Investigating the "One Farm Household, Two Production systems" in Rural China: The Case of Vegetable and Fruit Farmers

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Abstract: Food safety receives an escalating attention since the 2008 milk scandal in China. Chinese government faces a great challenge to safeguard the safety of food supply chain due to the significant fermentation of producers and weak institutional resources to monitor and enforce food safety standards. Chinese farm households often practice two separate production systems for the same crop for the market and self-consumption separately and, thus the so called "One Farm Household, Two Production Systems" (OFH-TPS) gain the popularity in the recent years. This study provides both a theoretical framework to model the OFH-TPS decision and an empirical analysis to identify factors affecting the OFH-TPS decision using household survey data. We find that information asymmetry of product quality and measures to reduce the asymmetry such as product inspections and certifications play an important role in the OFH-TPS decision. In particular, product inspections conducted by industry associations, agricultural cooperatives, or farmer themselves curb the adoption of the TFH-TPS, whereas government inspection has no statistically significant effect. Farmers who sell green foods are less likely but organic farmers are more likely to adopt the OFH-TPS, which echoes the expectation based on the theoretical model. We also find that training of pesticide applications reduce the adoption of the OFH-TPS, but the perceived adverse effects of pesticide applications have no statistical effects. Furthermore, farmers who uses highly toxic and banned pesticides and/or who perceive poor food safety of the local markets are more likely to adopt the OFH-TPS. This study provides rich policy implications. First, calling the engagement of private sector to safeguard food safety and improving the efficacy of government inspection are critical to improve food safety. Second, education on pesticide applications is critical, especially among retailers of pesticides.
Key words: food safety, "one household, two production systems", non-separable model, inspection, certification

1. Introduction

Rapid industrialization and urbanization along with unprecedented fast economic growth have profound impacts on food supply chain and food safety in China, especially in recent years (Lam, et al., 2013). The concern of food safety reached its climax upon the 2008 milk scandal[1]. Food safety was ranked first in the top five safety concerns in China in 2011, followed by the safety of public, traffic, health and the environment (Lam, et al., 2013). The fragmentation of producers/retailers in the food supply chain poses a great challenge to safeguard food supply. China launched the Household Responsibility System (HRS) in 1978 and it significantly accelerated economic growth and improved economy and the wellbeing of China, but it transferred a highly controlled collective system to an individual household farming system consisting of highly fragmented producers (Lin, 1992). The

[1] The 2008 milk scandal in China involved an intentional contamination of dairy products by melamine to artificially boost the protein reading. Tainted milk products have significant adverse health impacts, especially for infants and children. By November 2008, The Chinese Ministry of Health reported an estimated 300,000 ill children with six infants dying from kidney diseases.

structural change resulting from the HRS imposed a great challenge to monitor chemical inputs. China is the leading producer and consumer of pesticides in the world – exceeding 2.6 million tons for production and 1.8 million tons for consumption in 2011 (Li, et al., 2014). The average annual pesticide applied per hectare is 15 kilogram, higher than Japan (12kg/ha), the Republic of Korea (6.6kg/ha), and India (0.5kg/ha) (Jin, et al., 2010). Fertilizers are also extensively applied by Chinese farmers. The average annual fertilizer applied per hectare amounts to 300 kilogram in northern China, which is a 50% increase than the what is perceived as the high usage in Europe (Ju, et al., 2007). It is not uncommon that Chinese farmers apply highly toxic, even banned pesticides (Yang, et al., 2014). A high level of pesticide residue is commonly found in vegetables and fruits (Qin, et al., 2016), which becomes a significant safety concern.

The safeguard of food supply chain requires an understanding of production decisions of Chinese farmers. One phenomenon in China's agricultural production in recent five years is that farmers practice two separate production systems for the same agricultural commodity, one for self-consumption and the other one for the market. Two possible scenarios explain the need for separate productions. First, farmers are both the producer and consumer. When food safety is a concern, farmers may apply less pesticides and chemicals or use non-synthetic pesticides and fertilizers in the production for self-consumption, but apply more chemicals inputs, sometimes even banned ones, for the market-oriented production. Second, farmers may produce high quality products for the niche market (e.g., producing organic or export-oriented products), but they prefer relatively poor but still satisfactory quality for self-consumption to avoid the high production cost. We define the dual production practice as "One Farm Household, Two Production Systems" (OFH-TPS). Xu (2013) finds that nearly 60% interviewees of 60 farmers in Hebei province adopted the OFH-TPS. In another national survey, 34% out of 654 households are found to operate OFH-TPS(Ni, 2014). Although the real percentage of farmers adopting OFH-TPS remains unclear, this phenomenon arises huge attention from the public. Despite some descriptive analyses (Ni, 2014, Ni, 2014, Xu, 2013, Xu, 2014), little research has been conducted to understanding the underlying economic reasons. This study will fill the gap by providing both a theoretical framework to model the OFH-TPS decision and an empirical analysis to identify factors affecting the OH-TPS decision. Since food safety often arise because of asymmetric information on food quality between consumers and producers, this study focuses on the role of information asymmetry and measures to reduce information asymmetry (e.g., product inspections and third-party certifications) on the production decision among China rural farmers. The main findings are summarized below. First, product inspections conducted by industry associations, agricultural cooperatives, or farmer themselves curb the adoption of the TFH-TPS, whereas government inspection has no statistically significant effect. Second, farmers who sell green foods are less likely but organic farmers are more likely to adopt the OFH-TPS. Third, training of pesticide application reduce the adoption of the OFH-TPS, but the perceived adverse effects of pesticide applications have no statistical effects. Furthermore, farmers who uses highly toxic and banned pesticides and/or who perceive poor food safety of the local markets are more likely to adopt the OFH-TPS.

This rest of this paper proceeds as follows. Section 2 presents a conceptual framework to explain how information asymmetry, product inspections, and product certifications affect the OFH-TPS decision. Section 3 discusses the household survey and provides data summary statistics. Section 4 represents the empirical result based on instrument variable analysis. Section 5 concludes the paper and offers policy implications.

2. Conceptual Framework

A non-separable model is commonly employed to study market participation of economic agents who are the producer and consumer of their own products (De Janvry and Sadoulet, 2006, Key, et al., 2000, Singh, et al., 1986, Yutopoulos and Lau, 1974). We denote product quantity by q_k and product quality by s_k for the market (k = 1) or self-consumption (k = 2). Product quality differs if farmers engage in the

OFTS. Production costs can be affected by product quantity and quality: $C(s_{k,}q_k)$. A quality improvement requires an extra cost: $\frac{\partial C(s_k,q_k)}{\partial s_k} > 0$. We further assume that quality also affects product price such that $\frac{\partial P(s_k)}{\partial s_k} > 0$ if quality information is publicly available and/or searchable.

Following Auriol and Schilizzi (2015)'s framework, we assume that an individual farmer gains utility through two components: a) the net income from the market-oriented production that is expressed as $w = P(s_1)q_1 - C(q_{1,}s_1)$; and (b) the difference between the utility gained from self-consumption and the production cost: $u_2 = u(q_{2,}s_2) - C(q_{2,}s_2)$. We further assume a constant production cost with respect to quantity: $C(q_{k,}s_k) = q_k c(s_k)$ for k =1, 2. Thus, the overall utility of an individual household can be written as:

(1a) $$U = w + u_2 = \{P(s_1)q_1 - c(s_1)q_1\} + \{u(q_{2,}s_2) - c(s_2)q_2\},$$

(1b) s.t.: $I = P(s_1)q_1 - c(s_1)q_1 - c(s_2)q_2 \geq 0.$

where I indicates the household income.

The expectation and standard of product quality can been dramatically different among the society, individual consumers, and producers. We denote the society's minimum quality standard by $\underline{s}$ and the minimum acceptable quality for self-consumption for household i by s_{ia} such that $s_{ia} \geq \underline{s}$. Assuming that s_1^* and s_2^* be the optimal quality that maximize equation (1a) subject to the income constraint in equation (1b), we have the following conditions satisfied:

(2a) $$\frac{dU}{ds_1} = q_1\big(P'(s_1) - c'(s_1)\big) = 0$$

(2b) $$\frac{dU}{ds_2} = \frac{du(q_{2,}s_2)}{ds_2} - q_2 c'(s_2) = 0$$

If $s_1^* = s_2^*$, there is no need for farmers to engage in the OFTS. The following two scenarios can potentially lead to the OFTS. First, if $\underline{s} \leq max\{s_1^*, s_{ia}\} < s_2^*$, farmers will supply lower quality products to the market and those of high-quality for self-consumption. This scenario is more likely to occur if there is information asymmetry of product quality. With information asymmetry, farmers lack of incentive to supply high-quality products as they incur a high production cost but not able to differentiate their products from those of low-quality. Second, if $s_1^* > max\{s_{2,}^* s_{ia}\} \geq \underline{s}$, farmers will supply low-quality products for self-consumption and high-quality products for the market. For example, farmers may produce organic fresh produce to gain a significant price premium, but they prefer low but satisfactory quality for self-consumption to avoid the higher production cost as long as the produce quality is at least as high as their minimum acceptable level. In both scenarios, farmers will engage in the OFTS. Various factors can affect product quality levels, s_1^*, s_2^*, s_{ia} and $\underline{s}$; and thus affecting the likelihood of engaging in the OFTS.

Information asymmetry of product quality

Information asymmetry arises between two parties where the information is only available to one party and the other party could be potentially better if he/she had the information. Stiglitz (2002) highlights two types of information where asymmetry is particular important: information of quality and information of intent (e.g., effort). In the case of product quality, the literature has addressed different product attributes and how each type of attributes is related to information asymmetry. Nelson (1970) and Darby and Karni (1973) classify product attributes into search, experience, and credence ones. Credence attributions are those for which consumers cannot assess quality attributes either before purchasing or consuming the product like search attributes or after purchasing/consuming the product like experience attributes. In the context of food safety, pesticide/chemical residue is a credence attribute as consumers are less likely to find out the amount and frequency of applications as well as the residual measures before and after purchasing/consuming the products. Because consumers are not fully aware of product quality before they purchase and consequently quality is less likely to affect product price. If quality has completely no effect on product price, we have $P'(s_1) = 0$. As a result, the first order condition in Equation (2a) becomes $\frac{dU}{ds_1} = q_1\left(P'(s_1) - c'(s_1)\right) = -q_1 c'(s_1) < 0$ since $c'(s_1) > 0$. Farmers will produce at the minimum quality for the market: $s_1^* = \underline{s}$, if the society's minimum quality standard is enforced by product inspections and/or a significant monetary penalty for non-compliance. The quality deterioration due to asymmetric information is what Ackelof (1970) has suggested. The minimum quality standard could be a possible solution to maintain product quality (Leland, 1979). On the other hand, the optimal product quality for self-consumption is s_2^* such that $\left\{\frac{du(q_{2,}s_2)}{ds_2} - q_2 c'(s_2)\right\}\Big|_{\{s_2=s_2^*\}} = 0$ and $s_2^* \geq s_{ia}$. Thus, when the market faces information asymmetry of product quality, farmers will engage in separate productions as long as the optimal quality for self-consumption does not equal the minimum quality given the information asymmetry of product quality.

Inspections of Product Quality

One way to mitigate the adverse consequence of quality asymmetry and ensure the minimum quality is to conduct product inspections (Starbird, 2005). Product inspections can be done by various parties, including the government sector, industrial organizations, agricultural cooperatives, and farmers themselves. Following the model proposed by Starbird (2005), we assume farmers can choose to produce either high or low quality products: s_k^H for high quality and s_k^L for low quality. We denote the likelihood of passing inspections by θ^H and θ^L and the production cost by c^H and c^L, respectively for high- and low-quality products. We also assume that high-quality products have a higher probability to pass inspections and more costly to produce: $\theta^H > \theta^L$ and $c^H > c^L$.

The parties who conduct inspections often develop sampling strategies. Assume a random draw of *n* samples from batch size *N* such that $N \gg n$. Assume that the whole batch will be accepted for sale at price *p* if no more than *d* samples fail to pass the inspection. Otherwise, the farmers would face economic loss *F* per unit, which can be penalty and/or disposal cost. Given that the probability for a sample unit to pass the inspection is θ, the probability that an entire batch will be accepted for sale is

(3) $$\pi(\theta) = \sum_{t=0}^{d} \frac{A_n^t}{t!} (1-\theta)^t \theta^{n-t}$$

where *t* represents the number of sample units failed to meet the quality standard and A_n^t is the permutation of *t* out of *n*. Equation (3) suggests that the probability for the entire batch to pass inspections depends on the sample size (*n*), the maximum number of samples that can fail the inspection (*d*), and the probability for a sample unit to pass the inspection (*θ*). The incentive compatibility condition under which an individual farmer is more profitable to produce high-quality products is given below:

(4) $$\pi(\theta^H)pq_1 - \left(1-\pi(\theta^H)\right)Fq_1 - c^H q_1 \geq \pi(\theta^L)pq_1 - \left(1-\pi(\theta^L)\right)Fq_1 - c^L q_1$$

As shown in Equation (4), we assume that consumers are not able to distinguish quality difference as long as the products pass the inspection. Therefore, the price for the high- and low-quality products is assumed to be the same. The right-hand expression of equation (4) is the profit that the farmer could have if producing low-quality products and the left-hand expression for the profit associated with high-quality products. Rearranging equation (4) yields:

(5) $$\pi(\theta^H) - \pi(\theta^L) \geq \frac{c^H - c^L}{p+F}$$

Equation (5) shows that farmers are more likely to produce high quality products if the difference in the probability to pass inspections are significantly high, and/or the cost difference between high- and low-quality products is significantly low. Consumers will directly affect the producer's quality choice through their offering price *p*. An increase in consumers' offering price improves the likelihood that the producers will produce high-quality products. A higher penalty for non-compliance also increases the likelihood of producing high quality products. By rearrange equation (5), we can calculate the minimum offering price:

(6) $p \geq \frac{c^H - c^L}{\pi(\theta^H) - \pi(\theta^L)} - F.$

If farmers are more likely to produce high-quality products, they are less likely to engage in the OFH-TPS if food safety for self-consumption is an important concern.

Product inspections conducted by different parties (e.g., the government sector, industry associations, agricultural cooperatives, and consumer organizations) not only have a different choice of n, d and F, but also face different technical and institutional constraints to detect the quality failure θ. The inequalities presented in Equations (5) and (6) also depend on the production cost and consumer offering price. We expect that inspections conducted by different parties will affect the choice of product quality and the resultant adoption of the OFH-TPS, which results in the following hypothesis.

Hypothesis 1: *Product inspections affect the choice of product quality and the OFH-TPS. The inspection effect varies by who conduct the inspections.*

Signaling Product Quality by Certification

Quality signal are commonly used to reduce uncertainty under information asymmetry (Connelly, et al., 2011, Starbird, 2005). One popular approach for quality signaling pertaining to credence attributes is certifications provided by a third independent party at a cost (Auriol and Schilizzi, 2015). With the increasing severity of food safety and environmental concerns, a range of certification projects have been undertaken by the Chinese government such as the certification of Harmless Agricultural Product (HAP), Green Food, and Organic Food (see Yin, et al. (2010) for details). The HAP certification, funded in December, 2002 and formally commenced in March, 2013, is managed by the Center of Agri-Food Quality and Safety under the Ministry of Agriculture (MoA). Green Food, the main food quality label in China, is managed by the China Green Food Development Center, which was funded and commenced in 1992 under the MoA. Green Food requires testing residues and conducting field inspections. The certification of Organic Food in China is coordinated by three authorities: a) General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) that established national standards of organic products in 2004; b) China Organic Food Certification Center of the MOA commenced in 2003 and has been in charge of certification and management of organic food; and c) China Organic Food Development Center of the MOA funded in 1994 and is the only organic certifier in China that has been accredited by IFOAM (International Federation of Organic Agriculture Movement). Yu, et al. (2014) provide a summary of standards and requirements for these three certifications. HAP is less stringent and allows certified products to contain reasonable level of pesticide residues, heavy metal, and microorganism contents that comply with the standard set up by the government and food is still safe for consumers. Green Food is more stringent and more widely accepted than HAP. Organic Food, as the most stringent certification in China, limits the use of pesticides, chemical fertilizers, and other chemical inputs. Most Chinese consumers find organic foods are not affordable, while the certification of Green Food that has a lower standard is predominant in China. According to the report by *China Certification and Accreditation Administration* (*CCAA*), the certification of HAP, Green Food, and Organic Food rank top three based on the number of certificates issued in 2013 (CCAA, 2013). As shown in Fig. 1, the total available number of products that were certified as HAP outweighed those for Green Food and Organic Food; and the number of the Organic Food certification had the fastest growth in 2008-2013.

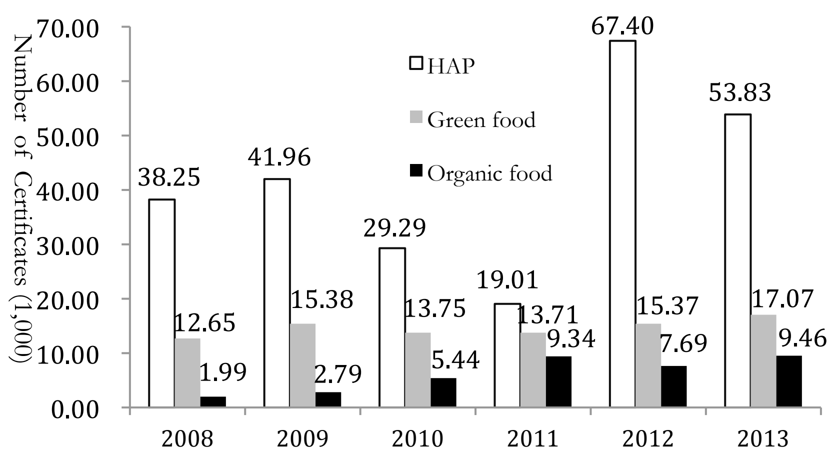

Fig. 1: Number of certificates issued for HAP, Green food and Organic food.
Data source: China Certification and Accreditation Administration[2]

[2] http://www.cnca.gov.cn/ywzl/rz/spncp/tzgg/index.shtml

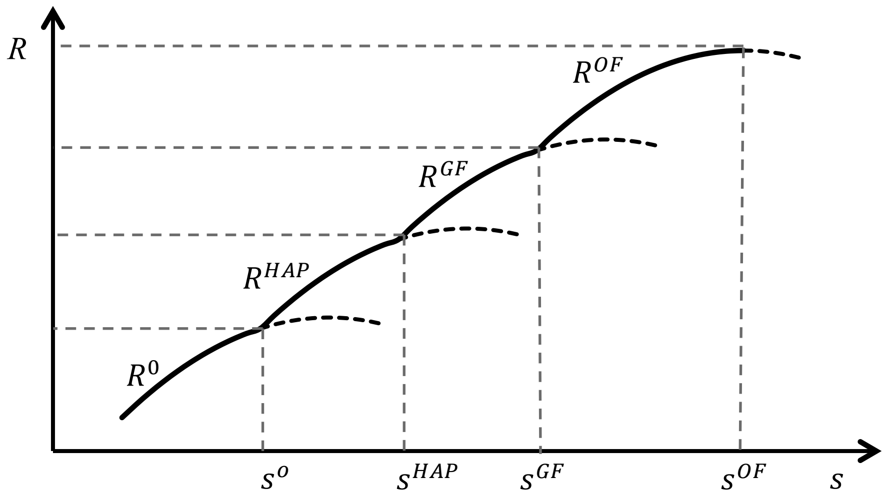

Fig. 2: Profitability and Quality by Different Certification

Producers use certifications to differentiate their product and enjoy price premium as a credible certification sends consumers quality signal. For example, the average price of organic vegetables in China's domestic market reaches 6-7 dollars per kilogram, which is usually 3-5 times higher than the price of un-certificated vegetable.[3] On the other hand, production costs vary significantly between certified products. For example, the cost of producing organic food is about four times higher than HAP.[3] The price and cost differences associated with different certifications are expected to affect the choice of the OFH-TPS differently. For example, farmers choose to provide organic food for a higher profit such that $s_1^* > s_2^* \geq max\{\underline{s}, s_{ia}\}$. However, they may choose not to consume organic food for themselves to save production costs if they believe it is not necessary to consume products with such high quality. As a result, farmers maybe engaged in the OFH-TPS – producing organic food for the market and leaving food with lower but satisfactory quality for self-consumption. For the illustrative purpose, we assume that product quality *s* is a continue variable. As shown in Fig. 2, the family net income of non-certified products is denoted by R^0, whereas R^{HAP}, R^{GF}, and R^{OF} represents the family income if the products are certified as HAP, Green Food, or Organic Food, respectively. The decision to certificate their products is summarized below:

3 http://news.cnfol.com/xiaofei/20140714/18385300.shtml

$$(7)\quad \begin{cases} \text{no certification} & if\ s_0 \leq s_1^* \leq s^0 \\ \text{HAP} & if\ s^0 < s_1^* \leq s^{HAP} \\ \text{Green Food} & if\ s^{HAP} < s_1^* \leq s^{GF} \\ \text{Organic Food} & if\ s^{GF} < s_1^* \leq s^{OF} \end{cases}$$

If $s_0 \leq s_1^* \leq s^0$ is satisfied, the individual household will not certify his/her products. If $max\{s^0, s_{ia}\} < s_2^*$ is satisfied, the product for self-consumption can be of a higher quality. In this case, the farmer will engage in the OFH-TPS and no certification will be pursued for self-consumption to avoid the certification cost and a possible cost increase in production. Furthermore, if $s^0 < s_1^* \leq s^{HAP}$ and $\{s^{HAP}, s_{ia}\} < s_2^*$, the farmer will sell the HAP-certified products. He also produces higher quality products for self-consumption but without any certification to avoid certification cost and a cost increase in production. These examples suggest that an individual household may engage in the OFH-TPS – producing a higher quality product for self-consumption, but a lower quality product for the market. On the other hand, if $s^{GF} < s_1^* \leq s^{OF}$ is satisfied, an individual farmer prefers to produce organic products. However, it may not be optimal to consume organic foods for the farm household due to the higher production cost and the certification cost. Furthermore, the choice of product quality for self-consumption satisfies the condition written in equation 2(b) and the optimal quality for self-consumption is likely to be significantly less than the quality of organic product. As a result, the farmer will engage in the OFH-TPS – producing organic food for the market and products with relative lower but satisfactory quality for self-consumption. Similar scenarios can also occur -- producing Green Food or HAP for the market and products with relative lower quality for self-consumption. In these scenarios, farmers engage in the OFH-TPS and they provide high quality products for the market as long as the price premium can offset the cost difference and low but acceptable quality for self-consumption.

Hypothesis 2: *Certifications affect the OFH-TPS decision, but effects vary by certification type.*

3. Data

This study uses a household survey of vegetable and fruit farmers in Shandong province in February-March, 2015. We choose the fresh produce industry due to the following reasons. First, China is one of the largest producers and exporter of fruits and vegetables worldwide (Goetz and Grethe, 2010, Weinberger and Lumpkin, 2007). China supplies about three quarters of vegetable imports in the Republic Korea and 37% of fresh vegetable imports in Japan in 2004 (Huang and Gale, 2006). Second, pesticide is applied more intensively for horticulture than cereal crops in China. Huang, et al. (2000) show that the pesticide cost per hectare for vegetables (tomatoes and cucumbers) and fruits (apples and oranges) is approximately 4.5-8 times higher than that for rice. It is common to find fresh produce have significant pesticide residue or contaminated by chemicals in China (Chen, et al., 2011, Wang, et al., 2015), which leads to an important food safety concern.

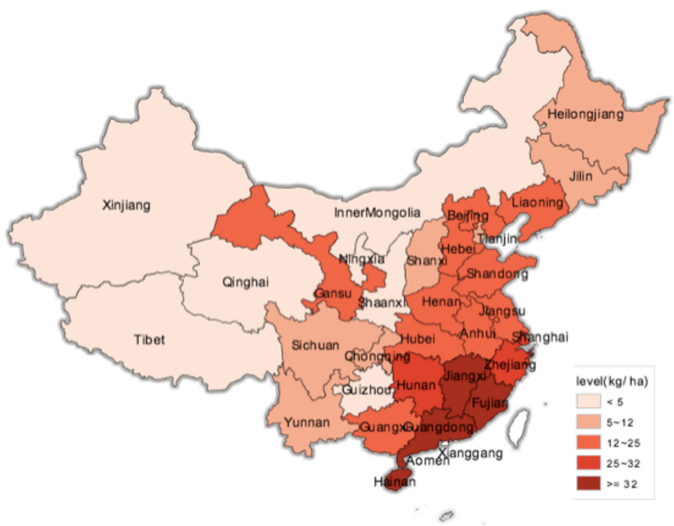

Fig. 3: Graphical distribution of pesticide application dosage in China: 2013
Data source: China Rural Statistical Yearbook 2015.

Shandong province was selected for the survey due to its position in horticulture production in China. Shangdong ranked first and sixth for vegetables and fruits in 2014, respectively, based on the cultivated areas; and the top one based on production volume of fresh produce – accounting for 13% and 12% of the total production for vegetables and fruits (CRSY, 2015). Shandong accounted for approximately 28% of the total export of vegetables of China in 2012 (CEH, 2013). National Development Plan for Vegetable Production of 2009-2015 selected approximately 550 counties in the nation as the national vegetable production bases. A total of 70 counties in Shandong have selected as the base. On the other hand, farmers in East and Southern China apply more pesticide per hectare of cultivated land as shown in Fig. 3. Shandong ranked 9th by the pesticide application dosage: 20.75 kilogram per hectare that exceeds the national average by one quarter (16.70 kilogram per hectare) (CRSY, 2015). The extensive pesticide applications in Shangdong will call for concern for food safety.

We randomly selected a total of 837 farmers from 241 villages in 47 counties of the national vegetable production bases in Shandong province. The survey site is shown in Fig.4. Excluding 90 incomplete surveys, a total of 747 surveys are used for this study. The survey questionnaires that are relevant to this study are household socio-demographic information, vegetable and fruit production and income, pesticide application and food safety, and unique features of production and sales by household types.

Fig 4. Survey site

Table 1 provides summary statistics of the survey data. Half of the farmer households were in the east costal region that is more economically developed, including Qingdao, Yantai, Weifang, Rizhao, and Weihai (see Fig. 4). The production of fresh produce is highly specialized in Shandong -- approximately 58% of the farmers are specialized in vegetables only; 28% are solely fruit farmers; and only 14% cultivate both vegetables and fruits. The farmers are specialized in less than two varieties of fruits and vegetables. Several policies contribute to the high level of production specialization. First, the Chinese government launched the so-called “Vegetable Basket Program” in 1980 and allowed private-owned wholesalers and retailers to be part of the supply chain (Hu, et al., 2004, Rozelle, et al., 2000). Second, the rapid growth of supermarkets since the 1990s further liberalized the food supply chain. Third, the No. 1 Central Document issued in 2007 promoted "One Village One Product" to create the relative competitiveness, which greatly induced both industry and graphical specialization.

Table1 Descriptive Statistics of variables

Variables	Mean	Standard deviation	Variables	Mean	Standard deviation
Male	0.77	0.42	Receive no product inspections	0.84	0.36
Age(year)	49.51	8.81	Inspections by the government	0.08	0.28
Education Attainment (year)	8.68	2.60	Inspections by agricultural coops	0.08	0.27
Married	0.95	0.22	Inspections by other agents	0.03	0.17
Rural cadre household	0.10	0.31	No product certifications	0.71	0.45
Religion	0.04	0.19	Harmless agricultural product	0.18	0.39
Self-owned land	5.53	4.69	Green food	0.08	0.27
Rent-in land	3.33	7.68	Organic food	0.03	0.16
Farming labor	2.06	0.72	Other certifications (GAP, HACCP, and others)	0.02	0.13
Migration labor	0.48	0.73	Receiving training of pesticide use	0.34	0.47
Income per capita	20.63	23.82	Using standard containers for pesticide use	0.69	0.46
Number of cash crops	1.63	0.81	Using forbid pesticides	0.18	0.38
Distance to the county center	20.52	11.30	Accessible to toxic pesticides	0.13	0.34
Agricultural Coops member	0.11	0.32	Perceive an acceptable quality of fresh produce sold in the market	0.77	0.42
Farm types (base =vegetable only)			Perceive adverse effect of pesticide application		
Fruit only	0.28	0.45	on food safety	0.92	0.28
Vegetable and fruit	0.14	0.35	to the environment	0.81	0.39
East regions (Qingdao, Yantai, Weifang, Rizhao, and Weihai)				0.50	0.50

The head and/or decision-maker of an average fruit and vegetable household is likely to be male (77%), married (95%), aged 50, and completed the middle school education. The average own farm size is approximately 5.53mu (equivalent to 0.91 acres), and the average land rented from others is 3.33mu (equivalent to 0.55 acres). Approximately 35% of the households have family member migrating to cities and work on non-agricultural jobs. The average migration labor is 1.36 of the migration households. Annul income per capital is 20,630 yuan (equivalent to 3,165 $US). Few households (11%)

have joined cooperatives and agri-companies to sell their fresh produce.

The questionnaire has multiple questions on pesticide applications. Only one third of sample households receive training on pesticide application and nearly two thirds use standard containers for pesticide application. Although the majority of the farmers perceive adverse effects of pesticide applications to food safety (92%) and to the environment (81%), pesticides have been extensively used. About 18% of households use highly toxic and banned pesticides and 13% report that they have a ready access to purchase such pesticides. The easy access to and the use of toxic pesticides may induce the adoption of the OFH-TPS. Only 76% of the farmers perceive acceptable quality of fresh produce sold in their local market. Those who do not perceive good product quality may prefer separable production for self-consumption.

Hypotheses 1 and 2 suggest that product inspections and certifications can be employed to reduce information asymmetry and improve product quality, which can affect the OFH-TPS decision. As shown in Table 1, the majority of the households does not receive any product inspections (84%) or certify their fresh produce (71%). Product inspection is mainly done by firms (agricultural cooperatives, downstream firms, and/or farmers themselves). In terms of product certification, only 18% of the farmers certify their products as HAP, followed by the Green Food certification (8%), and the organic Food certification (3%).

Table 2. the percentage of farmers adopting or non-adopting OFH-TPS.

Inspection	OFH-TPS farmers (N = 56)	Non OFH-TPS Famers (N = 691)	**Certification**	OFH-TPS Farmers (N = 56)	Non OFH-TPS Farmers(N = 691)
No inspection	0.89	0.84	No certification	0.77	0.71
Government	0.02	0.09	HAP	0.16	0.18
Firm	0.09	0.08	Green	0.04	0.08
Others	0.00	0.03	Organic	0.02	0.03
			Others	0.02	0.02

Furthermore, as shown in Table 2, compared with the farmers who do not practice the OFH-TPS, a larger proportion of the OFH-TPS farmers received no product inspections (89% vs. 84%). Similarly, the farmers who do not certify their products have a higher percentage among the OFH-TPS farmers versus their counterparts (77% vs. 71%).

4. Empirical Analysis

An individual farmer *i* in region *r* can either adopt the OFH-TPS (Y_{ir} = 1) or not (Y_{ir} = 0). We expect a set of factors in X_{ir} affect the OFH-TPS decision, such as socio-demographic factors, household endowments of labor and land, pesticide applications and perception of adverse impacts of pesticides on food safety and to the environment, product inspections and certifications, and the perception of product quality of fresh produce sold in the local market. The normal distribution assumption gives rises to the Probit model:

(8) $$Prob(Y_{ir=1}) = \int_{-\infty}^{\beta_r X_{ir}} \varphi(t)dt = \emptyset(\beta_r X_{ir})$$

where $\varphi(\cdot)$ and $\emptyset(\cdot)$ are the standard normal density and distribution, respectively. The set of parameters $\beta_r{}'s$ are to be estimated. The marginal effect of X_{ir} on the probability of adopting the OFH-TPS can be expressed as

(9) $$\frac{\partial E(Y_{ir})}{\partial X_{ir}} = \beta_r \varphi(\beta_r X_{ir})$$

We expect whether an individual farmer uses the highly toxic, even banned pesticides can be potentially endogenous. As the outcome Y_{ir} and the endogenous variable denoted by R_{ir} are both binary choice, the bivariate probit model (biprobit) and the IV regression model are proposed to deal with endogeneity (Nichols, 2011). The bivariate probit model can be written as

(10a) $$Y_{ir} = 1[\mu_Y(R_{ir}, X_{ir}) > \nu_{ir}]$$
(10b) $$R_{ir} = 1[\mu_R(A_{ir}, X_{ir}) > \varepsilon_{ir}]$$

where μ_Y and μ_R represent unspecified functions with error terms ν_{ir} and ε_{ir}. The error terms are assumed identically distributed as bivariate normal: $\begin{pmatrix} \nu_{ir} \\ \varepsilon_{ir} \end{pmatrix} \sim IIDN\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}\right)$, where ρ can be interpreted as correlation between unobservable explanatory variables of these two equations (Fabbri, et al., 2004). The ideal instrumental variable denoted by A_{ir} is expected to affect the probability of using the highly toxic and banned pesticides, but has no direct influence on outcome Y_{ir}, the probability of adopting the OFH-TPS. We use the ready access to highly toxic and banned pesticides in the local market as an instrumental variable and will test its validity. The error terms, ν_{ir} and ε_{ir}, are independent residuals distributed N(0, σ^2).

As shown in Table 3, the Wald test reject the null hypothesis that $\rho = 0$ at the 1% significant level (P-value = 0.001). The result indicates that R_{ir} is related with ν_{ir} and therefore endogenous (Fabbri, et al., 2004). Based on the IV regression model, Wooldridge (1995)'s score test also rejects the null hypothesis that the instrumental variable is exogenous at the 5% significance level (p-value = 0.015). Therefore, we conclude that the Biprobit model can potentially outperform the probit model and the IV regression model can also outperform the regular regression model. The F statistics in the first-stage estimation of the IV regression model is 1,420, significantly exceeding the threshold value of 10 based on the rule of thumb, indicating the selected instrumental variable is not weak (Stock, et al., 2012). Equation (9) shows that the marginal effects differ from the estimated coefficients in the biprobit model. We thus report the regression results of the probit, biprobit, IV regression models in Appendix and the marginal effects in Table 3. The discussions of the empirical results are discussed below based on the marginal effects.

Table 3 Marginal effects of the independent variables on the adoption of the TFH-TPS

Variable	Probit	Biprobit	Ivregress	Variable	Probit	Biprobit	Ivregress
Male	0.005	0.007	0.002	PA_Standard	-0.015***	-0.018***	-0.030**
	(0.013)	(0.015)	(0.017)		(0.003)	(0.006)	(0.015)
Age	0.000	0.000	0.001***	PerceptionFood	-0.017	-0.02	-0.026
	(0.000)	(0.000)	(0.000)		(0.033)	(0.030)	(0.024)
Edu	-0.001	-0.002	-0.002	PerceptionEnvi	0.017	0.02	0.021
	(0.004)	(0.005)	(0.004)		(0.033)	(0.044)	(0.023)
Married	0.019***	0.024***	0.011	Insp_Firm	-0.006***	-0.003***	0.027
	(0.001)	(0.007)	(0.017)		(0.001)	(0.000)	(0.020)
Cadre	0.015	0.017	0.020	Insp_Gov	-0.031***	-0.047	-0.017*
	(0.049)	(0.049)	(0.033)		(0.011)	(0.033)	(0.009)
Religion	0.022	0.021	0.011	Insp_Other	0	-0.533***	-0.046**
	(0.037)	(0.030)	(0.021)		(.)	(0.025)	(0.020)

Landself	0.003**	0.004**	0.004	Cert_HAP	-0.006	-0.008	-0.003
	(0.001)	(0.002)	(0.003)		(0.038)	(0.048)	(0.027)
LandRental	0.001	0.001	0.001	Cert_Green	-0.042***	-0.08*	-0.060***
	(0.002)	(0.002)	(0.002)		(0.010)	(0.042)	(0.012)
F_farming	-0.003	-0.001	0.007	Cert_Organic	0.042***	0.041***	0.026***
	(0.023)	(0.025)	(0.013)		(0.002)	(0.006)	(0.004)
F_migration	-0.002	-0.003	-0.009***	Cert_Others	0.023	0.032	0.050
	(0.005)	(0.007)	(0.002)		(0.086)	(0.072)	(0.055)
IncPer	-0.002***	-0.002***	-0.001***	PerceivedQuality	-0.052***	-0.048***	-0.042***
	(0.000)	(0.000)	(0.000)		(0.007)	(0.001)	(0.001)
Crop No.	0.006	0.005	-0.005	FarmerVegFru	-0.006	-0.009	-0.021
	(0.012)	(0.014)	(0.012)		(0.012)	(0.013)	(0.019)
Distance	-0.002	-0.002	-0.002**	FarmerFru	0.041***	0.04***	0.029***
	(0.002)	(0.002)	(0.001)		(0.014)	(0.006)	(0.007)
Agr-member	0.056	0.052**	0.030**	ForbidPestUse	0.082**	0.119***	0.284***
	(0.038)	(0.021)	(0.012)		(0.042)	(0.017)	(0.029)
PA_Training	-0.034***	-0.04***	-0.022				
	(0.013)	(0.013)	(0.015)				
Observation	724	747	747	No. of clusters	2	2	2
Pseudo R2	0.141			ρ		-0.225(0.063)	
F statistics			1420	Wald test ρ=0		11.619***	
Wald test exogeneity			1892**	Log pseudoliklihood	-169	-460	

Values in parentheses are standard deviations. Asterisks, ***, **, and *, represent the 1%, 5%, and 10% significance level, respectively.

Inspections Compared with farmers who receive no product inspection, farmers whose products are inspected are less likely to engage in the dual production system. Hypothesis 1 expects inspections conducted by different parties may impact the production decision differently. Pei, et al. (2011) state that product inspections conducted by the government sectors in China mainly focus on processed and packaged food items, but less on fresh produce or raw materials. The *Food Safety Law* effective in 2015 call for co-regulation between the government and private sectors to ensure national food safety (ZHANG, et al., 2015). Compared with product inspections conducted by the government, inspection conducted by industry associations and agriculture cooperatives is likely to be more efficient to improve food safety due to the shared reputation and greater economic adverse effects (Starbird and Amanor-Boadu, 2007). In terms of inspections conducted by farmers themselves, Zhou, et al. (2013)

find that self-inspection positively correlates with the improvement of product quality and consumer satisfaction. As shown in the biprobit model, product inspections conducted by downstream firms (N = 38) and cooperatives (N = 15) as well as self-inspection (N = 8) reduce the adoption of the OFH-TPS, but the inspection conducted by the government has no statistical effect though its impact is negative. Since the inspections conducted by agricultural cooperatives, firm associations, and farmers themselves are more likely to ensure better quality, we expect farmers who received such inspections are less likely to engage into OFH-TPS.

Production Certifications: Hypothesis 2 expects that different certifications reflect and/or signal the quality difference and affect the production decision differently. In particular, organic food is perceived to have superior quality, followed by green food and HAP food, and products without any certification are perceived to have relatively poor quality. We further speculate that either low or high quality may trigger farmers to adopt OFH-TPS, which have been confirmed by the regression results. As shown in Table 3, the likelihood of adopting the OFH-TPS is not statistically different among farmers who sell their product without any certification and who certify their products as HAP. However, compared with farmers who do not certify their products, green food farmers are statistically less likely to adopt the OFH-TPS, but organic farmers are statically more likely to practice OFH-TPS. The standard of organic food is more stringent for cultivation process (Ni, 2014) and it requires a significant extra cost to produce. To save the production cost, farmers may want to engage in the OFH-TPS to produce non-organic fresh produce with satisfactory quality for self-consumption. On the other hand, if famers sell high quality green foods to the market, they are less likely to have a concern of food safety if used for self-consumption and, thus, less likely to adopt OFH-TPS.

Food Safety and Pesticide Applications: We find that farmers do care about their own food safety. Famers who perceive poor food safety in the local market and those who apply highly toxic and banned pesticides are more likely to adopt the OFH-TPS. Training on pesticide application is an effective way to educate farmers how to apply pesticides more appropriately and effectively (Zhou, 2009；Wu，2012).

The results show that farmers who receive training on pesticide application and use standard containers for pesticide application are less likely to adopt the OFH-TPS. The finding can be explained by Zhou and Jin (2009) who find that vegetable farmers who receive training on pesticide application have a smaller probability of applying highly toxic pesticides, and thereby improving food safety. As a result, farmers may not need to adopt the OFH-TPS to ensure food safety for self-consumption. However, the perceived adverse effect of pesticide application to food safety and the environment has no statistically significant effect on the adoption of the OFH-TPS. One possible reason could be that, unlike the findings of Zilberman and Millock (1997) who show that farmers' perception on negative externalities of pesticide application reduces pesticide overuse or misuse, Chinese farmers are not concerned about the negative externality of pesticide application. Our findings suggest that intervention programs focusing on quality improvement and food safety should focus on training on pesticide/chemical applications, but less effective in the short run if focusing on educating farmers about negative externalities.

Household Characteristics and Endowments**:** We find that farmers who are married are more likely to adopt the OFH-TPS. Married farmers, especially those having children, may have higher quality preference for self-consumption. Large-size farmers are more likely to adopt the OFH-TPS as they have abundant land resources to allocate land parcels for self-consumption. Farmers who are the member of agricultural cooperatives or work for agricultural companies are more likely adopt the OFH-TPS. Household annual income per capita is found to be negatively and significantly associated with the likelihood of adopting the OFH-TPS, which differs from our expectation. We also find that fruit farmers are more likely to adopt the OFH-TPS than vegetable farmers. It can be explained by the fact that fruits are highly valued cash crops and on which more chemical and pesticides are used.[4]

5. Conclusion

A new phenomenon termed as OFH-TPS (One Farm Household, Two Production Systems) arises in

[4] http://www.theepochtimes.com/n3/2022766-strawberries-contain-the-most-pesticide-residue-of-50-produce-items/

rural China and receives an increasing attention in recent five years. Aiming to understand this phenomenon, this paper accomplishes the following two tasks: (a) providing a theoretical framework to examine how information asymmetry as well as measures to reduce asymmetry such as product inspections and certifications affect the OFH-TPS decision; and (b) presenting an empirical study using the survey of fruit and vegetable farmers in Shandong in 2015 by employing the instrumental variable approach. Specific findings and the corresponding policy implications are summarized below.

First, product inspections conducted by industry associations, agricultural cooperatives, or farmer themselves curb the adoption of the TFH-TPS, whereas government inspections have no statistically significant effect. If the goal of production inspections is to ensure food safety and enforce safety standards, we shall expect that inspections decrease the probability of adopting the OFH-TPS. The finding that government inspections have no statistical effect may suggest that such inspections are either not effective or incredible. Thus, the findings provide an indirect evidence for improving the efficacy of product inspections of the government sectors. On the other hand, engagement of private sectors such as industry associations, cooperatives, and farmers is critical to food safety.

Second, In terms of certifications, farmers who sell green foods are less likely but organic farmers are more likely to adopt the OFH-TPS. This finding suggests that farmers are satisfied with the quality that green foods provide, but they prefer relative lower but still satisfactory quality other than organic foods for self-consumption to avoid the increased cost associated with organic foods. It is less productive to have separate production systems for the same crop if productivity is the priority. The findings on product certifications imply that promoting green food certifications can improve both product quality and productivity.

Third, we find that training of pesticide application and appropriate pesticide applications reduce the adoption of the OFH-TPS, but the perceived potential adverse effects of pesticide applications to food safety and the environment have no statistical effects. Furthermore, farmers who uses highly toxic and banned pesticides and/or who perceive poor food safety of the local markets are more likely to adopt the OFH-TPS. These findings suggest that education programs should focus on how to apply pesticides/chemicals appropriately and efficiently and those focusing on the negative externality of pesticide applications is less effective. The findings also pin down an important role that pesticide retailers can play as they are the seller of banned pesticides if there are any and they are also the first hand educators/practitioners on how to apply pesticide appropriately.

This paper shows that inspection and certification might be effective methods to improve product quality and food safety in China, but the prevalence of food inspection and certification is still low. More researches should be done to investigate the motivations and constrains for Chinese smallholders to get their products certified and the procedure and efficacy of product inspections by different parties.

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Appendix: Regression Results

Variable	probit	biprobit	Ivregress	Variable	probit	biprobit	Ivregress
ForbidPestUse	0.59**	0.95***	0.28***	PA_Training	-0.37***	-0.32***	-0.02
	(0.28)	(0.19)	(0.03)		(0.09)	(0.09)	(0.01)
Male	0.06	0.05	0.00	PA_Standard	-0.14***	-0.14**	-0.03*
	(0.13)	(0.12)	(0.02)		(0.04)	(0.06)	(0.02)
Age	0.00	0.00	0.00***	PerceptionFood	-0.15	-0.16	-0.03
	(0.00)	(0.00)	(0.00)		(0.29)	(0.25)	(0.02)
Edu	-0.01	-0.01	-0.00	PerceptionEnvi	0.18	0.16	0.02
	(0.03)	(0.04)	(0.00)		(0.37)	(0.34)	(0.02)
Married	0.23***	0.19***	0.01	Insp_Firm	-0.06***	-0.03***	0.03
	(0.06)	(0.07)	(0.02)		(0.01)	(0.00)	(0.02)
Cadre	0.14	0.13	0.02	Insp_Gov	-0.41	-0.37	-0.02**
	(0.42)	(0.40)	(0.03)		(0.27)	(0.28)	(0.01)
Religion	0.19	0.17	0.01	Insp_Other	0.00	-4.25***	-0.05***
	(0.26)	(0.23)	(0.02)		(.)	(0.40)	(0.01)
Landself	0.03*	0.03*	0.00	Cert_HAP	-0.06	-0.07	-0.00
	(0.02)	(0.02)	(0.00)		(0.41)	(0.39)	(0.03)
LandRental	0.01	0.01	0.00	Cert_Green	-0.65	-0.64*	-0.06***
	(0.02)	(0.02)	(0.00)		(0.42)	(0.37)	(0.01)
F_farming	-0.03	-0.01	0.01	Cert_Organic	0.32***	0.33***	0.03***
	(0.22)	(0.20)	(0.01)		(0.04)	(0.06)	(0.00)
F_migration	-0.02	-0.02	-0.01***	Cert_Others	0.19	0.26	0.05
	(0.05)	(0.05)	(0.00)		(0.66)	(0.59)	(0.06)
IncPer	-0.02***	-0.02***	-0.00***	PerceivedQuality	-0.43***	-0.38***	-0.04***
	(0.00)	(0.00)	(0.00)		(0.00)	(0.01)	(0.00)
Crop No.	0.06	0.04	-0.01	FarmerVegFru	-0.06	-0.07	-0.02
	(0.11)	(0.11)	(0.01)		(0.12)	(0.10)	(0.02)
Distance	-0.02	-0.02	-0.00**	FarmerFru	0.36***	0.32***	0.03***
	(0.01)	(0.01)	(0.00)		(0.06)	(0.02)	(0.01)
Agr-member	0.42**	0.42***	0.03**	Constant	-0.95***	-1.02***	0.09***
	(0.19)	(0.14)	(0.01)		(0.32)	(0.32)	(0.03)

Figures in parentheses are standard deviations. Asterisks, ***, **, and *, represent the 1%, 5%, and 10% significance level, respectively,