. (2019). Harnessing ICT to increase agricultural production: Evidence from kenya. *Working Paper*.

Cole, S. A., & Fernando, A. N. (2021). 'Mobile'izing agricultural advice technology adoption diffusion and sustainability. *The Economic Journal*, *131*(633), 192–219.

Davis, K., Nkonya, E., Kato, E., Mekonnen, D. A., Odendo, M., Miiro, R., & Nkuba, J. (2012). Impact of farmer field schools on agricultural productivity and poverty in east africa. *World development*, *40*(2), 402–413.

Deutschmann, J. W., Bernard, T., & Yameogo, O. (2021). Contracting and quality upgrading: Evidence from an experiment in senegal. *Working Paper*.

Dranove, D., & Jin, G. Z. (2010). Quality disclosure and certification: Theory and practice. *Journal of Economic Literature*, *48*(4), 935-963.

European Commission. (2014-2019). *Rapid Alert System for Food and Feed on Vietnam Dragon Fruit.* Retrieved from https://webgate.ec.europa.eu/rasff-window/portal/.

Fafchamps, M., Islam, A., Malek, M. A., & Pakrashi, D. (2020). Can referral improve targeting? evidence from an agricultural training experiment. *Journal of Development Economics*, *144*, 102436.

Feder, G., Murgai, R., & Quizon, J. B. (2004). Sending farmers back to school: The impact of farmer field schools in indonesia. *Review of Agricultural Economics*, 45–62.

Food and Agriculture Organization. (2016). *A scheme and training manual on Good Agricultural Practices (GAP) for fruits and vegetables.* (Food and Agriculture Organization)

General Office of Customs. (2018). *Customs trade statistics.* (General Office of Customs, Hanoi)

Grimm, M., & Luck, N. (2020). Can training enhance adoption, knowledge and perception of organic farming practices? evidence from a randomized experiment in indonesia. *IZA Discussion Paper*.

Hausmann, R., Hwang, J., & Rodrik, D. (2007). What you export matters. *Journal of Economic Growth*, *12*(1), 1-25.

Jack, B. K. (2013). Market inefficiencies and the adoption of agricultural technologies in developing countries. *Working Paper*.

Jin, G. Z., & Leslie, P. (2003). The effect of information on product quality: Evidence from restaurant hygiene grade cards. *Quarterly Journal of Economics*, *118*(2), 409-451.

Karlan, D. (2005). Using experimental economics to measure social capital and predict financial decisions. *American Economic Review*, *95*(5), 1688-99.

Kondylis, F., Mueller, V., & Zhu, J. (2017). Seeing is believing? evidence from an extension network experiment. *Journal of Development Economics*, *125*, 1–20.

Krishna, K., & Sheveleva, Y. (2017). Wheat or Strawberries? Intermediated Trade with Limited Contracting. *American Economic Journal: Microeconomics*, *9*(3), 28-62.

Macchiavello, R., & Miquel-Florensa, J. (2019). Buyer-driven upgrading in gvcs: The sustainable quality program in colombia. *CEPR Discussion Paper No. DP13935*.

Macchiavello, R., & Morjaria, A. (2015). The Value of Relationships: Evidence from a Supply Shock to Kenyan Rose Exports. *American Economic Review*, *105*(9), 2911-2945.

Magnan, N., Hoffmann, V., Garrido, G. G., Kanyam, D. A., & Opoku, N. (2021). Information, technology, and market rewards: Incentivizing aflatoxin control in ghana. *Journal of Development Economics*, 102620.

Magruder, J. R. (2018). An assessment of experimental evidence on agricultural technology adoption in developing countries. *Annual Review of Resource Economics*, *10*, 299-316.

McKenzie, D. (2012). Beyond baseline and follow-up: The case for more t in experiments. *Journal of Development Economics*, *99*(2), 210-221.

McMillan, J., & Woodruff, C. (1999). Interfirm relationships and informal credit in vietnam. *Quarterly Journal of Economics*, *114*(4), 1285-1320.

Ministry of Agriculture and Rural Development. (2019). *List of pesticides permitted, restricted and banned for use.*

Mitra, S., Mookherjee, D., Torero, M., & Visaria, S. (2018a). Asymmetric Information and Middleman Margins: An Experiment with Indian Potato Farmers. *Review of Economics and Statistics*, *C*(1), 1-13.

Mitra, S., Mookherjee, D., Torero, M., & Visaria, S. (2018b). Asymmetric information and middleman margins: An experiment with indian potato farmers. *Review of Economics and Statistics*, *100*(1), 1–13.

Otsuka, K., Nakano, Y., & Takahashi, K. (2016). Contract farming in developed and developing countries. *Annual Review of Resource Economics*, *8*, 353–376.

Ozer, O., Zheng, Y., & Ren, Y. (2014). Trust, trustworthiness, and information sharing in supply chains bridging china and the united states. *Management Science*, *60*(10), 2435-60.

Saenger, C., Torero, M., & Qaim, M. (2014). Impact of third-party contract enforcement in agricultural markets: A field experiment in vietnam. *American Journal of Agricultural Economics*, *96*(4), 1220-1238.

Suri, T. (2011). Selection and comparative advantage in technology adoption. *Econometrica*, *79*(1), 159–209.

Trinh, X., Mai, V., Nguyen, T., Nguyen, T., Ha, M., & Nguyen, V. (2018). *Dragon fruit production in Vietnam: Achievements and challenges.* (Country Report for the Dragon Fruit Regional Network Initiation Workshop)

Verhoogen, E. (2008). Trade, quality upgrading, and wage inequality in the mexican manufacturing sector. *The Quarterly Journal of Economics*, *123*(2), 489–530.

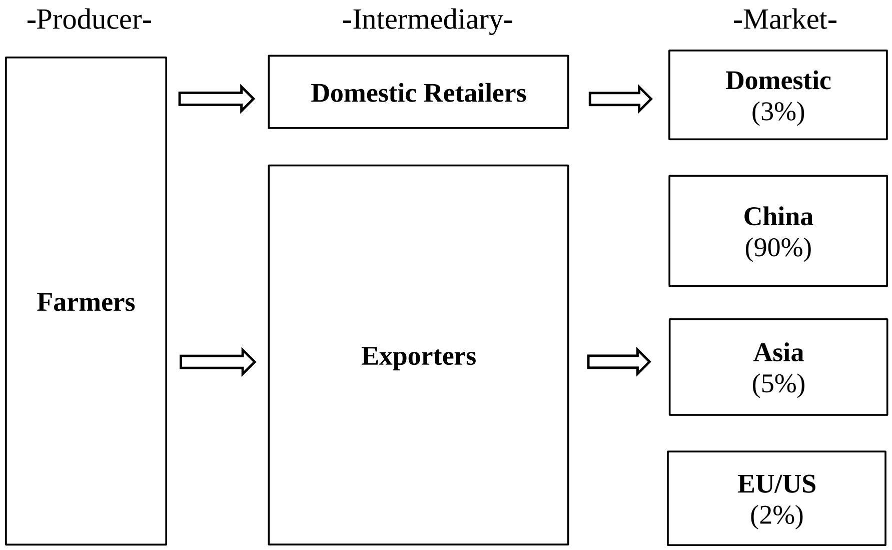
Verhoogen, E. (2021). Firm-level upgrading in developing countries. *Working Paper*.

World Bank. (2007). *World development report 2008: agriculture for development.* (World Bank, Washington, DC)

Young, A. (2019). Channeling fisher: Randomization tests and the statistical insignificance of seemingly significant experimental results. *Quarterly Journal of Economics*, *134*(2), 557-598.

Zhao, Y. (2020). Your (country's) reputation precedes you: Information asymmetry, externalities and the quality of exports. *Working Paper*.

Figure 1: Dragon Fruit Supply Chain



Notes: This figure illustrates the dragon fruit supply chain in Binh Thuan Province. Shares of volume sold to each market based on farmer's baseline survey data are reported in parentheses.

Figure 2: Experimental Design of GAP Training and Certification Eligibility

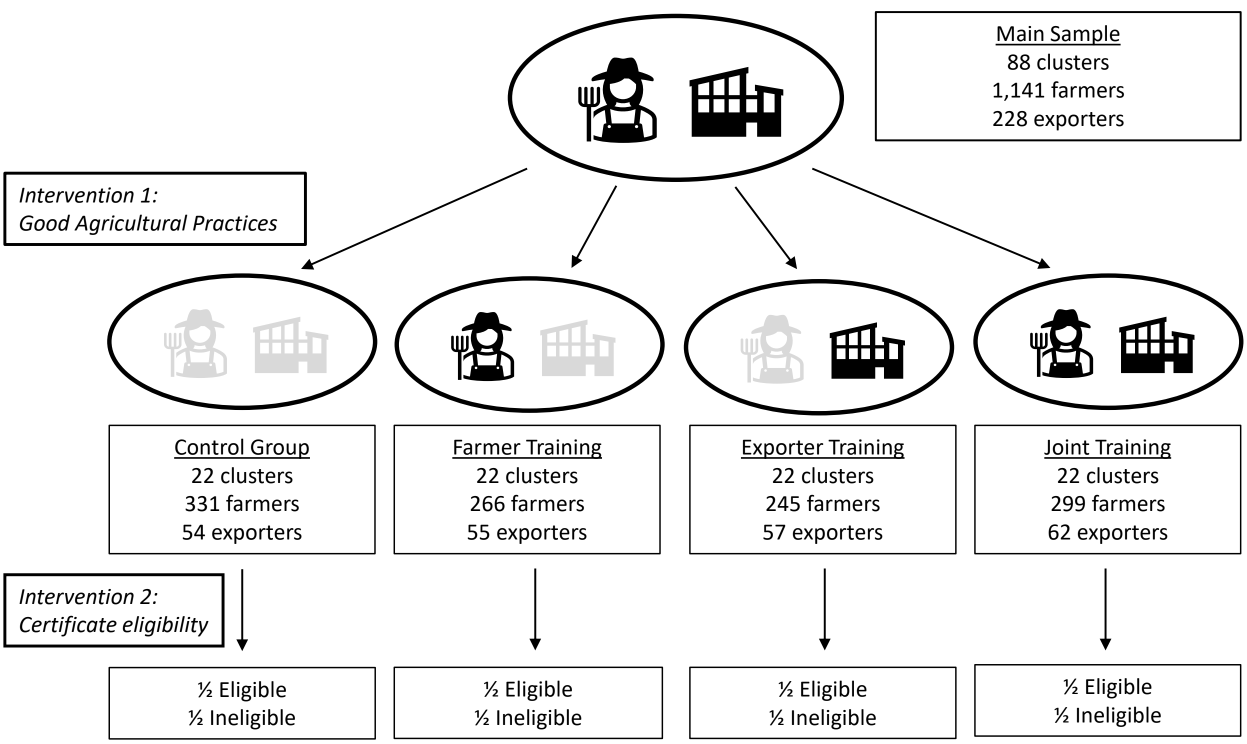
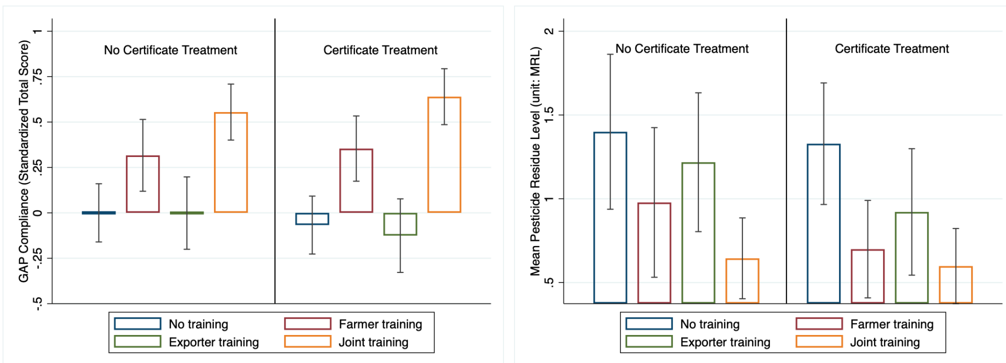


Figure 3: Timeline of Project

August 2018 - October 2018: Contact farmer groups and intermediaries, randomization of treatments for farmer-exporter clusters → **November 2018 - February 2019:** Conduct baseline survey, hold training sessions → **July 2019 - September 2019:** Conduct first followup survey and field audit → **December 2019 - March 2020:** Conduct second followup survey, field audit, and pesticide residue test

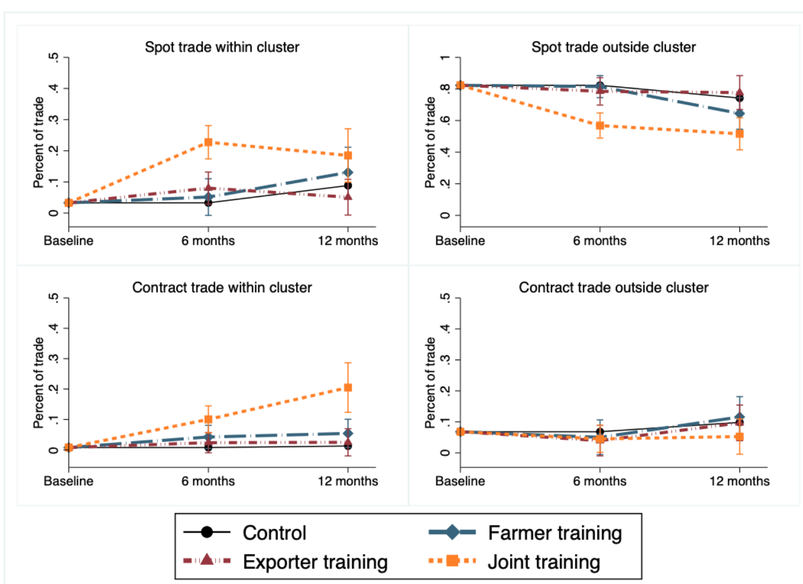
Figure 4: GAP Compliance and Pesticide Residue by Treatment Group



(a) Standardized GAP Compliance Rate (b) Mean Pesticide Residue Level

Notes: Good Agricultural Practices Compliance Rate is the on-farm audit score standardized by the control group's mean and standard deviation. Mean Pesticide Residue Level is the mean of 18 pesticide residues in units of Maximum Residue Limits (MRL) found in fruit samples. Vertical lines indicate 95 percent confidence intervals.

Figure 5: Impact of Training on Contract Trade



Notes: This figure uses farmer reports on trade with intermediaries, including exporters and local collectors, collected during followup surveys. Spot trade refers to trade without any informal or formal contracting with the intermediary. Contract trade includes both informal and formal contracts. Trade within cluster denotes trade with exporters assigned to the same matched farmer-exporter cluster.

Table 1: Summary Statistics - Baseline Survey

	Obs.	Mean	Median	S.D.	Min	Max
Panel A. Farmer Characteristics						
Age	1141	45.59	45.00	12.58	18	88
Female	1141	0.34	0.00	0.47	0	1
Secondary Education	1141	0.70	1.00	0.46	0	1
Experience growing dragon fruit (years)	1141	10.69	10.00	6.07	0	40
Size of dragon fruit farm (hectares)	1141	0.75	0.50	0.73	0	10
Number of dragon fruit trees	1141	764.88	600.00	705.47	100	10000
Self-reported GAP compliance	1141	0.60	0.57	0.20	0	1
Volume sold (tons)	1141	10.05	6.00	12.19	0	120
Average price (1,000 VND/kg)	1141	12.69	12.00	3.53	2	25
Total Expenses on inputs (1 Million VND)	1141	74.56	39.00	154.87	0	4046
Panel B. Farm-gate Trade Characteristics						
Years farmer has known buyer	1883	4.88	4.00	3.46	0	22
Trade based on formal written contract	1883	0.01	0.00	0.10	0	1
Purchased by local collector	1883	0.90	1.00	0.29	0	1
Purchased by exporter	1883	0.06	0.00	0.24	0	1
Purchased by domestic retailer	1883	0.03	0.00	0.17	0	1
Product for Chinese market	1876	0.93	1.00	0.25	0	1
Product for high-price Asian market	1876	0.03	0.00	0.16	0	1
Product for EU/US market	1876	0.01	0.00	0.11	0	1
Product for Domestic market	1876	0.03	0.00	0.17	0	1
Panel C. Exporter Characteristics						
Years of intermediation business	228	9.31	8.00	5.26	1	24
Size of packing/collection facility (m^2)	228	1176.05	800.00	1148.89	50	7000
Trade volume (tons)	228	422.32	320.00	318.84	50	2000
Average purchase price (1,000 VND/kg)	228	15.26	15.00	2.33	10	22
Average sales price (1,000 VND/kg)	228	17.62	17.00	2.79	11	26
Expenses on labor (1M VND)	228	439.82	355.00	342.92	0	1800
Expenses on utility (1M VND)	228	280.08	142.50	403.47	0	3000
Expenses on materials (1M VND)	228	491.95	200.00	740.48	0	5000

Notes: This table provides summary statistics on farmer demographics, farm characteristics, and farmer-intermediary trade reported by farmers collected from baseline survey and exporting firm characteristics. The unit of observation in panel B is transaction reported by farmers.

Table 2: Impacts of Training and Certificate Eligibility on GAP Compliance

	Standardized scores from GAP audit					
	Total	Pesticide	Equipment	Hygiene	Soil	Fertilizer
	(1)	(2)	(3)	(4)	(5)	(6)
Farmer Training	0.459***	0.352***	0.340***	0.147	0.301***	-0.113
	(0.097)	(0.072)	(0.099)	(0.089)	(0.093)	(0.093)
	[0.003]	[0.003]	[0.052]	[0.154]	[0.036]	[0.372]
Exporter Training	0.104	0.060	0.089	0.012	0.167	-0.207
	(0.105)	(0.076)	(0.112)	(0.099)	(0.104)	(0.116)
	[0.228]	[0.364]	[0.217]	[0.326]	[0.239]	[0.200]
Joint Training	0.676***	0.556***	0.463***	0.202*	0.373***	0.029
	(0.123)	(0.081)	(0.107)	(0.090)	(0.116)	(0.090)
	[0.001]	[0.001]	[0.001]	[0.001]	[0.008]	[0.271]
Certificate Eligibility (C.E.)	-0.058	0.030	-0.055	-0.190	0.128	-0.211
	(0.109)	(0.082)	(0.102)	(0.096)	(0.096)	(0.089)
	[0.536]	[0.792]	[0.552]	[0.124]	[0.293]	[0.180]
C.E. × Farmer Training	0.068	-0.092	0.017	0.210	-0.151	0.533***
	(0.164)	(0.138)	(0.161)	(0.146)	(0.141)	(0.137)
	[0.834]	[0.709]	[0.949]	[0.267]	[0.445]	[0.011]
C.E. × Exporter Training	-0.036	-0.029	0.010	0.080	-0.258	0.300
	(0.157)	(0.121)	(0.157)	(0.145)	(0.141)	(0.149)
	[0.562]	[0.733]	[0.702]	[0.785]	[0.292]	[0.236]
C.E × Joint Training	0.188	-0.019	0.218	0.260	-0.073	0.234
	(0.192)	(0.111)	(0.167)	(0.161)	(0.160)	(0.128)
	[0.104]	[0.025]	[0.164]	[0.568]	[0.182]	[0.987]
P-value ($H_0 : \beta_{\text{farmer}} = \beta_{\text{exporter}}$)	0.00	0.00	0.04	0.20	0.15	0.38
P-value ($H_0 : \beta_{\text{farmer}} = \beta_{\text{joint}}$)	0.08	0.01	0.29	0.54	0.52	0.06
P-value ($H_0 : \beta_{\text{exporter}} = \beta_{\text{joint}}$)	0.00	0.00	0.01	0.07	0.09	0.03
P-value ($H_0 : \beta_{\text{farmer}} + \beta_{\text{exporter}} = \beta_{\text{joint}}$)	0.49	0.18	0.84	0.74	0.54	0.01
Control mean (Pass/Total)	0.72	0.71	0.61	0.81	0.72	0.90
Control standard deviation	0.10	0.14	0.20	0.20	0.16	0.17
R-squared	0.16	0.11	0.15	0.13	0.08	0.05
Observations	2197	2197	2197	2197	2197	2197

Notes: Audit on GAP compliance was conducted in each of the two follow-up survey rounds. Audit scores are standardized by the control group's mean and standard deviation. Column 1 uses total audit score which is the number of items passed across all 32 items. Columns 2-6 use number of items passed in each management category. All specifications include farmer and exporter characteristics at baseline as control variables as well as strata and survey round fixed effects. Standard errors are clustered by farmer group and reported in parentheses. P-values from randomization inference are reported in square brackets. * denotes false discovery rate controlled statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Table 3: Impact of Training and Certificate Eligibility on Pesticide Residue

	Pesticide Residue Test				
	Mean	Compliance to country's MRL			
	Residue	China	Japan	EU	US
	(1)	(2)	(3)	(4)	(5)
Farmer Training	-0.432	-0.088	0.176	0.016	0.013
	(0.286)	(0.099)	(0.112)	(0.083)	(0.097)
	[0.128]	[0.530]	[0.190]	[0.825]	[0.875]
Exporter Training	-0.004	-0.082	-0.151	-0.080	-0.101
	(0.279)	(0.085)	(0.105)	(0.086)	(0.095)
	[0.978]	[0.166]	[0.233]	[0.134]	[0.208]
Joint Training	-0.671**	0.029	0.241**	-0.004	0.026
	(0.220)	(0.082)	(0.105)	(0.113)	(0.119)
	[0.000]	[0.686]	[0.002]	[0.864]	[0.495]
Certificate Eligibility (C.E.)	-0.031	0.033	-0.169*	-0.057	-0.125
	(0.221)	(0.067)	(0.096)	(0.091)	(0.094)
	[0.922]	[0.722]	[0.198]	[0.479]	[0.251]
C.E. × Farmer Training	-0.201	0.126	0.168	0.056	0.171
	(0.341)	(0.122)	(0.137)	(0.138)	(0.141)
	[0.593]	[0.397]	[0.392]	[0.715]	[0.267]
C.E. × Exporter Training	-0.295	0.079	0.415**	-0.012	0.082
	(0.314)	(0.104)	(0.138)	(0.121)	(0.125)
	[0.750]	[0.497]	[0.157]	[0.755]	[0.592]
C.E × Joint Training	-0.129	0.090	0.330*	0.131	0.074
	(0.293)	(0.101)	(0.141)	(0.149)	(0.151)
	[0.260]	[0.837]	[0.458]	[0.822]	[0.834]
P-value ($H_0 : \beta_{\text{farmer}} = \beta_{\text{exporter}}$)	0.18	0.95	0.00	0.22	0.23
P-value ($H_0 : \beta_{\text{farmer}} = \beta_{\text{joint}}$)	0.33	0.17	0.53	0.81	0.90
P-value ($H_0 : \beta_{\text{exporter}} = \beta_{\text{joint}}$)	0.01	0.13	0.00	0.45	0.25
P-value ($H_0 : \beta_{\text{farmer}} + \beta_{\text{exporter}} = \beta_{\text{joint}}$)	0.53	0.10	0.15	0.59	0.39
Control mean	1.40	0.85	0.55	0.21	0.24
R-squared	0.22	0.26	0.24	0.15	0.16
Observations	264	264	264	264	264

Notes: Unit of observation is farmer. Outcome variable is constructed using pesticide test results from randomly sampled farmers. Column 1 scales residue levels by the pesticide's Maximum Residue Limit (MRL) according to EU and Columns 2-5 indicates compliance of all 18 pesticides to each country's MRL. All specifications include farmer and exporter characteristics at baseline as control variables as well as strata fixed effects. Standard errors are clustered by farmer group and reported in parentheses. P-values from randomization inference are reported in square brackets. * denotes false discovery rate controlled statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Table 4: Impact of Training on Farm Sales and Profits

	Farm-gate		Revenue		Profit	
	Price	Volume	Direct	Implied	Direct	Implied
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. First Followup Survey - Six months after training						
Farmer Training	0.024	0.002	7.603	2.929	3.698	-0.887
	(0.032)	(0.072)	(9.560)	(7.962)	(7.046)	(6.985)
	[0.565]	[0.978]	[0.649]	[0.770]	[0.758]	[0.903]
Exporter Training	0.030	0.030	12.960	6.418	9.285	5.299
	(0.028)	(0.071)	(9.871)	(7.677)	(7.250)	(7.146)
	[0.418]	[0.572]	[0.019]	[0.048]	[0.074]	[0.396]
Joint Training	0.074	0.088	8.770	9.777	1.687	0.945
	(0.035)	(0.069)	(8.470)	(8.230)	(6.569)	(7.492)
	[0.006]	[0.257]	[0.064]	[0.041]	[0.435]	[0.989]
P-value ($H_0 : \beta_{\text{farmer}} = \beta_{\text{exporter}}$)	0.71	0.71	0.61	0.63	0.46	0.29
P-value ($H_0 : \beta_{\text{farmer}} = \beta_{\text{joint}}$)	0.02	0.22	0.90	0.35	0.77	0.71
P-value ($H_0 : \beta_{\text{exporter}} = \beta_{\text{joint}}$)	0.04	0.43	0.66	0.63	0.28	0.47
P-value ($H_0 : \beta_{\text{farmer}} + \beta_{\text{exporter}} = \beta_{\text{joint}}$)	0.58	0.57	0.39	0.97	0.26	0.68
Control mean (in levels)	13.40	6.08	85.71	84.41	47.89	45.47
R-squared	0.20	0.43	0.39	0.42	0.30	0.32
Observations	1081	1081	1081	1081	1081	1081
Panel B. Second Followup Survey - Twelve months after training						
Farmer Training	0.033	0.021	7.779	8.662	-5.926	-2.996
	(0.022)	(0.062)	(7.953)	(5.702)	(6.041)	(4.113)
	[0.161]	[0.787]	[0.268]	[0.129]	[0.192]	[0.458]
Exporter Training	-0.041	0.016	6.690	7.150	-0.449	1.495
	(0.021)	(0.090)	(7.444)	(6.433)	(5.995)	(5.436)
	[0.048]	[0.813]	[0.665]	[0.619]	[0.674]	[0.432]
Joint Training	0.106***	0.084	17.710	16.837**	8.605	9.232
	(0.027)	(0.060)	(7.207)	(5.829)	(5.483)	(4.648)
	[0.000]	[0.040]	[0.002]	[0.007]	[0.009]	[0.023]
P-value ($H_0 : \beta_{\text{farmer}} = \beta_{\text{exporter}}$)	0.00	0.96	0.87	0.80	0.29	0.32
P-value ($H_0 : \beta_{\text{farmer}} = \beta_{\text{joint}}$)	0.01	0.29	0.10	0.10	0.00	0.00
P-value ($H_0 : \beta_{\text{exporter}} = \beta_{\text{joint}}$)	0.00	0.45	0.05	0.09	0.05	0.12
P-value ($H_0 : \beta_{\text{farmer}} + \beta_{\text{exporter}} = \beta_{\text{joint}}$)	0.00	0.66	0.73	0.90	0.04	0.10
Control mean (in levels)	11.53	6.24	75.41	74.17	31.47	28.28
R-squared	0.35	0.52	0.61	0.63	0.40	0.38
Observations	1054	1054	1054	1054	1054	1054

Notes: Sales data was collected from two follow-up survey rounds. Estimates are separately reported in each panel. The price and volume are in logarithm, and the revenue and profits are in their original levels because they have zeros and even negative values (for profits). Here price is defined as the volume-weighted average of prices sold to intermediaries by each farmer in each survey round. We construct two measures of revenue by using the farmer reports in the surveys. Direct revenue is the total seasonal revenue from dragon fruit farming reported by farmers. To account for possible misreports in total revenue, we separately calculated implied revenue as the sum of revenue (price × volume) from all transactions during the season as a double check. Finally, direct Profit is derived by subtracting cost from direct revenue and implied profit is calculated by subtracting cost from implied revenue. All specifications include farmer and exporter characteristics at baseline as control variables as well as strata fixed effects. Standard errors are clustered by farmer group and reported in parentheses. P-values from randomization inference are reported in square brackets. * denotes false discovery rate controlled statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Table 5: Impact of Training on Behavior in Trust and Dictator Games

	Trust Game				Dictator Game	
	1st stage		2nd stage			
	Proportion farmer passed to exporter	Proportion exporter passed to farmer	Proportion farmer returned to exporter	Proportion exporter returned to farmer	Proportion farmer passed to exporter	Proportion exporter passed to farmer
	(1)	(2)	(3)	(4)	(5)	(6)
Farmer Training	0.040	-0.020	-0.012	-0.005	0.036	-0.056*
	(0.032)	(0.022)	(0.041)	(0.043)	(0.042)	(0.030)
	[0.248]	[0.442]	[0.788]	[0.918]	[0.433]	[0.033]
Exporter Training	0.013	0.012	-0.012	0.039	0.043	0.015
	(0.045)	(0.021)	(0.034)	(0.032)	(0.031)	(0.031)
	[0.841]	[0.345]	[0.935]	[0.184]	[0.110]	[0.498]
Joint Training	0.158***	0.177***	0.001	0.024	0.106***	0.071**
	(0.044)	(0.022)	(0.032)	(0.032)	(0.040)	(0.029)
	[0.000]	[0.000]	[0.668]	[0.094]	[0.021]	[0.000]
P-value ($H_0 : \gamma_{\text{farmer}} = \gamma_{\text{exporter}}$)	0.48	0.12	0.99	0.31	0.86	0.05
P-value ($H_0 : \gamma_{\text{farmer}} = \gamma_{\text{joint}}$)	0.01	0.00	0.76	0.51	0.14	0.00
P-value ($H_0 : \gamma_{\text{exporter}} = \gamma_{\text{joint}}$)	0.00	0.00	0.74	0.63	0.12	0.09
P-value ($H_0 : \gamma_{\text{farmer}} + \gamma_{\text{exporter}} = \gamma_{\text{joint}}$)	0.08	0.00	0.65	0.85	0.64	0.01
Control mean	0.36	0.14	0.43	0.23	0.35	0.15
R-squared	0.39	0.52	0.31	0.16	0.34	0.20
Observations	207	208	207	208	202	202

Notes: This table reports treatment effects on outcomes of trust and dictator games. Column 1 is the share of money a farmer or exporter (Column 2) passed to his or her partner in the first stage of the trust game and 3 is the share of money a farmer or exporter (Column 4) returned to his or her partner in the second stage. Column 5 is the share of money a farmer or exporter (Column 6) passed to his or her partner in the dictator game. Specifications include farmer or exporter (Columns 2,4,6) characteristics at baseline as control variables, indicators for certification eligibility and its interaction with training treatments, and strata fixed effects. Standard errors are clustered by farmer-exporter cluster and reported in parentheses. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Table 6: Impact of Training and Certification Eligibility on Contract Trade

	Any Trade	Spot Trade		Contract Trade	
	Within cluster	Within cluster	Outside cluster	Within cluster	Outside cluster
	(1)	(2)	(3)	(4)	(5)
Farmer Training	0.078**	0.032	-0.056	0.038	0.001
	(0.026)	(0.025)	(0.035)	(0.020)	(0.028)
	[0.004]	[0.251]	[0.100]	[0.026]	[0.967]
Exporter Training	0.031	0.005	-0.004	0.014	-0.014
	(0.021)	(0.021)	(0.042)	(0.019)	(0.023)
	[0.204]	[0.880]	[0.814]	[0.454]	[0.478]
Joint Training	0.309***	0.148***	-0.244***	0.142***	-0.034
	(0.028)	(0.029)	(0.039)	(0.027)	(0.023)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.074]
Certificate Eligibility (C.E.)	0.021	0.006	-0.039	0.011	-0.005
	(0.022)	(0.022)	(0.037)	(0.021)	(0.025)
	[0.588]	[0.776]	[0.413]	[0.637]	[0.813]
C.E. × Farmer Training	-0.074	-0.059	0.040	-0.015	0.015
	(0.040)	(0.035)	(0.052)	(0.028)	(0.040)
	[0.107]	[0.096]	[0.472]	[0.628]	[0.802]
C.E. × Exporter Training	-0.005	0.005	0.054	-0.003	-0.027
	(0.034)	(0.034)	(0.050)	(0.025)	(0.028)
	[0.686]	[0.998]	[0.861]	[0.737]	[0.988]
C.E. × Joint Training	0.080	0.044	-0.050	0.040	-0.027
	(0.044)	(0.043)	(0.055)	(0.049)	(0.036)
	[0.087]	[0.181]	[0.125]	[0.321]	[0.724]
P-value ($H_0 : \beta_{\text{farmer}} = \beta_{\text{exporter}}$)	0.07	0.33	0.19	0.22	0.58
P-value ($H_0 : \beta_{\text{farmer}} = \beta_{\text{joint}}$)	0.00	0.00	0.00	0.00	0.15
P-value ($H_0 : \beta_{\text{exporter}} = \beta_{\text{joint}}$)	0.00	0.00	0.00	0.00	0.31
P-value ($H_0 : \beta_{\text{farmer}} + \beta_{\text{exporter}} = \beta_{\text{joint}}$)	0.00	0.00	0.00	0.00	0.53
Control mean	0.07	0.06	0.79	0.01	0.09
R-squared	0.16	0.11	0.11	0.18	0.10
Observations	2730	2730	2730	2730	2730

Notes: This table reports treatment effects on contract trading between farmers and exporters. The results use farm-gate sales data from two follow-up survey rounds. The dependent variable in Column 1 indicates whether the farmer traded with exporter from same training group. Columns 2-3 report coefficient estimates on spot trade during the survey period. Columns 4-5 report estimates on informal or formal contract trade. Within cluster refers to trade with exporters in the same training cluster and Outside cluster refers to any intermediary, exporter or collector, not in the same training cluster. Standard errors are clustered by farmer group and reported in parentheses. All specifications include farmer and exporter characteristics at baseline as control variables as well as strata and survey round fixed effects. P-values from randomization inference are reported in square brackets. * denotes false discovery rate controlled statistical significance at 0.10, ** at 0.05, and *** at 0.01.