Technology Adoption in Agricultural Export Supply Chains: A Field Experiment in Vietnam

Pre-Analysis Plan

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1 Introduction

This plan outlines the hypotheses to be tested and specifications to be used in the analysis of the impact of offering a food safety training program (Good Agricultural Practices (GAP)) and a food safety verification certificate to farmers and intermediaries on the adoption of food safety technology and product quality in the dragon fruit industry of Vietnam. The author has completed this plan before the follow-up survey was administered to participants. Thus, the plan can provide a useful reference in evaluating the results of the study.

2 Overview of the Study

2.1 Motivation and Description

This study examines how to incentivize farmers and intermediaries to learn and comply with safe and sustainable agricultural practices. Despite the existence of a large body of research in economics and agricultural economics on the adoption of productivity enhancing agricultural technologies, such as use of hybrid seeds and fertilizers, very little work has been done to understand the challenges and methods to incentivize adoption of safe and environmentally sustainable agricultural technologies. The outcome of this research project can potentially benefit not only the dragon fruit industry but also other agricultural industries through serving as a guide for better policy design and resource support from government agencies.

For this project, I am collaborating with the Binh Thuan Dragon Fruit Research and Development Center (BTDC), a governmental organization overseeing dragon fruit production and research on agricultural technology in Binh Thuan province, to design and implement a randomized control trial across multiple districts in Binh Thuan Province, which accounts for 75% of all dragon fruit production in Vietnam. To understand the incentives in adopting safe and sustainable agricultural practices, I plan to conduct a two-stage randomized control trial on dragon fruit farmers and intrmediaries. Specifically, the first-stage intervention offers a randomly chosen set of farmers and intermediaries an opportunity to participate in a food safety training program designed to help participants learn and implement Good Agricultural Practices (GAP) and Good Handling Practices in farming and handling dragon fruits. BTDC staff members will provide an intensive three-day focus-group training course and on-site technical support throughout the study period. The second-stage intervention will randomly provide farmers an opportunity to receive a food safety verification certificate if they pass both an on-farm evaluation test and a lab-based pesticide residue test. Farmers assigned to the control group will be notified of test results but receive no formal certification. The second-stage intervention will be offered to a subsample of farmers due to budgetary reasons.

2.2 Sample Selection

The expected sample size is 800 farmers and 200 intermediaries across several major districts in Binh Thuan Province. Farmers and intermediaries are equally assigned across different treatment arms and the control arm in the first and second stages.

2.2.1 Farmer Selection

The unit of selection is a farmer group, consisting of around 15-20 farmers. Farmer groups are self-organized groups that are located in the same village or town. Government support or policy intervention is normally organized at the farmer group level. Thus, to receive governmental support farmers have to be associated with a farmer group that is registered with BTDC. Using the list of farmer groups registered with BTDC, I randomly sample farmer groups to participate in this study, stratified by commune, which is the lowest official administrative unit. Therefore, all farmers in

the same farmer group will be invited to participate under the same treatment.

2.2.2 Intermediary Selection

At the time of designing this project, there was no available information about the intermediaries operating in the sample area. Accordingly, I conducted a pilot survey in August 2017 to collect geo-referenced information of all intermediaries operating in the two major districts of Binh Thuan province. In total, I collected information on the location of 325 intermediaries, consisting the base for sample selection. Intermediaries will be clustered with a farmer group to form a geographical cluster of farmers and intermediaries, which will serve as the unit of treatment throughout this project. Intermediaries will be matched with the farmer group within the same village or if there is no farmer group within the same village then with the geographically closest farmer group within the same commune.

2.3 Experimental Design

I plan to conduct a two-stage randomized control trial (RCT) on dragon fruit farmers and intermediaries to examine the effects of offering a food safety training program and a food safety verification certificate on the adoption of safe and sustainable agricultural technologies, product quality, and business practices. Figure 1 provides an overview of the experimental design. The experiment is designed with three different treatment groups and one control group in the first stage which are each additionally divided into treatment and control for food safety certification in the second stage. The following provides details of each treatment group in the first stage. In the first treatment group (Treatment 1) only farmers will be invited to the GAP training and information sessions. In the second treatment group (Treatment 2), only intermediaries will be invited to GAP training and information sessions. In the third treatment group (Treatment 3), both farmers and intermediaries will be invited to GAP training and information sessions. Farmers and intermediaries in the control group (Control) will receive no information or training.

In the second stage I randomly assign farmer groups to either a certificate treatment group, which upon successfully passing a laboratory test on the pesticide residue in the fruit sample receives

a certificate issued by the lab, or a control group, which undergoes the identical laboratory pesticide test but without any certification. Randomization will be stratified by first-stage treatment arm. Intermediaries receive no direct treatment in the second stage. Farmers are informed about the pesticide test and certification (second-stage treatment status) at the end of the first-stage intervention.

2.4 Assignment of Treatment

First-stage treatment assignment will be randomized within the commune level. In total, I sample from 23 communes and towns in the catchment area for assignment to treatment and control. In addition, I sample four farmer groups from 2 communes outside the catchment area and assign to control groups to serve as a spillover-proof control group. For each commune, I randomly pick 4 farmer groups from the registered list. If a commune has less than 4 farmer groups I combined it with an adjacent commune and considered them as one commune. Overall, I end up sampling 88 clusters of farmer groups and intermediaries. Each cluster was randomly assigned to one of four first-stage treatment arms. Therefore, each treatment arm consists of 22 farmers groups and around 60 intermediaries. For assignment to second-stage treatment, within each first-stage treatment arm, I randomly assign half to certificate treatment (11 farmer groups) and half to control group (11 farmer groups). Because of budget limits, I sample a subset of farmer groups from the treatment and control groups. Both treatment and control group farmers will receive the lab test but only farmers in the treatment group will receive a lab-issued certificate on satisfying GAP pesticide residue standards.

3 Key Data Sources

The primary sources of data are collected through a baseline survey conducted before the training sessions, lab test on pesticide residue levels, and two follow-up surveys which will be conducted approximately 6 months and 12 months after the end of trainings.

3.1 Baseline Survey

The BTDC sent out personalized invitations to sampled farmers and intermediaries to participate in the baseline survey. For treatment groups, the baseline survey was conducted one day before the training session. For control groups, only the baseline survey was conducted. The baseline data collection took place for four months between November 2018 and February 2019.

3.2 Follow-up Surveys

The first follow-up survey will be conducted from June to August 2019. Surveyors will visit individual farm sites and packing facilities to collect information from farmers and intermediaries. Surveyors will also conduct on-site evaluations to inspect the product quality and check complicance with GAP standards. For lab testing, BTDC staff will visit farms to collect fruit samples during the first follow-up survey and send the samples to a pesticide residue analysis and testing laboratory in Vietnam. The second follow-up survey will be conducted in Novermber 2019 - February 2020. Surveyors will re-visit the farm sites and packing facilities to collect data from farmers and intermediaries.

3.3 Primary Outcome Variable

The first set of primary outcome variables is (i) food safety and (ii) (observable) product quality. Food safety will be measured in two ways. First, surveyors will perform an on-site evalutation using the GAP checklist developed by BTDC. This will measure observable food safety practices implemented in the field. The second measure is the level of pesticide contained in the fruit sample. This will provide a true measure of food safety and will be the main measurement for the training outcome. I plan to construct and use two statistics from the measure of pesticide content: one is a binary variable incidating whether the content level meets the GAP standard and the other is a continuous measure of pesticide content normalized at the entire sample level. The binary variable will be informative about the extensive margin of passing requirements on food safety while the continuous measure will be informative about the intensive margin regarding pesticide use.

Observable product quality is measured along four dimensions: sweetness, appearance, size,

and weight. Sweetness will be measured by surveyors using a special equipment provided by the research center. The remaining three dimensions of product quality follow the evaluation procedure commonly practiced by intermediaries. Appearance is a combination of color and and cleanness. Size measures the length and circumference of the fruit, and weight will be measured in grams using a scale.

The second set of primary outcome variables consists of information on investment, profits, and business activities. This data will be collected from farmers and intermediaries during two-rounds of follow-up surveys.

3.4 Secondary Outcome Variable

Secondary outcome variable is the standardized score on GAP knowledge test which will be taken by all farmers and intermediaries during the first follow-up survey. The test will be designed by BTDC to measure participants knowledge on food safety and GAP agricultural practices in farming and trading dragon fruits.

4 Hypotheses

The hypotheses are grouped by intervention stage and presented in Table 1.

4.1 Hypothesis Group A. Impact of Training

Hypothesis Group A concerns the impact of offering training on food safety and GAP technology to farmers and intermediaries on primary outcome variables. Outcome variables can be grouped into three categories: (1) food safety measures, (2) observable quality measures, and (3) business outcomes.

The following variables will be collected during the follow-up surveys and will consist of outcomes for food safety measures:

- Standardized score of on-site staff evaluation using GAP checklist
- Pesticide residue analysis from laboratory test

  - binary measure indicating whether result satisfies GAP requirement
  - continuous measure of pesticide content levels (planning to test with five widely used pesticides)

The following variables will be collected during follow-up surveys and will consist of outcomes for product quality measures:

- Sweetness measure
- Rating of appearance (color and cleanliness) of fruit
- Size of fruit: height and circumference
- Weight of fruit

Each measure will be averaged across three randomly sampled dragon fruits from the farm. All measures will be standardized using the sample mean and sample standard deviation.

The following variables will be collected during the follow-up surveys and will consist of outcomes of business activities:

- Total revenue (as in baseline survey C-5)
- Input costs (as in baseline survey C-5)
  - purchase of equipments, fertilizer, pesticides and hired labor
- Export volume (as in baseline survey F-1)

Hypothesis A.1: Offering training and information on food safety is likely to have positive impacts on adoption of GAP technology of farmers and intermediaries and increase food safety of the products.

Hypothesis A.2: Offering training and information on food safety may have an ambiguous impact on observable product quality.

Hypothesis A.3: Offering training and information on food safety may have an ambiguous impact on revenue and profits. I expect there to be heterogeneous effects with respect to whether the product's true measure of food safety is verifiable by intermediaries or buyers.

Hypothesis A.4: Offering training and information on food safety is likely to have the largest impacts on outcomes of farmers and intermediaries in treatment group 3. If technologies of farmers and intermediaries are complementary in the dragon fruit supply chain then I expect farmers and intermediaries to be more likely to adopt GAP technology and have higher measures of food safety relative to other treatment groups.

Hypothesis A.5: Offering training and information on food safety may create spillover effects across the supply chain. Specifically, training farmers in treatment group 1 is likely to have positive impacts on food safety and adoption of Good Handling Practices by intermediaries in treatment group 1 if training and knowledge on food safety can spillover across the supply chain. Similarly, training intermediaries in treatment group 2 is likely to have positive impacts on food safety outcomes of farmers in treatment group 2 if intermediaries' technology can spillover to farmers.

4.2 Hypothesis Group B. Impact of Certification

Hypothesis Group B concerns the impact of providing certification, a technology that allows verification of food safety, to farmers. Outcome variables can be grouped into three categories: (1) food safety measures, (2) observable quality measures, and (3) business outcomes. Measures are identical to the outcomes in Hypothesis Group A.

Hypothesis B.1: Offering certification on food safety is likely to have positive impacts on food safety outcomes and GAP technology adoption of farmers. I expect that knowing the possibility of certification can lead to an increase in adoption of food safety practices.

Hypothesis B.2: Offering certification on food safety is likely to have positive impacts on business outcomes of farmers who successfully pass the pesticide test.

Hypothesis B.3: Offering certification on food safety is likely to have the largest impacts on food safety and business outcomes for farmers in treatment group 3. This is because agricultural technologies on food safety and product quality are likely complementary between farmers and intermediaries.

4.3 Hypothesis Group C. Heterogeneity of Impacts

Hypothesis group C examines whether the impacts of training and certification depend on the individual characteristics of farmers and intermediaries. I will examine heterogeneity according to the following dimensions:

- Gender (baseline survey B-1): There is no clear prediction ex-ante
- Education (baseline survey B-2): There is likely to be a positive association between education and outcomes on food safety and product quality: more educated farmers may show larger increases in measures of food safety but smaller decreases in product quality.
- Experience in dragon fruit farming and trading (baseline survey C-2): I expect the impacts of training and certification to be increasing with farmers' and intermediaries' experience.
- Size of farm or facility (baseline survey C-3 and C-4): With increasing returns to scale, larger farmers and intermediaries may be more likely to adopt the new technology and have higher levels of food safety
- Financial constraints (pre-existing loans measured in baseline survey E-2 and current savings measured in baseline survey E-3): farmers and intermediaries with financial constraints may have difficulty implementing GAP technology if they have restrictions on investment or purchases of certain inputs
- Business attitude (behavior survey Q2): I expect certification to have a larger impact among farmers who score higher on the business attitude survey.
- Entrepreneurial ability (behavior survey Q3): I expect training and certification to have larger impacts on food safety and business outcomes for farmers and intermediaries with higher scores on the entrepreneurial ability test.
- Time discounting (behavior survey Q4 and Q14): Time-inconsistent discounting may be negatively associated with adoption of GAP technology and food safety outcomes.

- Risk attitude (behavior survey Q5): Risk aversion may be negatively associated with adoption of GAP technology and pesticide residue levels.
- Cognitive ability (behavior survey part B and Q13): There is likely to be positive associations between cognitive ability and GAP technology adoption and food safety outcomes.

5 Estimation Method

5.1 Estimation of the Impact of Training

To estimate the impact of GAP training on farmers' and intermediaries' outcomes, I use the following specification:

$$Y_{ij} = \beta_0 + \beta_1 T1_j + \beta_2 T2_j + \beta_3 T3_j + X_i + \theta_j + \epsilon_{ij} \tag{1}$$

where Y_{ij} is the outcome of individual i in farmer-intermediary group cluster j, TN_j is an indicator variable for treatment group N, X_i is a vector of individual characteristics, θ_j is a vector of cluster-specific characteristics, and ϵ_{ij} is the error term. Since randomization is at the farmer-intermediary group level I cluster the standard errors at this group level. The coefficients $\beta_1, \beta_2, \beta_3$ are interpreted as the intent-to-treat effects.

Treatment group 1 offers GAP information and training only to farmers. Therefore, for the farmer group, β_1 is the direct effect of offering information and technology training on farmers' outcomes. For the intermediary group, β_1 is the indirect effect of offering information and training to farmers on the local intermediaries' outcomes. For instance, a positive technology shock on the farmer group may induce intermediaries without direct treatment to adopt new technology on food safety.

Treatment group 2 offers GAP information and training only to intermediaries. For the intermediary group, β_2 is the direct effect of offering information and training on intermediaries' outcomes. For the farmer group, β_2 is the indirect effect of offering information and training to intermediaries on farmers' outcomes. In the event of a technology diffusion process from intermediaries to farmers

this would be captured by the estimate β_2 using farmers' outcomes.

Treatment group 3 offers information and training to both farmers and intermediaries. Thus, β_3 is the aggregate effect of offering information and training to both farmers and intermediaries. If technology upgrading in the supply chain requires complementarity, then we would expect the coefficient estimate of β_3 to be significantly larger than the coefficient estimate of β_1 and β_2 for both groups. In addition to the ITT estimate, I will derive an estimate of the treatment-on-the-treated (TOT) effect by instrumenting for take-up with the training offer.

5.2 Estimation of the Impact of Certification

To estimate the impact of certification on farmers' and intermediaries' outcomes, I use the following specification:

$$Y_{ij} = \gamma_0 + \gamma_1 \text{Certificate}_j + X_i + \theta_j + \epsilon_{ij} \tag{2}$$

where Certificate_j is an indicator for farmer groups' certificate treatment status. γ_1 estimates the effect of offering certification on post-treatment outcome variables. I can also examine the certification effects across first-stage treatment groups by estimating the coefficient on the interaction term $\text{Certificate}_j \times TN_j$ for each treatment group N. Heterogeneous treatment effects can be estimated by interacting treatment indicators with individual characteristics.

5.3 Other procedures for estimation and data cleaning

Most outcome measures that are collected for this study do not overlap with each other. Therefore, I do not plan to group the measures into domains. To account for multiple hypothesis testing with respect to the heterogeneity of treatment effects, I will employ the Benjamini and Hochberg (1995) method to minimize the false non-discovery rate (FNR).

I will drop data for individuals who have indicated during the survey as not being the primary responsible person for farming or trading dragon fruit. I will not impute for missing data from lack of response in the baseline and follow-up surveys. I will test whether missing data is systematically correlated with treatment status. To account for survey attrition, I will first test whether attrition is related to treatment status. Also, to address issues with attrition, I plan to obtain bounds on

the treatment effect.

6 Randomization Method and Balance Check

6.1 Randomization Method

Randomization at first and second stages are carried out using the researcher's computer. The research center provided a list of registered farmer groups in the catchment area which covers 22 communes and towns across two disricts, Ham Thuan Bac and Ham Thuan Nam. For first-stage randomization, within each commune, I randomly sampled four farmer groups.[1] The four farmer groups were then randomly assigned to one of the first-stage treatment arms. For second-stage randomization, within each first-stage treatment arm, I randomly assign 11 farmer groups to the certficate treatment and 11 farmer groups to the no certificate (control) group. Furthermore, based on the 2017 census of dragon fruit intermediaries in the sample area, intermediaries are matched with farmer groups based on location. The treatment statuses of intermediaries were determined by the matched farmer group's randomization outcome.

6.2 Balance Check

I will use observable characeristics collected from the baseline survey to conduct balance checks across treatment arms. Specifically, for each individual characteristic listed in Section 4.3, I regress the dependent variable on indicators for the farmer or intermediary being assigned to one of the four treatment arms. Commune fixed effects will be included in all regressions.

[1] One commune, Ham Can, had only two registered farmer groups. Accordingly, I combine these farmer groups with farmer groups in the nearest commune, Ham Thanh, for randomization.

Figure 1: Experimental Design: Training and Certification of Food Safety

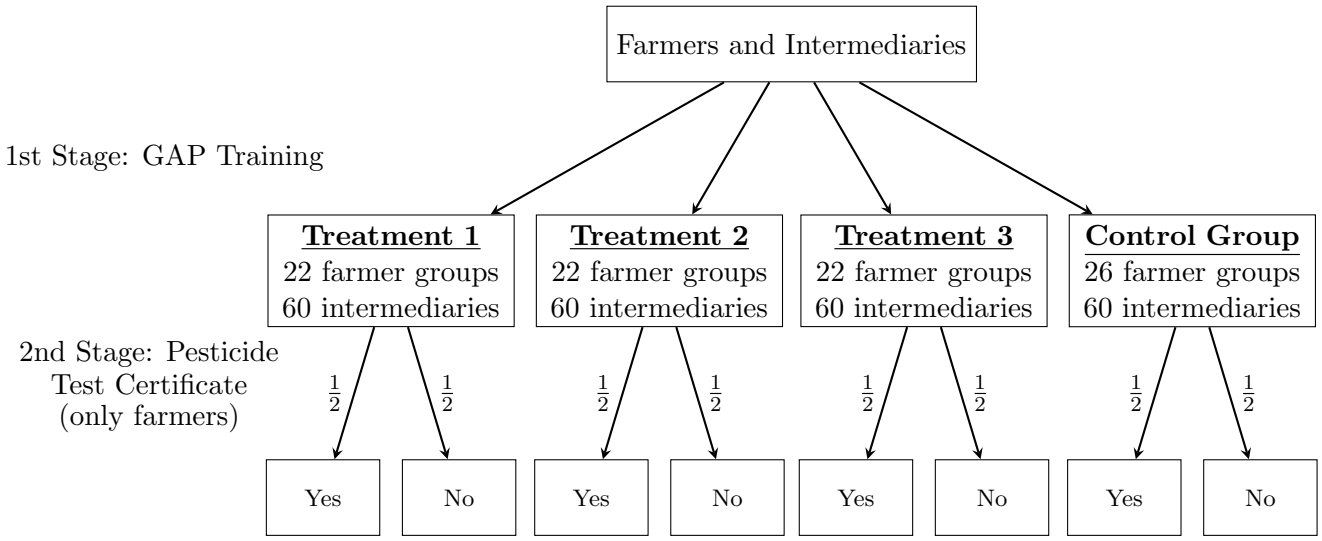

Table 1: Hypothesis Groups

	Intervention	Outcomes
A.	**Impact of Training**	Information and training on food safety and GAP technology may have short-run positive impacts on the adoption of safe agricultural practices and food safety. I expect training to have larger effects when farmers and intermediaries are trained together than when only the farmer or intermediary group is trained. The impact of training on product quality is ambiguous because there might be a tradeoff between food safety and product quality in terms of appearance, size or sweetness. The impact of training on profits and business outcomes may well depend on whether adopting food safety promoting agricultural technology negatively affects product quality.
B.	**Impact of Certification**	Certification may have a positive impact on technology adoption if farmers are more likely to adopt GAP technology if food safety can be objectively verified by intermediaries and buyers. The effect on product quality again depends on potential tradeoffs between food safety and product quality. due to potential increases to profits and exporting activities. That is, in the absence of certification the positive impact of training may not last.
C.	**Heterogeneity of Impacts**	Individual level characteristics of farmers and intermediaries may determine differential impacts of training and certification. Specifically, characteristics of interest are gender, education level, cognitive ability, entrepreneurial behavior, risk behavior, and normalized scores on double-sided auction games with other participants.