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# Food traceability system awareness and agricultural operation: A Study of tea farms in Fujian, China

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China is establishing a Food Traceability System (FTS), but the policy implementation is behind most developed countries. The lack of FTS awareness may be a factor contributing to farming practices that are not consistent with FTS policies. Furthermore, the structure of an agri-food supply chain is a factor influencing farms' compliance with FTS. The present study focuses on pesticide residue control and traceability issues in one of the largest tea production areas in China. It aims to examine the effect of FTS awareness and related policies on tea farms' operations as well as the influences of supply chain structure on the effects of policy awareness.

In this study the data were collected from Fujian province, which is a traditional, major tea-growing region in China with 18% of national production. Farms were recruited through a Stratified Sampling procedure that included 428 participating farms from the four largest tea-producing counties in Fujian. The participating farms answered questions regarding their awareness of FTS and related policies as well as the supply chain structure. The participants also reported their agricultural record-keeping practices related to pesticide residue control, including pesticide use, pesticide residue test, and sales record.

The results reveal that farm owners' or operators' FTS awareness has a positive effect on pesticide use and sales record-keeping practice, and the supply chain structure importantly moderates the effects of policy awareness on operations related to pesticide residue control. Compared to independent growers, tea farms within an integrated supply chain were more likely to take pesticide residue tests or keep sales records. The results suggest that increasing FTS awareness among tea growers would be crucial to establish a safe and traceable system. Furthermore, governments need to take the supply chain structure into account.

## 1. Introduction

Tea is one of the most consumed drinks worldwide. As China is the largest tea producing country (Chang, 2015), a safe and traceable tea production system in China would significantly contribute to the health and wellbeing of the global population. In recent years, there are frequent reports of excessive and inappropriate pesticide use on tea crops in China and the world market (Liu and Guo, 2019; Wang et al., 2017; Wei et al., 2012). As pesticides may remain on or in food after applied to crops, food safety incidents may occur through the consumption of treated crops (Lam et al., 2013). Therefore, it is crucial to establish a Food Traceability System (FTS) to improve tea safety and quality. A Food Traceability System consists of regulatory, technical, logistic, and business systems to reduce and control food safety risks with the ability to follow food ingredients and products across the processes of farming, processing, and distribution (Olsen and Borit, 2018). To establish an effective FTS, governments must implement policies to ensure that all players along the agri-food supply chain comply with the related regulations (Aung and Chang, 2014; Regattieri et al., 2007). As farms widely use pesticides for agricultural pest management (Carvalho, 2006; Cooper and Dobson, 2007), an FTS must regulate agricultural operations to control the pesticide residue level and minimise the impact.

China is actively establishing regulatory frameworks for an FTS (Jia and Jukes, 2013; Lam et al., 2013), but the progress of policy implementation is still behind most developed countries. The lack of FTS awareness among farmers may be one crucial factor contributing to farming practices that are not consistent with FTS policies (Charlebois et al., 2014; Tang et al., 2015; Wu et al., 2018). Furthermore, the structure of an agri-food supply chain in which a farm operates is another critical factor influencing the degree of compliance to FTS (Roth et al., 2008). Chinese farms are operating in diversified structures of agri-food supply chain. Being part of a consolidated supply chain, some tea farms supply products to large business organisations through formal contractual agreements (Zhang, 2012). Other tea farms, often smallholder farms, sell products to consumers through direct channels, such as farmers' markets. Since a consolidated food supply chain may offer farms with technical, financial, and other competitive advantages (Aung and Chang, 2014), the FTS policymaking process needs to take the diversified structures of the China tea supply chain into account. The present study focuses on the pesticide residue control and traceability issues in one of the largest tea production areas in China, Fujian province, and aims to examine the effect of FTS awareness and related policies on tea farm operations as well as the influences of supply chain structure on the effects of policy awareness.

### 1.1 Pesticide residue control and traceability

The use of agrochemicals contributes significantly to feed the growing world population. However, driven by health and environmental concerns, many countries have been tightening the regulations on pesticide use and lowering the maximum permitted concentration of pesticide residue in food (Carvalho, 2006). In order to reduce the health risks, it is vital to regulate the use of agrochemicals in farming practices, select appropriate types of pesticides, control the amounts of application, and allow sufficient intervals between pesticide applications and harvest. Beyond pesticide application control, the principles of traceability further require a transparent information collection and sharing system along the agri-food supply chain (Hobbs, 2004). As an essential part of this system, farms need to collect and store accurate information regarding pest management operations (Aung and Chang, 2014). This information would help improve food safety and quality and facilitate traceback operations in food safety incidents (Golan et al., 2004; Opara, 2003).

This study focuses on tea farms' information collection and keeping practices that are critical to controlling the hazards of pesticide residue, namely, pesticide application record-keeping, residue level testing, and sales record-keeping. (1) Pesticide application records include the time of applications, the formulation and manufacturer/supplier of the pesticide, as well as applied amount and concentration. This information is necessary for an FTS to track and control the potential hazards brought by pesticides (Aung and Chang, 2014; Peets et al., 2009). (2) Before the tea product enters the market, it is important to test the pesticide residue and compare the results to the legal maximum allowed level. The tests help not only to ensure chemical residue levels are tolerable and safe for consumption but also to provide useful data for optimal pesticide and FTS policies (Skevas et al., 2013). (3) Sales records document the time of the transaction, buyers' information, and the amount and specific product sold. Such transactional information is a critical resource to control potential hazards in a timely and appropriate manner.

### 1.2 Awareness of FTS and pesticide management policies

The Chinese government enacted the Agri-food Quality and Safety Law, specifically dedicated to food quality and safety control in 2006, which first mentioned the concept of a food traceability system. Since then, China has been progressively building and revising the regulation, inspection, and enforcement


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system aiming at a national wide FTS (Jia and Jukes, 2013). The Food Safety Law of China was first enacted in 2009 and was revised in 2015, in which a detailed FTS policy implementation structure was specified. The current Food Safety Law of China is a result of a progressive process of revision and improvement. This policymaking and implementation process has distinctive characteristics of experimentalism governance (Heilmann, 2008). That is, policies usually start from pilot projects or policy experiments at the municipal or provincial level and are eventually adopted by the upper-level legislation or regulatory bodies (Zhu and Zhao, 2018). This process takes the advantages of evidence-based policymaking, but policy awareness can sometimes not keep up with the speed of policy revision. Facing such a rapidly changing regulatory environment, food producers, distributors, retailers, and even local governments often experience some difficulties and uncertainty while keeping their standards of business/administrative conduct up-to-date. The lack of awareness may seriously influence farms' operations related to controlling the pesticide residue level.

Empirical evidence from both developed and developing countries has shown that the awareness and attitudes toward the financial, environmental and social benefits of the program may influence farms' participation in programs and compliances to policies (Atari et al., 2009; Liao et al., 2011; Mattevi and Jones, 2016; Winter and May, 2001). FTS contributes to public health and provides logistic, technological, and marketing support to farms (Monteiro and Caswell, 2009; Parreño-Marchante et al., 2014; Saltini and Akkerman, 2012). The awareness of FTS may be able to leverage farms to adopt certain agricultural operation practices consistent with the principles of a safe and traceable agri-food system (Liao et al., 2011; Mattevi and Jones, 2016). Therefore, this study hypothesises that:

H1: Tea producers' awareness of FTS and its related policies is positively associated with the likelihood of information collection and keeping practices related to pesticide use.

### 1.3 Supply chain structure

The tea industry in China adopts diversified structures of the supply chain to organise the physical products and information flow moving from farm to end-consumer, and tea farms differ in the degree to which they integrate into a consolidated supply chain (Guo et al., 2007). On the one hand, many Chinese tea farms, usually smallholders, operate in a relatively independent manner; they sell most of their products directly to end-consumers through less industrialised distribution channels, such as farmers' markets and tea gardens. On the other hand, supply chain integration influences the tea industry's operations and brings benefits and competitive advantages to many tea farms within the chain. From a vertical chain integration perspective, some farms are an integral part of Tea Industry Bases, usually located in large-scale tea production areas. Often with the financial and policy support from local and regional governments, a typical industry base consolidates the operations of farms, manufacturers, and distributors by providing agricultural material supply, production and processing technology, product quality and safety control, innovation incubator, personnel training, as well as marketing and information services. From a horizontal integration perspective, some tea farms form strategic partnerships (e.g., through family ties) or cooperatives to gain competitive advantages; they usually negotiate and supply most of their products to large-scale manufacturers or distributors through long-term contractual arrangements (Ito et al., 2012).

Even with the awareness of FTS and its related regulation/policy, agricultural businesses are not necessarily willing or able to operate in accordance with FTS, which often needs to overcome cost and technique barriers. The integrated supply chain usually has a contractual structure to specify the rights and obligations of farms, which may include operational guidelines or requirements for food safety and traceability (Gale and Hu, 2011). As such, this study hypothesises that supply chain integration has a direct effect on the farming operation:

H2: Tea producers within an integrated supply chain are more likely to collect and keep information related to pesticide use than independent tea farms.

An integrated supply chain may offer farms with financial or informational support, including understanding the policy and principles of traceability, learning and adopting new technology, as well as purchasing equipment and information technology systems. The agricultural industry bases and cooperatives have long been recognised as one of the most influential organisations that positively contribute to food safety-sensitive operations. The membership of a relatively integrated or consolidated supply chain, be it vertical (Banterle and Stranieri, 2008) or horizontal integration (Fischer and Qaim, 2012; Francesconi and Heerink, 2010; Verhofstadt and Maertens, 2014), within an agri-food supply chain is generally associated with greater willingness and better supporting resources to adopt improved agricultural practices or programs aiming at a higher standard of food quality and safety. This study aims to test the hypothesis that being part of an integrated supply chain moderates the effect of FTS policy awareness.

H3: The effect of FTS and policy awareness on information collection and keeping practices related to pesticide use is stronger for farms within an integrated supply chain than for that of independent farms.

### 1.4 Tea farms in Fujian

The present study collected data from Fujian province, a traditional and prominent tea-growing region in China with 18% of national production in volume contributing over 90 billion RMB (14 billion USD) in GDP. The Fujian tea industry hires over 3 million employees working for 16,000 tea-producing/trading business entities. Among them, are 1,500 grower cooperatives, and many more independent growers. Some farms are integrated into one of the 26 registered tea industry bases or have contractual selling arrangement with the 62 government-recognised leading ("dragon head") tea-producing/trading enterprises. Alternatively, a large number of growers operate outside of such integrated value chain structures and mainly sell products directly to end-consumers. In 2012, the Fujian provincial government enacted a regulatory document (Fujian People's Congress, 2012) devoted to a strategic development plan for the tea industry, which is the first of its kind in China. In 2015, the provincial "agri-food quality and safety action plan" further stipulated critical measures to control the pesticide residue of tea products, including the development and implementation of a tea-traceability information platform, pesticide use monitoring system, and market entry permission-based tests and record-keeping mechanism (Fujian Provincial Government, 2015). Facing diversified types of tea farms, governments heavily emphasise the function of consolidated value chain structure captained by tea industry bases and leading enterprises on building FTS. It is of practical importance to gather information regarding farms' policy awareness and examine the direct and indirect influence of value chain structure on tea growers' pesticide use control practice.

## 2. Materials and Methods

### 2.1 Data collection

Sampling: This survey study recruited tea-producing farms in Fujian province. The Tea Division of Fujian Provincial Agricultural Department provided a registration list of tea-producing farms in the four largest tea-producing counties (Anxi, Duding, Wuyishan, and Fuan) within the province. Based on the registered addresses, the study selected the sample through a stratified sampling procedure. From each of the four counties, the study identified two to four of the largest tea-producing towns. The number of towns selected is proportional to the production share in volume within the province. For each of the 12 selected towns, the study randomly selected 40 farms from the registration list. Researchers first contacted the farms and then had a face-to-face interview with the owner of each consenting farm. Four hundred and eighty farm owners agreed to participate in this study. Among them, 428 farm owners completed the interviews with valid answers to the questionnaire.

Measurements: Researchers and trained research assistants conducted the interviews. For each farm, the participant was the owner of the farm, head of the family, or someone primarily responsible for the tea farm's operation. As most of the participants were expected to have a high school education or less, this study took a face-to-face interview based on a questionnaire. To further simplify the interview, the questionnaire mainly consisted of yes or no (Y/N) questions. Layperson language was adopted in interviews as much as possible, and researchers and research assistants provided an explanation when participants were not clear with the questions.

The questionnaire included questions regarding tea-producing farms' FTS related operations, partic-


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ipants' awareness of FTS related policies, and the distribution channel as an indicator of the membership of a consolidated value chain structure. Participants also reported some questions regarding the characteristics of their farms. The interview also included three Y/N questions regarding FTS related operations in the year of this investigation. The questions asked, "Have you done (or have you been doing) the following for your tea farm in the past 12 months?" For operations during tea growing, whether they keep records (paper or digital) of pesticide use in their tea farm; for operations after harvest, whether test pesticide residue before selling the product; for operations after sales, whether records of sales are kept (product sold, date, buyer, quantity etc.).

There were pesticide controlling and monitoring policies built into the Fujian province FTS framework (Fujian Provincial Government, 2015). (1) Register the purchase of agricultural supplies: to buy pesticides or other agricultural supplies from designated agricultural materials suppliers, farms must obtain an agricultural supply purchase card, which links to the farm's business identity. By showing this card when purchasing restricted pesticide, the transaction information, including buyer and supplier's identity, product types and trade name, and the quantity is registered in a record system. (2) Pesticide Residue Testing (PRT) mechanism in the local tea market. It is required that tea products to be sold in Fujian province shall be tested for pesticide residue and compared to the maximum allowed level set by the policy. The participants indicated whether they were aware of the following policies (in two separate Y/N questions): The Agricultural Material Purchase Registration policy and the Maximum Pesticide Residue Levels allowed for tea products sold in the market. Participants also reported whether they knew the Food Traceability System (Y/N). The questions read: "Have you ever heard of xxx (xxx represents the name of each policy mentioned above or Food Traceability System)?"

For the supply chain structure, the interviewer asked participants, "Have you sold your tea products to industrial organisations such as tea industrial bases/centres or "big" companies last year? (Y/N). If the answer to this question was "No," this study assumes farms sold all products directly to individual consumers and were independent growers. In contrast, those who answered "Yes" were counted as growers within an integrated value chain. The interview also included some questions regarding owners' demographic and tea farm characteristics (See Table 1 for details of the sample).

## 2.2 Statistical model

This study examined three types of farms' FTS related operations, namely record-keeping of pesticide use, pesticide residue test, and sales record-keeping. In a multivariate probit model, the three types of operation were specified as outcomes. These were explained by the awareness of FTS and FTS-related policies, the distribution channel, as well as the two-way interactions between distribution channel and awareness. The model also controlled farms' and participants' characteristics. As compared to three independent conventional binary probit models, the multivariate probit model can simultaneously capture the factors that influence three outcome variables in one single model and allows for the correlations between the equations (Greene, 2008; Hausman et al., 1978; Chib et al., 1998). The model was specified as follows:

$$
\begin{aligned}
y^*_{1i} &= x_i\beta_1 + \varepsilon_{1i} \\
y^*_{2i} &= x_i\beta_2 + \varepsilon_{2i} \qquad (1) \\
y^*_{3i} &= x_i\beta_3 + \varepsilon_{3i} \\
y_{hi} &= 1 \text{ if } y^*_{hi} > 0 \text{ and } y_{hi} = 0 \text{ if } y^*_{hi} \leq 0 \ (h=1,2,3)
\end{aligned}
$$

Through probit link functions, y*hi represents the probability of the binary outcomes of pesticides records-keeping (y1), pesticide residue test (y2), and sales record-keeping (y3). The x and β vectors are predictors and their coefficients. To capture the correlation between three outcome variables, the model specified that the error terms follow a multivariate normal distribution ø(0,Σ) with a zero mean and a variance-covariance matrix Σ as indicated in function (2) (Maddala, 1983). Where, ρhk, are the correlation between each pair of outcomes. The model was estimated using the maximum likelihood method.

$$
\begin{bmatrix} 1 & \rho_{12} & \rho_{13} \\ \rho_{12} & 1 & \rho_{23} \\ \rho_{13} & \rho_{23} & 1 \end{bmatrix} \quad (2)
$$

**Table 1:** Descriptive Statistics of Key Questions

| Interview Questions | Percentage (n=482) |
|---|---|
| FTS-related Operations | |
| Keep Pesticides Use Record | 57% |
| Test Pesticide Residue | 75% |
| Keep Sales Record | 69% |
| Supply Chain Structure (Distribution channel) | |
| Farms within an integrated supply chain (Sold product to industrial organizations) | 52% |
| Awareness of FTS and related Policies | |
| FTS Awareness | 43% |
| Agricultural Material Purchase Registration | 49% |
| Maximum Pesticide Residue Levels | 39% |
| Owner's Demographic and Farm Characteristics | |
| Age > 44 | 39% |
| Tea Producing Experience > 17 years | 42% |
| Education > high school | 27% |
| Farm Scale in > 1 ha | 15% |
| Percent of household income from Tea> 70% | 44% |

## 3. Results and discussion

Table 2 presents the estimated coefficients. After accounting for all the predictors and control variables, the pesticide use record-keeping and sales record are positively correlated ($\rho = 0.20$, $p = 0.03$). In contrast, no other correlation between outcome variables was found significant. Participants older than 44 were less likely to keep pesticide use and test pesticide residue ($ps < 0.02$). An education level higher than high school contributed to a decreased probability of pesticide use record-keeping ($p = 0.02$). Farms larger than 1 hectare were more likely to keep records of pesticide use and test the pesticide residue after harvest ($ps = 0.01$). If tea sales contributed to more than 70% of a farm's total income, the farm was more likely to take pesticide residue tests ($p=0.01$). The following sections will discuss the key predictors and their influences on the three outcome variables.

### 3.1 Pesticide use record-keeping

In support of H1, FTS and policy awareness influenced whether or not a farm kept pesticide use records. Specifically, the awareness of FTS had a significant positive influence on the likelihood of keeping pesticide use records ($z=3.60$, $p<0.01$), and participants who were aware of the policy of Maximum Pesticide Residue Levels were more likely to keep recording pesticide use (marginal significant, $z=1.70$, $p=0.09$). H2, which expects a direct effect of the supply chain on pesticide use record-keeping, was not supported. As indicated by the farmer's adopted distribution channel (direct selling to consumers vs selling to organisations), the supply chain structure (independent vs integrated) was not a significant predictor of the odds of farmers' pesticide use record-keeping.

In terms of H3, the moderating effect of supply chain structure was found significant ($p=0.05$), as indicated by the interaction of distribution channel by the awareness of the Agricultural Material Purchase Registration policy (registration policy hereafter). Specifically, for farmers within an integrated supply chain, those with registration policy awareness were more


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likely to keep pesticide use records than those not aware of the policy (see Table 3). Whereas, the effect of the registration policy awareness was not as salient for independent farms.

### 3.2 Pesticide residue tests

As for the results regarding the pesticide residue tests (PRTs), the awareness of policies had significant positive influences on the odds of taking pesticide residue tests after harvest (supporting H1). Specifically, the effects of awareness of both registration policy (z=2.22, p=0.03) and the Maximum Pesticide Residue Levels (MRLs) policy (z=4.25, p<0.01) were significant. In terms of H2, farms who were an integral part of a supply chain had a positive influence (z=3.54, p<0.01) on the odds of taking pesticide residue tests (PRTs).

Significant interactions between supply chain structure and policy awareness indicated that the supply chain structure moderated the effects of policy awareness on PRTs. However, the direction of moderating effects was opposite to the H3. In terms of the effect of registration policy awareness among the independent growers (see Table 3), those who were aware of the registration policy were more likely to take PRTs than those who were not aware of it. For farms within an integrated supply chain, the awareness of the registration policy was surprisingly associated with a decreased odds of taking PRTs. A similar pattern was found for MRL policy awareness. Independent growers who were aware of the MRL policy were more likely to test the pesticide residue than those who did not have the awareness. Among farms within an integrated supply chain, the awareness of MRL policy had a negative impact on the likelihood of taking PRTs.

### 3.3 Sales record-keeping

In terms of the results regarding the record-keeping

**Table 2:** The Estimated Coefficients of the Multivariate Probit Model

| Outcomes: Farming Operations | Before harvest: $Y_1$ | | | After harvest: $Y_2$ | | | Before Sales: $Y_3$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pesticide Use Record | | | Pesticide Residue Test | | | Sales Record | | |
| Coefficients: | β | z | p | β | z | p | β | z | p |
| Intercept | -0.40 | -1.74 | 0.08 | -0.20 | -0.88 | 0.38 | 0.20 | 0.89 | 0.37 |
| Supply Chain Structure (SCS) | 0.17 | 0.65 | 0.51 | 0.93 | 3.54 | <0.01 | 0.51 | 1.98 | 0.05 |
| FTS awareness (FTS) | 1.00 | 3.60 | <0.01 | 0.25 | 0.89 | 0.37 | 0.90 | 3.03 | <0.01 |
| MRLs Policy awareness (MRL) | 0.38 | 1.70 | 0.09 | 1.15 | 4.25 | <0.01 | 0.37 | 1.65 | 0.10 |
| Registration Policy awareness (REG) | 0.13 | 0.57 | 0.57 | 0.51 | 2.22 | 0.03 | -0.46 | -2.11 | 0.04 |
| FTS X MRL | -0.44 | -1.49 | 0.14 | -0.62 | -1.88 | 0.06 | -0.26 | -0.80 | 0.42 |
| FTS X REG | -0.47 | -1.66 | 0.10 | -0.08 | -0.27 | 0.78 | -0.76 | -2.49 | 0.01 |
| FTS X SCS | 0.03 | 0.10 | 0.92 | 0.35 | 1.15 | 0.25 | 0.03 | 0.10 | 0.92 |
| MRL X SCS | 0.24 | 0.85 | 0.39 | -0.99 | -3.09 | <0.01 | 0.30 | 0.95 | 0.34 |
| REG. X SCS | 0.54 | 1.93 | 0.05 | -1.10 | -3.77 | <0.01 | 0.47 | 1.56 | 0.12 |
| Age | -0.56 | -3.68 | <0.01 | -0.39 | -2.40 | 0.02 | 0.05 | 0.30 | 0.76 |
| Tea Farming Experience | 0.25 | 1.76 | 0.08 | 0.04 | 0.25 | 0.80 | -0.08 | -0.54 | 0.59 |
| Education | -0.36 | -2.27 | 0.02 | 0.10 | 0.57 | 0.57 | -0.27 | -1.63 | 0.10 |
| Farm Size | 0.50 | 2.53 | 0.01 | 0.65 | 2.51 | 0.01 | 0.32 | 1.49 | 0.14 |
| Tea Sales Income | 0.04 | 0.28 | 0.78 | 0.39 | 2.56 | 0.01 | -0.16 | -1.05 | 0.29 |
| Correlations between Outcomes: | ρ | z | p | | | | | | |
| Between $Y_1$ and $Y_2$: $\rho_{12}$ | 0.11 | 1.24 | 0.22 | | | | | | |
| Between $Y_1$ and $Y_3$: $\rho_{13}$ | 0.20 | 2.23 | 0.03 | | | | | | |

**Table 3:** Observed percentages (%) of participating farms who reported "yes" for FTS related farming and selling practices

| Policy Awareness | Registration Policy | | MRLs Policy | | FTS Awareness | |
|---|---|---|---|---|---|---|
| | No | Yes | No | Yes | No | Yes |
| Number of Participating farms in each group (n) | | | | | | |
| Independent Growers | 78 | 127 | 142 | 63 | 134 | 71 |
| Integrated Supply Chain | 140 | 83 | 120 | 103 | 109 | 114 |
| Observed percentages of FTS practices (%) within each group | | | | | | |
| Pesticide Use Record | | | | | | |
| Independent Growers | 44.9% | 44.1% | 43.0% | 47.6% | 35.1% | 62.0% |
| Integrated Supply Chain | 63.6% | 78.3% | 64.2% | 74.8% | 56.0% | 81.6% |
| Pesticide Residue Test | | | | | | |
| Independent Growers | 56.4% | 77.2% | 60.6% | 88.9% | 67.2% | 73.2% |
| Integrated Supply Chain | 85.7% | 68.7% | 82.5% | 75.7% | 71.6% | 86.8% |
| Sales record-Keeping | | | | | | |
| Independent Growers | 66.7% | 42.5% | 49.3% | 57.1% | 47.8% | 59.2% |
| Integrated Supply Chain | 88.6% | 80.7% | 80.0% | 92.2% | 81.7% | 89.5% |

of sales information (product sold, date, buyer, quantity, etc.), FTS awareness was a significant predictor ($z=3.03$, $p<0.01$). Consistent with the expectation of H1, participants with FTS awareness were more likely to keep the sales record than those who did not know about FTS. The awareness of registration policy, however, was a significant negative predictor of the likelihood of sales record-keeping ($z=-2.11$, $p=0.04$); farms with policy awareness were less likely to keep the record than those without awareness. In support of H2, the supply chain structure was a significant predictor of the likelihood of taking sales records ($p=0.05$). Specifically, the farms within an integrated supply chain were more likely to keep records of sales than independent tea growers. No interaction between policy awareness and supply chain structure was found to be significant.

### 3.4 Discussion and implications

This study investigated Fujian tea farms' agricultural operation practices that related to pesticide residue control. The results reveal that farm owners' or operators' FTS awareness has a positive effect on pesticide use as well as in sales record-keeping practice. This finding is consistent to the literature (Liao et al., 2011; Mattevi and Jones, 2016) showing that, with the knowledge of logistic, marketing, and social benefits that an FTS may bring to the farm, growers may have a stronger willingness to operate following the principles of a traceable system for food safety and quality. Given that only 43% of tea farms in our sample were aware of FTS, this result highlights the importance of FTS awareness in establishing a safe and high-quality food system.

For specific policies related to pesticide residue control, the results indicate that the awareness of these policies is an essential factor influencing farms' operation. The awareness of policy for maximum pesticide residue level was positively associated with all three practices measured in this study, and such awareness was particularly salient in predicting a farm's likelihood of conducting pesticide residue tests after harvest. As only 39% of participants reported they were aware of this policy, it indicates that an awareness program would greatly improve the farms' operations for an effective food traceability system.

The awareness of the Agricultural Material Purchase Registration policy, however, had mixed effects on farms' operations. The registration policy awareness demonstrated a positive effect on farms' likelihood of taking pesticide residue tests, but such awareness had


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a negative effect on sales record-keeping. The registration policy regulates the supply of pesticide, and suppliers are required to check the identity of pesticide buyers, control the supplied pesticide type and volume, and record the transactions. This policy effectively encourages agricultural material suppliers to provide farmers with more information regarding pesticide residue hazards and how to reduce or control the risks. As such, it is no surprise to observe that tea farms were more likely to test the residue if they knew this policy. The study also found a negative effect of registration policy on sales record-keeping. One possible explanation is that the registration policy highlights the hazard of pesticide use as well as the potential legal and financial consequences of food safety incidents. To avoid taking responsibility in case a food safety incident happens, tea growers may choose not to keep the sales record.

The results also reveal the supply chain integration as an important factor influencing pesticide control practices. Compared to independent growers, tea farms in an integrated supply chain were generally more likely to take pesticide residue tests or to keep sales records. The reality of China's agriculture sector is that most farmers are smallholders with low education levels (Qiao et al., 2016). As food traceability is a relatively a new concept in agricultural communities, time is needed to communicate with farmers the benefits of a food traceability system, and more so to leverage meaningful changes in their operations. An integrated supply chain is usually led by larger organisations, such as agricultural cooperatives, processors, distributors, or retailers, which generally have better policy awareness, technical support, and financial resources. Within a consolidated business structure, these advantages of larger and more formal organisations may have a direct effect on the operations of smallholder farms through the contractual agreements, which may specifically require tea growers to test the pesticide residue and keep sales records.

The results also reveal that the supply chain structure importantly moderates the effects of policy awareness on operations related to pesticide residue control. Previous literature argues that an integrated supply chain would provide the necessary support to help growers operate by the principles of an FTS (Gale and Hu, 2011; Ito et al., 2012). The results regarding the record-keeping practice are consistent with these findings. With an awareness of the registration policy, farms within an integrated supply chain were more likely to keep tracking pesticide use. Conversely, this effect of policy awareness was not observed for independent growers. However, in terms of pesticide residue tests, the direction of the supply chain structure's moderating effect is the opposite of the hypothesis. For independent tea growers, the awareness of registration policy and maximum residue level was associated with an increased likelihood of taking pesticide residue tests. Among the farms within an integrated supply chain, those who were aware of the registration or MRL policies were less likely to test the pesticide residue than those who did not know the policies. An explanation to these unexpected results may be that knowing the policy, some farms within a consolidated business operation may assume testing pesticide residue is the responsibility of the channel captain. This responsibility shift may be the cause for the low rates of testing. In contrast, independent growers have no other organisations to rely on and must test the residue on their own, if they will.

The food traceability program was initiated in China in 2006. However, this study finds that many tea growers in Fujian province are still not operating as per the policy requirements of an effective food traceability system. The results of the study suggest that to increase FTS awareness among tea growers would be crucial to establish a safe and traceable system. However, policymakers need to take a closer look at some of the negative effects of policy awareness identified in this study. The results reveal potential challenges for policy implementation. A mere increase in policy awareness would not necessarily improve primary agricultural operation.

Furthermore, governments need to take the supply chain structure into account. An integrated supply chain would influence how farms operate, and this study finds that the influences may not always be positive. Opposite to the widely accepted notion that a consolidated supply chain would improve the food quality and safety, this study observed that among farms with policy awareness, independent tea growers are more likely than farms within an integrated supply chain to test pesticide residue after harvest. The pattern of the results points that when designing the regulatory system for food safety, the government needs to take a holistic view of all the links in a food supply chain instead of examining the players along the supply chain separately.

### 3.5 Study limitations

The results need to be interpreted with the study's limitations. The study sample was from one province of China. As different areas of China differ in the implementation of food safety and traceability regulations, further investigation comparing various areas of China may discover valuable insights for effective policy. This research reveals the relationships between policy awareness, supply chain structure, and agricultural operations, but the study took very simplified dichotomous measurements on these key concepts. Future studies would benefit from measurements with more extensive details, multiple items, and a more accurate description of the reality. This was a cross-sectional study depicting the current situation of the food traceability system in China. While China is actively developing the system, it is of theoretical and practical interests to conduct longitudinal research to study the long-term effects of policy changes. Finally, the study only investigated the operations of tea growers. While the results demonstrated the complicated influences of supply chain structure, it calls for future studies to include the interactions between tea farms and larger organisations in the supply chain.

## 4. Conclusion

This paper presents an empirical study investigating agricultural operations related to the food traceability system in China. There were less than half of the tea growers in our study that reported they were aware of FTS and related policies. The results indicate that to grow the awareness of FTS and policies may positively contribute to food safety and quality. The results also emphasise the importance of supply chain structure, implying that the policy implementation must be considered in the context of local and regional markets.

## Conflict of interest

The authors declare no conflict of interest. In addition, the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

## References

Atari, D. O. A., Yiridoe, E. K., Smale, S. & Duinker, P. N. (2009). What motivates farmers to participate in the Nova Scotia environmental farm plan program? Evidence and environmental policy implications. Journal of Environmental Management, 90(2), 1269-1279. https://doi.org/10.1016/j.jenvman.2008.07.006

Aung, M. M., & Chang, Y. S. (2014). Traceability in a food supply chain: Safety and quality perspectives. Food control, 39, 172-184. https://doi.org/10.1016/j.foodcont.2013.11.007

Banterle, A., & Stranieri, S. (2008). The consequences of voluntary traceability system for supply chain relationships. An application of transaction cost economics. Food Policy, 33(6), 560-569. https://doi.org/10.1016/j.foodpol.2008.06.002

Carvalho, F. P. (2006). Agriculture, pesticides, food security and food safety. Environmental science & policy, 9(7-8), 685-692. https://doi.org/10.1016/j.envsci.2006.08.002

Chang, K. (2015). World tea production and trade: Current and future development. Food and Agriculture Organization of The United Nations, Rome.

Charlebois, S., Sterling, B., Haratifar, S., & Naing, S. K. (2014). Comparison of global food traceability regulations and requirements. Comprehensive reviews in food science and food safety, 13(5), 1104-1123. https://doi.org/10.1111/1541-4337.12101

Cooper, J., & Dobson, H. (2007). The benefits of pesticides to mankind and the environment. Crop Protection, 26(9), 1337-1348. https://doi.org/10.1016/j.cropro.2007.03.022

Fischer, E., & Qaim, M. (2012). Linking smallholders to markets: determinants and impacts of farmer collective action in Kenya. World Development, 40(6), 1255-1268. https://doi.org/10.1016/j.worlddev.2011.11.018

Francesconi, G. N., & Heerink, N. (2010). Ethiopian agricultural cooperatives in an era of global commodity exchange: does organisational form matter?. Journal of African Economies, 20(1), 153-177. https://doi.org/10.1093/jae/ejq036

Fujian People's Congress. (2012). Regulations of promoting the development of tea industry in Fujian province, Fujian People's Congress. Fujian, China: 2012. http://www.fjrd.gov.cn/ct/63-88053

Fujian Provincial Government. (2015). The implementation opinions about accelerateing transformation of agricultural development of people's government of Fujian province. Fujian, China: Minzheng 2015 (No. 51).

Gale, H. F., & Hu, D. (2011). Food safety pressures push integration in China's agricultural sector. American Journal of Agricultural Economics, 94(2), 483-488. https://doi.org/10.1093/ajae/aar069

Golan, E., Krissoff, B., & Kuchler, F. (2004). Food traceability: One ingredient in a safe and efficient food supply. Amber Waves, 2(2), 14-21.

Guo, H., Jolly, R. W., & Zhu, J. (2007). Contract farming in China: perspectives of farm households and agribusiness firms. Comparative Economic Studies, 49(2), 285-312. https://doi.org/10.1057/palgrave.ces.8100202

Heilmann, S. (2008). From local experiments to national policy: the origins of China's distinctive policy process. The China Journal, (59), 1-30. https://doi.org/10.1086/tcj.59.20066378

Hobbs, J. E. (2004). Information asymmetry and the role of traceability systems. Agribusiness, 20(4), 397-415. https://doi.org/10.1002/agr.20020

Ito, J., Bao, Z., & Su, Q. (2012). Distributional effects of agricultural cooperatives in China: Exclusion of smallholders and potential gains on participation. Food policy, 37(6), 700-709. https://doi.org/10.1016/j.foodpol.2012.07.009

Jia, C., & Jukes, D. (2013). The national food safety control system of China–a systematic review. Food Control, 32(1), 236-245. https://doi.org/10.1016/j.foodcont.2012.11.042

Lam, H. M., Remais, J., Fung, M. C., Xu, L., & Sun, S. S. M. (2013). Food supply and food safety issues in China. The Lancet, 381(9882), 2044-2053. https://doi.org/10.1016/S0140-6736(13)60776-X

Liao, P. A., Chang, H. H., & Chang, C. Y. (2011). Why is the food traceability system unsuccessful in Taiwan? Empirical evidence from a national survey of fruit and vegetable farmers. Food Policy, 36(5), 686-693. https://doi.org/10.1016/j.foodpol.2011.06.010

Liu, P., & Guo, Y. (2019). Current situation of pesticide residues and their impact on exports in China. In IOP Conference Series: Earth and Environmental Science, 227(5), 052027.

Mattevi, M., & Jones, J. A. (2016). Traceability in the food supply chain: Awareness and attitudes of UK Small and Medium-sized Enterprises. Food Control, 64, 120-127. https://doi.org/10.1016/j.foodcont.2015.12.014

Monteiro, D. M. S., & Caswell, J. A. (2009). Traceability adoption at the farm level: An empirical analysis of the Portuguese pear industry. Food Policy, 34(1), 94-101. https://doi.org/10.1016/j.foodpol.2008.07.003

Olsen, P., & Borit, M. (2018). The components of a food traceability system. Trends in Food Science & Technology, 77, 143-149. https://doi.org/10.1016/j.tifs.2018.05.004

Opara, L. U. (2003). Traceability in agriculture and food supply chain: a review of basic concepts, technological implications, and future prospects. Journal of Food Agriculture and Environment, 1, 101-106.

Parreño-Marchante, A., Alvarez-Melcon, A., Trebar, M., & Filippin, P. (2014). Advanced traceability system in aquaculture supply chain. Journal of food engineering, 122, 99-109. https://doi.org/10.1016/j.jfoodeng.2013.09.007

Peets, S., Gasparin, C. P., Blackburn, D. W. K., & Godwin, R. J. (2009). RFID tags for identifying and verifying agrochemicals in food traceability systems. Precision Agriculture, 10(5), 382-394. https://doi.org/10.1007/s11119-009-9106-4

Qiao, Y., Halberg, N., Vaheesan, S., & Scott, S. (2016).

Assessing the social and economic benefits of organic and fair trade tea production for small-scale farmers in Asia: a comparative case study of China and Sri Lanka. Renewable Agriculture and Food Systems, 31(3), 246-257. doi:10.1017/S1742170515000162

Regattieri, A., Gamberi, M., & Manzini, R. (2007). Traceability of food products: General framework and experimental evidence. Journal of food engineering, 81(2), 347-356. https://doi.org/10.1016/j.jfoodeng.2006.10.032

Roth, A. V., Tsay, A. A., Pullman, M. E., & Gray, J. V. (2008). Unraveling the food supply chain: strategic insights from China and the 2007 recalls. Journal of Supply Chain Management, 44(1), 22-39. https://doi.org/10.1111/j.1745-493X.2008.00043.x

Saltini, R., & Akkerman, R. (2012). Testing improvements in the chocolate traceability system: Impact on product recalls and production efficiency. Food Control, 23(1), 221-226. https://doi.org/10.1016/j.foodcont.2011.07.015

Skevas, T., Lansink, A. O., & Stefanou, S. E. (2013). Designing the emerging EU pesticide policy: A literature review. NJAS-Wageningen Journal of Life Sciences, 64, 95-103. https://doi.org/10.1016/j.njas.2012.09.001

Tang, Q., Li, J., Sun, M., Lv, J., Gai, R., Mei, L., & Xu, L. (2015). Food traceability systems in China: The current status of and future perspectives on food supply chain databases, legal support, and technological research and support for food safety regulation. Bioscience trends, 9(1), 7-15. https://doi.org/10.5582/bst.2015.01004

Verhofstadt, E., & Maertens, M. (2014). Can agricultural cooperatives reduce poverty? Heterogeneous impact of cooperative membership on farmers' welfare in Rwanda. Applied Economic Perspectives and Policy, 37(1), 86-106. https://doi.org/10.1093/aepp/ppu021

Wang, J., Tao, J., Yang, C., Chu, M., & Lam, H. (2017). A general framework incorporating knowledge, risk perception and practices to eliminate pesticide residues in food: A structural equation modelling analysis based on survey data of 986 Chinese farmers. Food control, 80, 143-150. https://doi.org/10.1016/j.foodcont.2017.05.003

Wei, G., Huang, J., & Yang, J. (2012). The impacts of food safety standards on China's tea exports. China Economic Review, 23(2), 253-264. https://doi.org/10.1016/j.chieco.2011.11.002

Winter, S. X. C., & May, P. J. (2001). Motivation for compliance with environmental regulations. Journal of Policy Analysis and Management, 20(4), 675-698. https://doi.org/10.1002/pam.1023

Wu, Y. N., Liu, P., & Chen, J. S. (2018). Food safety risk assessment in China: Past, present and future. Food Control, 90, 212-221. https://doi.org/10.1016/j.foodcont.2018.02.049

Zhang, Q. F. (2012). The political economy of contract farming in China's agrarian transition. Journal of Agrarian Change, 12(4), 460-483. https://doi.org/10.1111/j.1471-0366.2012.00352.x

Zhu, X., & Zhao, H. (2018). Experimentalist governance with interactive central–local relations: Making new pension policies in China. Policy Studies Journal. https://doi.org/10.1111/psj.12254


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