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Farmers' adoption of pollution-free vegetable farming in China: Economic, informational, or moral motivation?

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Abstract: Based on the survey data of 420 vegetable farmers in China, the logit model is used to analyze farmers' adoption motivation of pollution-free vegetable farming and quantify the degree to which pollution-free vegetable farming is the result of economic benefits, information acquisition, moral obligation incentives or a combination of these motivations. The results reveal that besides the effects of non-farm income and vegetable acreage in farm characteristics, farmers' adoption of pollution-free vegetable farming is mainly motivated by economic, informational and moral incentives. Specifically, pollution-free vegetable price, economic support from the governments, joining rural economic organizations and market supervision are verified to affect farmers' adoption positively. Relative to the incentives from information acquisition and moral obligation, economic benefits play a greater role in promoting farmers' pollution-free vegetable farming. Economic support from the governments has the biggest impact on adopting pollution-free vegetable farming. Therefore, pollution-free vegetable farming may be promoted towards a profit-driven way. Furthermore, it is necessary to explore a joint mechanism between farmers and rural economic organizations, and provide agricultural extension services with a joint

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PUBLIC INTEREST STATEMENT

Individual and small scale production by farmers in China is considered to be one of the main causes of food safety problems, so farmers are encouraged to adopt pollution-free farming. This article is to understand why farmers are willing to adopt pollution-free vegetable farming in China. Based on a survey from January to February in 2015 on vegetable farmers in Shandong, Hebei and Jiangsu provinces which are located in the eastern, middle and western China, the results reveal that farmers are affected by economic, informational and moral incentives. Understanding farmers' motivations can improve future pollution-free farming programs and policies. Although this article focuses on vegetable farming, farmers' motivations for adopting pollution-free vegetable farming may be applied to other types of farming.

goal of agri-food yield and safety. Market supervision also needs to be strengthened by improving relevant laws and rules and implementing them more strictly.

Subjects: Agriculture and Food; Food Laws & Regulations; Industrial Economics; Microeconomics

Keywords: pollution-free vegetable farming; economic benefits; information acquisition; moral obligation; China

1. Introduction

Over the past two decades China has been confronted with an increasing number of reported food quality incidents (Xue & Zhang, 2013). Individual and small scale production by farmers in China is considered to be one of the main causes of food safety problems (Jin & Zhou, 2011). Millions of farmers are engaged in agricultural operations and the average farm size is 0.6 hectares (Ding et al., 2015). The problems including inappropriate, excessive or even illegal use of agrochemicals have caused wide public concern and there is a growing consumer demand for safe food. Despite limited knowledge about safe food, Chinese consumers generally hold positive attitudes towards it and are willing to pay more for safe food (Liu, Pieniak, & Verbeke, 2013). China has launched several programs with regard to safe farming. In these programs, the Action Plan for Pollution-free Agricultural Products (APPAP) is acting as a compulsory standard for agri-food in China. APPAP was formally launched by the Ministry of Agriculture (MoA) in April 2001, and is now managed as a certification scheme. The MoA is in charge of implementing the APPAP, while the agricultural departments at various government levels are responsible for enforcing it. Local governments can work out their own practical and applicable plans to enforce the APPAP according to the local situation. The overall objective of the APPAP is to establish a sound system and complete institutions for supervising, inspecting and controlling the whole process of agricultural production and marketing—from field to dining table—for food safety purposes and to improve the overall level of agri-food safety in China. Pollution-free food (also known as “hazard-free” or “no public harm” food) is characterized as being of good quality, nutritious and safe: harmful or toxic residues, such as fertilizers, pesticides, heavy metals, and nitrates are controlled within limits set by national standards (Huang, Wu, Rong, You, & Jiang, 1999). Beyond the roles of central government in institutionalization of standards, the second major role of the state in developing pollution-free food is its provision of policy support. This has been particularly significant at the provincial and local government levels, although there is substantial variation. Realizing the potential for safe food in the Chinese market, local governments use diverse administrative procedures and financial support e.g. subsidies and rewards to encourage farmers’ adoption of pollution-free farming within their jurisdictions.

In pollution-free farming, vegetable farming is an important part of the agricultural sectors in China. As the world’s largest producer and exporter of vegetables, not only China’s vegetable acreage and production ranked No. 1 for many years in the world, but also its export volume and market share maintain its leading position (Peng & Wang, 2013). The vegetable industry is the second largest industry in the crop production sector in China (Xiong, Xu, & Wang, 2015). The data from National Bureau of Statistics of China (NBSC) shows that although the sown area for vegetables accounts for only 12.9% of the total sown area for all crops in China, its production value accounts for 33% of the total production value of China’s crop production sector NBSC (2015). In addition, vegetable farming is characterized with complex crops rotation, short growth cycle, more disease and insect pests, and high water demand. These characteristics require more elaborate safety control and more of farmers’ knowledge of cultivation and management in vegetable farming. Moreover, China is facing a huge challenge in agri-food export due to an increasing and severe control from import countries focusing on agri-food quality and safety. In 2014 China exported vegetables worth 12.499 billion dollars with a trade surplus of 11.985 billion dollars, topping all the exported agricultural products. Speeding up pollution-free vegetable farming (PFVF) will not only meet domestic consumers’ increasing demand but also strengthen international competitiveness in vegetable industry.

In previous economics literature, the producers adopting safe and ecological practices were usually assumed to be profit maximizers (Cary & Wilkinson, 1997; Honlonkou, 2004; Lichtenberg, 2004; Musshoff & Hirschauer, 2008). However, the impact of adopting PFVF on farm income and profitability in China is not clear. According to cost-benefit analysis, Yang (2006) compared the prices of pollution-free vegetables and traditional vegetables, and found that the price of pollution-free vegetables was about 40% higher than that of traditional vegetables. Zhang (2011) also found that although input costs of pollution-free vegetables were higher compared to traditional vegetables, the profits of pollution-free vegetables were still higher due to higher production and price. Zhang (2006) argued that the higher price could be attained by producing pollution-free vegetables, whereas physical and labor inputs were also higher than traditional vegetable farming. Moreover, considering some factors such as extra depreciation costs, hired labor availability, price uncertainty of pollution-free vegetables and minimum labor income requirement, PFVF is not necessarily more profitable than traditional vegetables even though price premiums and subsidies are received. However, this assumption has not been well confirmed. Only an earlier survey in China showed that the profits of pollution-free tomatoes and celeries were separately 44.1 and 12.4% lower than those of traditional tomatoes and celeries (Liu, 2004). In the context of developed countries, several studies supported the idea that farmers adopted intensive farming (Green Revolution) not only as a profit maximizing decision, but also because of the desire to progress on moral obligation (Mzoughi, 2011; Rigby, Young, & Burton, 2001). Besides, informational incentives are a promising and effective way to promote technological adoption in the farming sector, because farmers' allocative ability may be improved through informational incentives that revise their perceptions about the profit-effectiveness of new farming technologies (Genius, Pantzios, & Tzouvelekas, 2006). Unlike farmers' condition in developed countries, a large number of poor and small farmers in China are characterized with low level in education, information acquisition and moral obligation, and it remains to be identified whether Chinese farmers' PFVF adoption is driven by profit maximization or other reasons.

The main objective of this research is to understand the role of factors including economic benefits, information acquisition and moral obligation in motivating farmers to adopt PFVF in China. Although this paper focuses on vegetable farming, farmers' motivations for adopting PFVF investigated here may be applied to other types of farming. A survey was conducted for Chinese farmers in January and February of 2015. The results provide evidences that farmers' PFVF adoption is mainly motivated by economic, informational and moral incentives. The rest of the paper is organized as follows: First is a literature review, and then methods are established for the analysis of farmers' PFVF adoption; the following section details the administration of the survey and offers an empirical analysis based on a logit model; Conclusions and some implications are given in the last section.

2. Literature review

Many studies have investigated economic drivers behind farmers' adoption of ecologically-friendly practices such as conservation practices, integrated crop protection, organic farming, environmental management systems, retailers' specifications, and so on. For instance, Cary and Wilkinson (1997) argued that the best way to increase the use of resource conservation practices would be to ensure they were economically profitable. Musshoff and Hirschauer (2008) emphasized the prominence in general of financial reasons with regard to conversion to organic production. In economic incentives, premiums and subsidies from ecologically-friendly practices are regarded as powerful instruments to motivate farm conversion. Lohr and Salomonsson (2000) found that a subsidy for conversion to organic agriculture in Sweden was influential for 27% of organic farmers in their sample. Especially for later adopters who adopted organic production after subsidies for organic production were introduced, were strongly motivated by profits (Läpple & Rensburg, 2011). However, the benefits of ecologically-friendly practices may not outweigh the costs for several reasons. For instance, in organic farming, due to the fast-paced growth of organic industry, organic producers face a shortage of organic seed, pesticides and other inputs or face higher price for these inputs, organic producers tend to have higher operating costs than traditional producers (Greene et al., 2009; Hanson, Dismukes, Chambers, Greene, & Kremen, 2004). Moreover, high production costs due to

relatively intense use of labor, specialized equipment and other substitutes for synthetic chemicals and lack of access to organic markets or handlers also result in little or no premium (Dimitri & Oberholtzer, 2008; Oberholtzer, Dimitri, & Greene, 2005).

In addition to economic incentives, information acquisition has been found to be one of the most important factors affecting farmers' adoption. According to Just and Zilberman (1983), information accumulation reduces uncertainty, and therefore may induce new technology adoption by risk-averse farmers. Many scholars have strived to understand how information spreads in farming communities and exerts influence on farmers' production decisions. Lohr and Salomonsson (2000) argued that market services and information sources rather than subsidies were more effective in encouraging organic farming and informational incentives may be less costly than economic incentives in the long run as information spreads throughout the rural communities (Genius et al., 2006). In a study on the adoption of the Euro gap standard by mango producers in Peru, Kleinwechter and Grethe (2006) reported that access to information about the standard was a major barrier to its adoption. Adesope, Matthews-Njoku, Oguzor, and Ugwujua (2012) found that information systems for organic and traditional producers were different. Organic producers benefited from more information sources than traditional producers (Demiryurek, 2010). A high level of information, regardless of whether or not it refers to the innovation itself, is expected to enhance resource allocation skills and to increase the efficiency of adoption decisions (Just & Zilberman, 1983). But a different view exists that information acquisition does not constitute a prerequisite for technology adoption, e.g. in the late adoption stages of organic farming practices, farmers may not be willing to gather information but simply imitate their neighbors (Genius et al., 2006).

An increasing number of scholars have found that farmer's adoption of ecologically-friendly practices reflected their philosophical beliefs. Several studies have documented that concern for the environment is the importance of non-economic motivations in producers' decisions to adopt more environmentally-friendly practices. Hanson et al. (2004), Stofferahn (2009) and Khaledi, Weseen, Sawyer, Ferguson, and Gray (2010) studied the characteristics of organic grain farmers in North America and found that organic producers were motivated by both profit and environmental goals. Chouinard, Paterson, Wandschneider, and Ohler (2008) integrated profit and stewardship motives into a decision model and concluded that there were farmers who were even willing to forego some profits to achieve conservation goals. Lynne (2006a, 2006b) built a conceptual model and concluded that farmers may temper their profit motive with a small amount of self-sacrifice to meet social and environmental goals. In the study of Peterson and Kastens (2006), farmers' environmental stewardship has been certified to motivate organic grain production in the United States. They also argued that many farmers maintained an attitude and ethic that treats farming as "a way of life" and not a venture only to maximize profits. Sheeder and Lynne (2011) used a dual-interests theoretical framework to examine self-interest and other interest in the decision to adopt conservation tillage. They conclude that while it is undeniable that profits do play a role, the assumption that they play the only role in economic decision-making is highly contentious.

Pollution-free farming is put forward as a basic minimum requirement for Chinese agriculture and has received considerable attention. Research on pollution-free farming in the context of China has also been initiated in recent years. Huang, Wu, Zhi, and Rozelle (2008) argued that the Chinese farmers' high preference for risk aversion resulted in increasing use of pesticides, particularly for small-scale subsistence farmers, and interfered safe farming adoption. Some studies mainly focus on the effect of economic factors on pollution-free farming adoption. Dai and Wang (2008) emphasized the importance of financial reasons with regard to the production of pollution-free Chinese white pears. Chen, Qiao, and Yan (2009) argued that the main drivers of adopting pollution-free farming were to ensure high quality and high price. According to the survey from Jiangxi province of China, Zhang (2011) found that the price of pollution-free vegetables was higher through the comparison of pollution-free and traditional vegetables. Besides price incentive, the influence of subsidies is also concerned by some scholars. Luo and Qin (2010) certified that the influence of subsidies for pollution-free farming was remarkable for farmers' adoption based on the survey data covering nine provinces of

China. Yang and Lin (2011) discussed economic incentives for farmers to use pollution-free and green pesticides, and suggested that financial subsidies should be provided to encourage farmers' adoption of PFVF. Although economic profits are quite crucial for small farmers in pollution-free farming adoption decision, there are no formal studies that systematically investigate the economic and non-economic factors affecting pollution-free farming adoption. Several recent studies in Chinese which discussed the factors affecting farmers' adoption of PFVF mainly focused on the influence of farmer and farm characteristics. For instance, Wu, Zhong, and Wang (2014) argued that education level and skills of farmers, household income and production scale have strong influence on farmers' willingness to produce PFVF. Zheng and Chen (2015) showed that income capita, labor employment and agricultural technology extension were the main influential factors affecting pollution-free production. Xiao, Hong, and Zhou (2015) argued that farmer educational level, vegetable income percentage in household income and organizational role were the main factors affecting PFVF. However, these studies do not pay enough attention to the effects of information acquisition and moral obligation on PFVF. Limited understanding about what motivates pollution-free farming may undermine the effectiveness of policies and business strategies aimed at the agricultural sectors. Compared to traditional farming, pollution-free farming requires greater levels of management and is often more restricted in utilizing the local resources, which increases farmers' need to balance the different parts of the production system. Hence, the role of information acquisition should also be considered in farmers' adoption of pollution-free farming. Besides, in recent years food safety incidents and environmental pollution events happened frequently in China, which arouse wide concern in the society. Based on the agri-food quality and safety law of China, government regulation has been reinforced and this may stimulate farmers' reflection for safe farming adoption. From this perspective, PFVF may be more likely to be adopted by those farmers who have strong moral obligation. In general, it will be more specific to understand the motivations promoting farmers' PFVF adoption by combining the analysis of economic, informational and moral incentives and relevant policy-making references could be provided to improve farmers' enthusiasm for PFVF and other types of safe farming.

3. Methodology

In the practices of vegetable farmers, some of them adopt pollution-free farming and some others who refuse to adopt pollution-free farming still adopt traditional farming. Thus, the farmer's adoption of PFVF is specified as a discrete 0/1 variable: 1 if the farmer adopts PFVF and 0 if the farmer does not adopt PFVF. The binomial logit model is suitable to analyze impact factors. The model assumes that a farmer's probability to adopt PFVF depends on a vector of independent variables (X_{ij}) associated with farmer i and variable j , and a vector of unknown parameters β :

$$P_i = F(Z_i) = F(\beta X_{ij}) = 1/[1 + \exp(-Z_i)] \quad (1)$$

where F is the cumulative distribution function (CDF). The β parameters can be estimated using the maximum likelihood procedure. Binary choice models differ only in the assumption about the functional form of F . The logit model can be employed to estimate the probability of adopting PFVF and can be expressed as:

$$P_i = P[y_i = 1] = \frac{e^{x_i \beta}}{1 + e^{x_i \beta}} \quad (2)$$

After obtaining the maximum likelihood estimates of the logit model, the following four post-estimation analyzes can be undertaken. First, predict the probability of PFVF adoption given specific farmer characteristics (x_i). Second, estimate the change in probability (ΔP) for a change in farmer-specific characteristics (x_i). For example, if x_1 (e.g. PRICE variable) has two specific values $x_a = 2$ (pollution-free vegetable price is unchanged compared to traditional vegetable price) and $x_b = 3$ (pollution-free vegetable price is higher compared to traditional vegetable price), the estimated ΔP of PFVF adoption as a result of the change in PRICE from 2 to 3 is computed as:

$$\Delta P = F(\beta_0 + \beta_1 x_b + \beta_2 x_2 + \dots + \beta_k x_k) - F(\beta_0 + \beta_1 x_a + \beta_2 x_2 + \dots + \beta_k x_k) \quad (3)$$

Third, estimate the marginal effect, which is defined as the effect of a unit change in x_i , all other factors held constant, on the probability that a farmer chooses to adopt PFVF. It can be presented that:

$$\frac{\Delta p_i}{\Delta x_i} \Big|_{\text{all other } x \text{ constant}} = \frac{\partial p_i}{\partial x_i} \quad (4)$$

Finally, calculate the odds ratio of technology adoption, which is the frequency that a farmer will adopt PFVF rather than traditional vegetable farming:

$$\frac{p_i}{1 - p_i} = e^{x_i \beta} \quad (5)$$

4. Definition of the variables

As mentioned in previous discussion, the factors that may affect farmers' PFVF adoption include the four groups, i.e. economic benefits, information acquisition, moral obligation and farmer and farm characteristics. The specific variables used in the empirical part will thereafter be stated and described.

4.1. Economic benefits

It has been argued that farmers are motivated to adopt PFVF when it is considered to be more profitable compared to traditional vegetable farming. For vegetable farmers, pollution-free vegetable price relates directly to farmers' income and it is crucial to encourage their PFVF adoption. Thus, price variable (PRICE) is defined through the price comparison of pollution-free and traditional vegetables and graded from 0~3, i.e. if a farmer was asked to state pollution-free vegetable price compared to traditional vegetables, the response may be that pollution-free vegetable price is unclear, lower, unchanged and higher and the value of PRICE is set to 0, 1, 2, 3 corresponding to four responses. Furthermore, the Chinese governments from national to local levels have launched economic support for pollution-free farming. Therefore, the variable (SUPPORT) is reflected through whether or not the governments provide economic support, 1 for yes and otherwise 0. It is expected that higher pollution-free vegetable price and economic support from the governments will encourage farmers' PFVF adoption.

4.2. Information acquisition

Farmers' ability in adopting production techniques and field management depends very much on their information acquisition. For Chinese farmers, the main information channels associated with agricultural production are agricultural extension services. Public agricultural extension stations are organized by agricultural sub-sectors. Most counties have crop, livestock, agricultural machinery, aquaculture, and economic management stations or centers. Many counties have established specialized sub-stations, including crop management, plant protection, horticulture, and soil- and fertilizer-technology sub-stations with stations or centers, as well as establishing stations corresponding to locally important agricultural products (Hu, Yang, Kelly, & Huang, 2009). The variable (AES) is reflected through whether or not a farmer has access to agricultural extension services, 1 for yes and otherwise 0. Rural economic organizations including agricultural firms, cooperatives and farmer groups also provide information services and technical guidance by building a tight or loose relationship with individual farmers. The variable (ORG) is reflected through whether or not a farmer joins rural economic organizations, 1 for yes and otherwise 0. Besides, if many surrounding farmers adopted PFVF, the information dissemination may provide demonstration effects for encouraging later adopters. Thus, this variable (DEMO) is separately set to 0, 1, 2 when the response from the surveyed farmer is that there is no, a few or many surrounding farmers who adopt PFVF. It is assumed that vegetable farmers who have attained agricultural extension services, joined rural economic organizations, and are affected by demonstration effects of surrounding farmers are more likely to adopt PFVF.

4.3. Moral obligation

As was discussed before, farmers’ moral obligation may affect their subjective perception about PFVF and thus affect their adoption decision. As far as Chinese farmers are concerned, their moral obligation in farming is formed from themselves and outside. That is one from farmers’ perception of vegetable quality and safety, and another from the intensity of government regulation and market supervision. In the study of Dai and Xu (2012), vegetable quality and safety control of Chinese farmers is identified from three respects, i.e. whether or not farmers use prohibited pesticides or fertilizers, whether or not farmers improve the mixed concentration of pesticides and fertilizers, and whether or not farmers take the interval of using pesticides or fertilizers into consideration. With reference to this research, farmers’ perception of vegetable quality and safety is assessed from the three respects above. To be specific, if a farmer uses prohibited pesticides or fertilizer in PFVF, the score for this item is assigned 0 and otherwise 1; if a farmer improves the mixed concentration of pesticides and fertilizers or has no idea about the standard of mixed concentration, the score for this item is assigned 0 and otherwise 1; if a farmer does not take the interval of using pesticides or fertilizers into consideration or do not know the interval, the score for this item is assigned 0 and

Table 1. Variable definitions

Variable	Description
<i>Dependent variable</i>	
ADOPTION	1 = adopt pollution-free vegetable farming, 0 = otherwise
<i>Independent Variables</i>	
<i>Economic benefits</i>	
PRICE	0 = unclear, 1 = lower, 2 = unchanged, 3 = higher
SUPPORT	Whether or not the governments provide economic support, 1 for yes and 0 otherwise
<i>Information acquisition</i>	
AES	1 if a farmer has access to agricultural extension services and 0 otherwise
ORG	1 if a farmer joins rural economic organizations (e.g. agricultural firms, cooperatives and farmer groups) and 0 otherwise
DEMO	Surrounding farmers adopt pollution-free vegetable farming (0 = no, 1 = a few, 2 = many)
<i>Moral obligation</i>	
PEPT	Perception of vegetable quality and safety is assessed with total score from three items
REG	The influential degree of government regulation (0 = not influential, 1 = little influential, 2 = weakly influential, 3 = influential, 4 = strongly influential)
SUPV	The influential degree of market supervision (0 = not influential, 1 = little influential, 2 = weakly influential, 3 = influential, 4 = strongly influential)
<i>Farmer and farm characteristics</i>	
GENDER	0 = male, 1 = female
AGE	Real age
EDUC	0 = illiterate, 1 = primary school, 2 = middle school, 3 = high school or technical secondary school, 4 = junior college and upper
YEAR	Years of vegetable farming
LABOR	The number of laborers working on the farm
NFI	Non-farm income (1 = “¥0-1999”; 3 = “¥2000-3999”; 5 = “¥4000-5999”; 7 = “¥6000-7999”; 10 = “¥8000-11999”; 15 = “¥12000+”)
SIZE	Vegetable acreage
PARCEL	Parcels of vegetable land
PCT	Percentage of household income earned from pollution-free vegetable farming
REGION	Taking Shangdong province as a reference group, dummy variables including Hebei (D_1) and Jiangsu (D_2)

otherwise 1. The total score from three items ranges from 0 (if the score for each item is assigned 0) to 3 (if the score for each item is assigned 1) and reflects perception variable (PEPT). Besides, it is difficult to directly measure the intensity of government regulation and market supervision. Therefore, government regulation (REG) and market supervision (SUPV) are evaluated by farmers' perception and valued from 0~4. More specifically, these two variables are set to 0, 1, 2, 3, 4, if government regulation or market supervision perceived by a farmer is not influential, little influential, weakly influential, influential and strongly influential, respectively. Farmers' perception of vegetable quality and safety, government regulation and market supervision are expected to be positively correlated with farmers' PFVF adoption.

In addition to the main variables above, farmer and farm characteristics, and region are also included in the empirical model as control variables. Specifically, gender, age, education and vegetable farming years reflect farmer characteristics. Laborer inputs, non-farm income, vegetable acreage, parcels of vegetable land and percentage of household income earned from vegetable farming reflect farm characteristics. Region is regarded as dummy variables including Hebei and Jiangsu provinces. The variable definitions are presented in Table 1.

5. Data source and descriptive statistics

The data in this paper comes from a survey from January to February in 2015 on vegetable farmers in Shandong, Hebei and Jiangsu provinces which are located in the eastern, middle and western China, respectively. These locations are major vegetable production areas of China and the survey is convenient to implement because the duration of this survey is just the slack season for farmers and the winter holiday for college student investigators. The way to sampling is to first select five counties (cities) in each province. Specifically, the counties (cities) of each province are sorted by GDP per capita and systematic sampling is taken, then appropriate adjustment is made by geographical location. Second, among the five selected counties (cities), we take the same sampling way to select two rural areas (towns) in each county (city). Third, two villages are selected in each rural area (town). With the consideration of time and cost, the specific method in the selection of villages is as follows: the college students whose hometowns are just in previous selected rural areas (towns) or close to them are picked out, then those villages which are in the vicinity of selected students' homes become survey places. The selected villages are geographically distributed due to dispersion of students' homes. At last, ten households in each village are stochastically selected as the samples and the household heads are investigated by the students.

Six-hundred questionnaires are used in face-to-face interview and 180 observations have to be dropped from the data-set due to missing information. For instance, some farmers were not sure for evaluating the degree of government regulation or market supervision and others refused to disclose anything about their incomes. Finally, 420 valid questionnaires are attained and the effective rate is 70%. 190 farmers in effective sampling have adopted PFVF, taking a rate of 45.2% in the total sampling, whereas 230 farmers have not adopted PFVF, taking a rate of 54.8%. All respondents were asked to indicate whether or not they attained pollution-free vegetable certification, and then the questions have been proposed encompassing farmer and farm characteristics, economic incentives, information acquisition and moral obligation.

Among the respondents, 66.9% of them are males. 27.1% are under 40 years old, 62.3% between 40 and 60, and 10.5% over 60. The farmers with illiterate and primary school education account for 7.4 and 18.1% separately. 44.3% received middle school education, and 10 and 3.1% graduated from high school or technical secondary school and junior college and upper. The average experience of vegetable farming is 10 years. The proportions of farmers planting vegetables for 5 years or below, 6 to 10 years and more than 10 years are 6.7, 59 and 34.3%, respectively. 86.9% of the farmers have only 1~2 laborers working on vegetable farming. Vegetable farming is characterized with small size of 3.12 μ and fragmentation with 2.2 parcels on average. Here Mu is a unit commonly used to measure land areas in China and one mu equals about 0.067 hectares. The percentage of household income earned from vegetables varies from 5~100%. The average percentage is 48.4%. Only

2.9% of the respondents have non-farm income of less than 2,000 Yuan in last year, whereas 19.3% state this earning over 8,000 Yuan.

Compared to traditional vegetable farming, 41.7% of the farmers expect that higher price can be gained from PFVF whereas 35.5, 4.3 and 18.6% expect it unchanged, lower or unclear, respectively. The survey about economic support for PFVF shows that only 47.1% of the respondents received support from the governments. Additionally, 53.3% of the respondents gained agricultural extension services, while other channels of information acquisition seem to be weak. Only 24.3% joined economic organizations, and 42.1% state that no or a few farmers around them adopt PFVF. Farmers' perception for vegetable quality and safety is still in the low level. Only 15.7% of them can give right answers for all questions about vegetable quality and safety. 38.1% of the respondents state that government regulation is influential or strong influential, whereas nearly half (47.4%) view it not influential or little influential. In addition, about one-third (33.8%) perceive market supervision to be influential or strong influential, whereas 39% state that it is not influential or little influential. The descriptive statistics of the variables is presented in Table 2.

Table 2. Descriptive statistics of the variables for PFVF adopters and non-adopters

Variables	Adopters		Non-adopters		All respondents	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
<i>Dependent variable</i>						
ADOPTION	1	0	0	0	0.452	0.498
<i>Independent Variables</i>						
<i>Economic benefits</i>						
PRICE	2.537	0.753	1.561	1.142	2.002	1.098
SUPPORT	0.689	0.464	0.291	0.455	0.471	0.500
<i>Information acquisition</i>						
AES	0.679	0.468	0.413	0.493	0.533	0.499
ORG	0.374	0.485	0.135	0.342	0.243	0.429
DEMO	1.137	0.798	0.574	0.712	0.829	0.802
<i>Moral obligation</i>						
PEPT	1.689	1.015	1.2	0.893	1.421	0.980
REG	2.242	1.175	1.761	1.193	1.979	1.207
SUPV	2.426	1.109	1.974	1.144	2.179	1.149
<i>Farmer and farm characteristics</i>						
GENDER	0.300	0.459	0.357	0.480	0.331	0.471
AGE	45	10.934	46.922	11.088	46.052	11.047
EDUC	1.847	0.862	1.509	0.850	1.662	0.871
YEAR	10.658	5.582	10.157	4.825	10.383	5.181
LABOR	2.126	1.066	1.448	0.756	1.755	0.969
NFI	5.432	2.497	6.922	3.391	6.248	3.106
SIZE	3.591	2.920	2.709	1.448	3.108	2.277
PARCEL	2.416	1.034	2	0.724	2.188	0.901
PCT	0.544	0.213	0.436	0.226	0.484	0.227
<i>Region</i>						
D ₁	0.268	0.443	0.317	0.466	0.295	0.457
D ₂	0.321	0.468	0.257	0.438	0.286	0.452

6. Results and discussion

Before running the logit regression, the variance-inflation factor (VIF) is used to test the multicollinearity among independent variables. It did not suggest any serious problem. None of the VIF values exceeded 3. VIF values of 5.3 (Hair, Anderson, Tatham, & William, 1992) and 10 (Studenmund, 1992) have been suggested as cutoffs for multicollinearity. The values of Pearson correlation among independent variables is presented in Appendix A. The estimated coefficients of the parameters and the marginal effects in the binary logit model are summarized in Table 3. The χ^2 test statistic is significant at the 1% level, which implies the joint significance of PFVF adoption variables. The power of prediction of the estimated model is 0.757, suggesting that 75.7% of the observations are accurately predicted by the logit model.

Table 3. Estimated coefficients and marginal effects of the logit model

Variables	Coefficient estimates		Marginal effect		Odds ratio
	Coef.	Std. error	Coef.	Std. error	
Dependent variable: PFVF adoption (1: If farmer adopt PFVF, 0: Otherwise)					
Constant	-4.214***	1.299	-	-	-
<i>Economic benefits</i>					
PRICE	0.636***	0.177	0.154***	0.042	1.890
SUPPORT	1.231***	0.367	0.291***	0.083	3.423
<i>Information acquisition</i>					
AES	0.312	0.286	0.075	0.069	1.366
ORG	0.564*	0.337	0.139*	0.083	1.758
DEMO	0.132	0.216	0.032	0.052	1.141
<i>Moral obligation</i>					
PEPT	0.195	0.147	0.047	0.036	1.216
REG	0.175	0.118	0.042	0.029	1.192
SUPV	0.380***	0.139	0.092***	0.033	1.462
<i>Farmer and farm characteristics</i>					
GENDER	-0.100	0.276	-0.024	0.066	0.905
AGE	-0.009	0.015	-0.002	0.004	0.991
EDUC	0.211	0.190	0.051	0.046	1.235
YEAR	0.028	0.028	0.007	0.007	1.029
LABOR	0.253	0.183	0.061	0.044	1.288
NFI	-0.144**	0.066	-0.035**	0.016	0.866
SIZE	0.202**	0.097	0.049**	0.024	1.224
PARCEL	-0.275	0.212	-0.066	0.051	0.760
PCT	0.401	0.822	0.097	0.199	1.494
<i>Region</i>					
D ₁	0.517	0.351	0.127	0.086	1.678
D ₂	0.031	0.319	0.007	0.077	1.031
Predicted 1s that were actual 1s (%)	77.39		Log likelihood function	-194.826	
Predicted 0s that were actual (%)	73.68		Prob. [$\chi^2 > \text{value}$]	0.000	
Power of prediction (%)	75.71		McFadden R ²	0.326	

*Significant at 10% level.

**Significant at 5% level.

***Significant at 1% level.

Table 4. Predicted probabilities of PFVF adoption in sample regions

Region	Probability				No. of Obs.
	Mean	Std. Dev.	Min	Max	
Shandong	0.388	0.226	0.012	0.990	176
Hebei	0.352	0.219	0.022	0.998	124
Jiangsu	0.496	0.156	0.012	0.954	120
China	0.407	0.264	0.012	0.998	420

The estimated results indicate that besides relatively weak effects of non-farm income and vegetable acreage, farmers are mainly motivated to adopt PFVF by the combination of economic benefits, information acquisition and moral obligation. Specifically, in terms of economic benefits, pollution-free vegetable price plays an important role. It is positive and significant at the 1% level. Its marginal effect indicates that if pollution-free vegetable price is higher compared to traditional vegetable price, the probability of adopting PFVF will be increased by 15.4%. Meanwhile, if economic support from the governments is provided to the farmers, the probability of adopting PFVF will be increased by 29.1%. This reflects that government support acts as an important guide and strengthens farmers' ability in PFVF.

In terms of information acquisition, only the variable ORG is significant at the 10% level. The result shows that if farmers join rural economic organizations, the probability of their adoption will be increased by 13.9%. It is understood that the advantages of production and sales of organizations may reduce various risks faced by individual farmers and bring them more stable profits. The variable AES is not significant. The weak effect of agricultural extension services on PFVF adoption may be explained by the fact that agricultural extension services are provided to increase yield, not to improve agri-food quality and safety as showed by Zhou (2008). Besides, demonstration effect on farmers' adoption is also weak. It may be related to the current low adoption rates.

The next set of explanatory variables is composed of factors associated with moral obligation. Only the variable SUPV is significant at the 1% level. The result shows that as market supervision is strengthened, the probability of adopting PFVF will be increased by 9.2%. It means that although moral obligation is one of the reasons for farmers to adopt PFVF, it is still pushed by external forces, not by their own perception. Government regulation does not take an effect on farmers' adoption, which may be related to the weak performance of multiple agencies with overlapping responsibilities.

Besides economic, informational and moral motivations, the effects of farmer and farm characteristics are also verified through empirical research. Non-farm income and vegetable acreage are found to be significant. More specifically, the variable NFI is negative at the 5% level. The marginal effect of NFI reveals that as non-farm income increases, farmers are 3.5% less likely to adopt PFVF. A possible explanation is that if the farmer can gain more non-farm income, he is more likely to put his time and energy into non-farm work and less likely to adopt PFVF. This may be the main reason why many farmers prefer to work outside rather than produce pollution-free vegetables. This situation also results in a very low proportion of PFVF in vegetable acreage. Although we did not have access to this proportion, the data from agri-food quality and safety center of MoA shows that the sown area of pollution-free food accounts for only 4.8% of the total sown area in China and it indicates the insufficient supply of pollution-free food including pollution-free vegetables. The negative effect of NFI also reflects the importance of increasing pollution-free vegetable profits. The effect of the variable SIZE is positive at the 5% level and as vegetable acreage becomes larger, the probability of farmers' PFVF adoption will be increased by 4.9%. A greater potential to convert to new production for larger farms was partly explained by the associated high costs involved in the conversion and risk considerations (Perrin & Winkelmann, 1976).

Furthermore, the comparison among marginal effects of economic benefits, information acquisition and moral obligation shows that economic benefits have stronger effects on farmers' PFVF adoption, while the incentives from moral obligation are comparatively weak. It indicates that Chinese farmers are mainly profit-driven in PFVF.

The estimated logit model from the maximum likelihood procedure can be represented by:

$$F(\text{PFVF}) = \text{PFVF adoption} = -4.214 + 0.636\text{PRICE} + 1.231\text{SUPPORT} + 0.312\text{AES} + 0.564\text{ORG} \\ + 0.132\text{DEMO} + 0.195\text{COG} + 0.175\text{REG} + 0.380\text{SUPV} - 0.100\text{GENDER} - 0.009\text{AGE} \\ + 0.211\text{EDUC} + 0.028\text{YEAR} + 0.253\text{LABOR} - 0.144\text{NFI} + 0.202\text{SIZE} - 0.275\text{PARCEL} \\ + 0.401\text{PCT} + 0.517D_1 + 0.031D_2$$

If we substitute the mean values of each explanatory variable into this logit model and use Equation (2), we can make a general statement about the probability of PFVF adoption:

$$P = P[y = 1] = \frac{e^{F(\text{PFVF})}}{1 + e^{F(\text{PFVF})}} = \frac{e^{-0.377}}{1 + e^{-0.377}} = \frac{0.686}{1.686} = 0.407$$

Given the current characteristics and behaviors of vegetable farmers and the environment in which they operate, there is a low probability (40.7%) of adopting PFVF. This prediction is consistent with the survey data in which only 45.2% of the total farmer respondents adopt PFVF. It is also possible to draw some conclusions about the general status of PFVF adoption in each region by substituting the regional mean values of the explanatory variables into the model and then solving for the probabilities. Table 4 shows the predicted probability values given the regional characteristics of vegetable farmers. Values vary from 35.2% in Hebei to 49.6% in Jiangsu. This result may be related to government support and economic environment. Now the governments of Jiangsu province and Shandong province subsidize 10,000 Yuan for each kind of pollution-free food. Besides subsidies on the provincial level, subordinate governments also provide some subsidies for pollution-free food based on local finance. As opposed to these two provinces, the government of Hebei province has not launched uniform subsidy standard on a provincial level. In addition, the consumers of pollution-free food in China are mainly high-income group in over medium-size cities, so there are market advantages and stronger production willingness in developed areas. Zhou and Peng (2006) studied consumers' willingness to pay (WTP) for food safety based on a case of reduced pesticide residues *B. Chinensis* in Jiangsu province, and found that the mean WTP was 2.68 yuan per half a kilogram, which gave a 335% price premium. Zhou, Li, and Zhang (2004) reported that consumers were only willing to pay a 20% price premium for food safety based on the survey data from Tianjing city, the capital of Hebei province. Such information on probability indices reinforce the important role of economic benefits in PFVF.

7. Conclusions and policy implications

This study contributes to identify the factors affecting farmers' PFVF adoption. The results show that farmers are mainly motivated by multiple objectives including economic benefits, information acquisition and moral obligation. The research reveals that the assumption of economic motive alone may be inadequate in the understanding of farmers' PFVF adoption. Pollution-free vegetable price, economic support from the governments, joining rural economic organizations, market supervision and vegetable acreage have significantly positive impacts on farmers' adoption and the effect of non-farm income is significantly negative. Moreover, relative to the motivations of information acquisition and moral obligation, the incentives from economic benefits play a greater role.

According to the empirical results, it suggests that a number of means can be taken to improve farmers' PFVF adoption. First, PFVF may be promoted towards a profit-driven way. When PFVF is economically profitable to the farmers, it may be expected to be sustainable. The Chinese government through "No. 1 Central Document" in 2014 has put forward that a target price system for agri-food should be gradually established to ensure farmers' benefits. The subsidies are provided to

farmers when market prices fall below target prices. For PFVF farmers, this policy may strengthen their confidence. Besides, consumers' demand and willingness to pay a price premium for food safety are essential requirements to ensure economic benefits of PFVF. When consumers accept this kind of safe farming and are willing to pay higher price for higher quality and safety, it may lead to farmers' increased income and encourage their adoption of PFVF. Furthermore, the gains from the premiums of food safety can reduce dependency of farmers on additional support payments. Hence, policy design should be guided by the aim that farmers engaging in PFVF have access to safe food markets and receive the premiums for their output. In economic incentives, economic support from the governments is also important. It appears to be effective means of reducing farmers' risk in PFVF and strengthening farmers' confidence in an early stage. From this perspective, the scope of support should be further expanded, e.g. adding subsidies on purchasing capital goods for safe food production, especially on investing in pollution-free and green agricultural chemicals. Moreover, the effect of government support may be more obvious in the developed areas of China due to better development environment for safe food in these areas where consumers would like to pay more for safe food.

This study also presents the positive effect of joining rural economic organizations. Therefore, it is necessary to explore a joint mechanism between farmers and organizations for the improvement of farmers' organization level. Rural economic organizations such as agricultural firms, cooperatives and farmer groups should be promoted to educate farmers on the PFVF technologies and guide small and scattered land into scale operation and management which has been examined to significantly influence farmers' PFVF adoption, but now these organizations in China are still in development. A support of policies and funding should be provided to strengthen anti-risk capability and long-term earning power of these organizations. The information and communication technology approach which relies on these organizations can be continued with wider coverage to increase farmers' access with latest innovation in PFVF.

Additionally, although agricultural extension services have no significant effect on farmers' PFVF adoption, it does not mean that the agricultural extension services have no effect on farmers' production decision. As we mentioned, the present agricultural extension services in China pay more attention to yield increases, but do not attach importance to the improvement of agri-food quality and safety. Thus, extension services could play a better role in farmers' PFVF adoption if they are delivered with a joint goal of output and safety. The government should also tap more on farmer-cooperators to utilize their farms for pollution-free vegetable field trials and on-farm demonstrations. Such capacity-enhancement activities provide farmers with the opportunity to learn, understand, apply and adopt PFVF.

Our research also shows that market supervision is effective to lead farmers' moral obligation and promote their PFVF adoption. The present task is not only to establish and perfect relevant laws and rules, but also to implement them more strictly. Authorities in China are greatly concerned about food safety. By the end of 2012 agricultural supervision stations covering all towns have been established to strengthen supervision. Meanwhile, in order to reduce supervision costs, it is essential to urge producers to provide real and accurate production information, and expose false information and illegal production behaviors. This can give the public a right to know the truth so that the multi-faceted supervision pressures are formed to motivate farmers to adopt safe farming technology. Through these efforts, the overall level of agri-food safety in China could be improved, but there is still a long way to go.

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Competing Interests

The authors declare no competing interest.

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Appendix A

Table A1. Pearson correlation coefficients

	Gender	Age	Educ	Year	Labor	NFI	Size	Parcel	PCT
Gender	1	-	-	-	-	-	-	-	
Age	-0.06	1	-	-	-	-	-	-	
Educ	0.05	-0.54	1	-	-	-	-	-	
Year	-0.05	0.37	-0.14	1	-	-	-	-	
Labor	-0.15	0.05	0.07	0.03	1	-	-	-	
NFI	-0.01	-0.06	0.04	-0.11	-0.13	1	-	-	
Size	-0.09	0.07	-0.01	0.08	0.54	-0.002	1	-	
Parcel	-0.05	0.01	0.05	0.07	0.59	-0.10	0.70	1	-
PCT	-0.06	0.02	-0.06	0.10	0.18	-0.69	-0.02	0.09	1
Price	-0.03	-0.15	0.29	-0.03	0.24	-0.17	0.02	0.18	0.14
Support	0.06	-0.11	0.26	-0.11	0.22	-0.12	-0.12	0.11	0.14
AES	-0.10	-0.02	0.13	0.08	0.24	-0.05	0.13	0.21	0.04
ORG	-0.10	0.01	-0.04	0.01	0.28	-0.15	0.12	0.17	0.15
DEMO	-0.08	-0.05	0.09	-0.05	0.23	-0.15	-0.02	0.21	0.13
PEPT	-0.09	-0.07	0.23	-0.03	0.22	0.02	0.16	0.19	-0.03
REG	0.04	0.01	0.01	0.01	0.18	-0.10	0.24	0.13	0.16
SUPV	0.001	0.08	-0.06	0.11	0.35	-0.01	0.45	0.31	0.12
D_1	-0.05	-0.07	-0.09	-0.07	0.07	-0.02	-0.05	-0.07	-0.06

	Gender	Age	Educ	Year	Labor	NFI	Size	Parcel	PCT
D_2	0.07	0.10	0.027	0.10	-0.07	-0.06	-0.08	-0.13	-0.003

	Price	Support	AES	ORG	DEMO	PEPT	REG	SUPV	D_1	D_2
PCT	-	-	-	-	-	-	-	-		
Price	1	-	-	-	-	-	-	-		
Support	0.65	1	-	-	-	-	-	-		
AES	0.32	0.30	1	-	-	-	-	-		
ORG	0.22	0.15	0.17	1	-	-	-	-		
Demo	0.53	0.61	0.39	0.40	1	-	-	-		
PEPT	0.21	0.13	0.19	0.38	0.26	1	-	-		
REG	0.08	0.01	0.07	0.11	0.05	0.25	1	-		
SUPV	-0.01	-0.13	0.03	0.08	-0.03	0.14	0.32	1		
D_1	0.04	-0.18	-0.24	-0.24	-0.001	-0.15	-0.07	-0.05	1	
D_2	0.06	0.210	0.32	0.03	0.10	0.17	0.002	-0.12	-0.41	1



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